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PROJECT-BASED LEARNING FOR ENHANCED BIM IMPLEMENTATION IN THE SUSTAINABILITY DOMAIN

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ABSTRACT

Integration of building information modeling (BIM) in college curriculum has been taking various forms across the architecture, engineering and construction management disciplines with program-driven priorities. This study explores BIM implementation in the sustainability domain through a joint course project in two upper division elective courses in an undergraduate construction management program. The goal is to experiment innovative pedagogic approaches to improve critical student learning outcomes (SLOs) pertaining to institutional and accreditation assessment requirements. Specifically, CM-177 introduces green building design criteria, rating systems and compliance strategies, while CM-132 covers BIM concepts, modeling skills, and project execution planning. Using an ongoing campus project, students from the two classes collaborated as groups and played distinct roles as they would in a real project team. Major project deliverables included developing the Leadership in Energy and Environmental Design (LEED) certification strategy and the BIM project execution planning, performing schematic design, conducting performance simulation for LEED credit compliance, and document project information for LEED submittals. The project-based learning pedagogy and joint course experience enhanced students' understanding of and working knowledge in BIM implementation in the sustainability domain. It also provided instructors with opportunities to align course redesign with curriculum assessment requirements. The paper outlined the strategies of implementing and managing the joint course project, and shared various metrics and tools adopted in project evaluation. Results and findings of this joint course project are expected to shed light on competency-based program assessment and future BIM curriculum innovation.

Keywords: BIM, sustainability, project-based learning, student learning outcome, assessment

1. INTRODUCTION

This study was motivated by the dual pressure from program assessment requirements and industry needs identified in communication with recruiters. The Construction Management program at Fresno State has just gone through the American Council for Construction Education (ACCE) reaccreditation. Internal review of assessment reports has revealed significant weaknesses of students in graphical communication, construction modeling and visualization. At the institution level, a major goal of the program Student Outcomes Assessment Plan (SOAP) is to provide the necessary acquisition of professional knowledge, skills, and technical competencies for advanced participation within the construction field. Prompt response and adaptation to regional industry needs is thus critical and held as a program priority in curriculum design. Slowly but steadily, the Central Valley has seen an uprising trend in green building and adoption of building information modeling (BIM). Recent recruiting events have clearly confirmed that employers of different sizes in various industry sectors are looking for new graduates with competencies in sustainability and BIM to fill in the gaps in their talent pools. Therefore, the goals of this study are to align course redesign with assessment requirements and emerging industry needs in mind, and to cultivate student competencies with practical and effective means. The decision of utilizing a joint course project was based upon the well-acknowledged synergies between BIM and sustainability (e.g. McGraw-Hill Construction 2010, and Wu

and Issa 2015). Furthermore, as ACCE accreditation criteria are migrating from categorical topics towards the use of performance-based standards, student learning outcomes (SLOs) should be assessed in line with core competencies that will prepare students for their anticipated roles in a challenging project-based industry.

2. PEDAGOGICAL APPROACH, PROJECT OBJECTIVES AND ASSESSMENT PLAN

2.1 Project-based Learning

Today's CM graduates must have strong communication and teamwork skills; they must have the ability to work efficiently within co-located teams; and finally, they must know how to apply fundamental engineering, management, and computer skills in practice (Becerik-Gerber et al. 2012). Traditional lecture-based pedagogy models that treat students as passive recipients with linear and fragmented teaching presentations have been criticized for depriving students of the opportunities for learning the holistic nature of the discipline (Chinowsky et al. 2006). Empirical evidence found in the adoption and implementation of BIM has suggested that integration, instead of specialization, is setting new skill set requirements for workforce in the construction industry featured with a brand new technological infrastructure. Project-based learning holds the promise of cultivating the desired competency with breadth and depth (Goedert et al. 2013).

Project-based learning is a proven effective student-centered pedagogical approach (Bas 2011) that focuses on real-world issues (Chinowsky et al. 2006). It allows students to build knowledge (Liu et al. 2010), develop critical thinking, creativity (Kubiatko and Vaculová 2011) and a number of soft skills (e.g. leadership and communication) (Waters and Sirotiak 2011). These outcomes of project-based learning overlay very well with the objectives of the proposed study to assess selected program SLOs through the joint course project. Aside from student learning process, project-based learning also redefines and transforms the role of the instructor. Instead of being the point of authority and source of solution, the instructor in project-based learning works as a mentor and/or an expert consultant that helps students formulate their own strategies towards the accomplishment of project goals with open-ended, heuristic suggestions while avoid offering the "answer key". The underlying purpose is to instill metacognition and self-monitoring skills of students in facing, analyzing and resolving problems and complexities in realistic project scenarios (Chinowsky et al. 2006). Interest in project-based learning has grown in the past two decades and been increasingly implemented in engineering and construction management education settings, especially with improved information technology and the Internet (Goedert et al. 2013).

2.2 Joint Course Project Activities and Objectives

The CM faculty and the highly engaged Industry Advisory Board (IAB) have reached consensus on the urgency and significance to cultivate green building and BIM competency through curriculum innovation and course redesign. An action plan has been called for and the joint course project was a pilot experiment. Instructors and students from CM-132: Advanced Architectural Design and CM-177: Sustainable Construction collaborated on a campus laboratory project that had just broken ground. The project was designed to meet the 2010 California Green Building Standards Code, Title 24/Part 11. The university attempted to pursue LEED certification at the initial stage of design but didn't follow through due to budget concerns. Nevertheless, for the purpose of the course project, the instructors added LEED certification at both "Certified" and a higher level (decided by the students) as project sustainability goals.

Students of the two classes formed project teams of 4 or 5 people with roles negotiated on their own. A typical team consisted of one (1) LEED consultant (the student from CM-177), one (1) BIM coordinator/project manager, one (1) design professional, one (1) Owner's Representative, and one (1) optional project engineer. During the joint course project, the LEED consultant led the LEED charrettes to develop alternative design strategies aiming at varied LEED targets. The BIM coordinator/project manager established the BIM execution plan with identified sustainability goals and inputs from Owner's

Representative. The design professional built the conceptual design model and conducted performance modeling based upon the design strategies and performance criteria proposed by the LEED consultant. Except for the LEED consultant, team members were encouraged to rotate roles along the project progress to enhance their learning experience. All team members must contribute to their assigned communication and documentation management responsibilities. In-depth discussions and design iterations were expected as students from the two classes were learning from each other while collaborating as a team to obtain optimal solutions under the constraints set by the project context.

The ultimate goal was to walk the students through a realistic green building design process with BIM facilitation, and expose them to a full spectrum of activities that they would not typically experience should there be no such a joint course project. Specifically, the instructors would like to assess the following program SLOs:

- **SLO 1: Communication.** Effective communication in graphical, oral, and written forms common in the construction industry.
- **SLO 3: Teamwork and Team Relations.** Work closely with other team members that are internal and external to the construction project team.
- **SLO 4: Problem Solving and Critical Thinking.** Solve diverse problems in the design and construction of the project.
- **SLO 11: Sustainability.** Become literate in sustainability and apply the principles to the design and construction process.

Due to the fact that BIM has been a new element of the curriculum, **SLOs 1 and 4** are used as the tentative placeholders for assessment activities pertaining to BIM competencies. More comprehensive metrics will be developed as the CM program accumulates experience and student learning data in BIM. For this study, the assessment of knowledge, modeling skills and analysis abilities of using BIM in the sustainability domain will be addressed by developing grading rubrics for specific project deliverables.

2.3 Assessment Plan

The overall assessment plan of this study emphasizes on the learning progressions and periodical reflections, and includes both formative and summative approaches. Table 1 summarizes the corresponding direct/indirect measures planned for assessing the preceding list of program SLOs. Considering the lack of previous exposure of students to similar topics, the instructors opted to leverage external educational resources provided by Autodesk, and incorporated the online Building Performance Analysis Certificate (BPAC) program as part of project personnel training requirements. The certificate program embraces a broad but fundamental knowledge and skills in building physics, building systems, and information modeling applications that can jumpstart students' understanding of the synergies between sustainability and BIM. As for LEED resources, students in CM-177 were provided with access to USGBC's interactive web-based LEED reference guide that offers step-by-step guidance on how to achieve and document each LEED credit for both the current and previous LEED rating systems. In addition, students in CM-177 did case studies on two LEED platinum projects on a nearby university campus after reviewing their complete final LEED submittals. Students were expected to learn LEED strategies from the real LEED projects and apply them to the joint-course project as they saw fit.

3. TECHNOLOGY SELECTION AND PROJECT MANAGEMENT

For beginners, BIM education usually starts with strong technological flavor and inevitably involves the selection of appropriate tools that are anticipated to address concerns of learning curve as well as the project needs, which in this case are to achieve sustainable performance and meet green building code/rating system compliance requirements. Meanwhile, to mimic typical BIM execution and project delivery, students are assigned with certain roles and responsibilities. Management of time and resources by students and tasks and role differentiation is very important in project-based learning. Therefore, tools for model sharing,

documentation management and regular team communication are also essential. Table 2 summarizes the technology selection relevant to the joint course project.

Table 1. Joint course project assessment plan.

Program SLOs	Direct Measures				Indirect Measures		
	Model & Design Documentation	Team Presentation	Team Final Report	Team Google Site	Autodesk BPAC	Entry Survey	Exit survey
SLO 1	×	×	×	×		×	×
SLO 3		×	×	×			×
SLO 4	×	×	×		×		×
SLO 11			×	×	×	×	×

To better manage the documentation and information exchange among team members, each team was required to maintain a Google site introducing the team members' roles and presenting their project updates on a weekly basis. In the meantime, the instructors of the two courses co-managed a Google site for the joint-course project. From this central location, students could find weekly assignments and/or announcements from both courses, project documentation (i.e. links to original building plans and models), as well as grading rubrics. The central site also served as a team management tool for the instructors. It listed links to all the team sites which were only accessible to the instructors and thus allowed for immediate feedback to the teams. Figure 1 below show screenshots of the joint-course site and a sample team site. The teams were expected to meet weekly either face-to-face or online to collaborate on the project.

Table 2. Technology selection for the joint course project.

Project activity/task	Recommended technology	Optional technology
Site selection/analysis	Google Earth	
Model authoring	Autodesk Revit 2014	Sketchup
Energy simulation	Autodesk Green Building Studio	Sefaira
Water efficiency calculation	Autodesk Green Building Studio	N/A
Daylighting simulation	Autodesk Green Building Studio	Sefaira; Autodesk Daylighting Analysis plug-in*
Materials takeoff	Autodesk Revit 2014	On Screen Takeoff
Design documentation communication & management	Google Apps; Dropbox; PlanGrid	Autodesk A360
LEED certification management	Google Apps	Autodesk Revit Credit Manager for LEED**

*, **: Both are Autodesk Labs products.

4. PROJECT RESULTS, ASSESSMENT AND DISCUSSION

The joint course project kicked off on September 26, 2014 and closed out on December 11, 2014. Students were required to make two milestone submissions and a final report/presentation. Interaction with industry partners was a key in this project. The general contractor of the campus project provided the bid set contract documents in both digital format and hard copies. The project manager and BIM manager also met with the students, answering questions and sharing their insights in BIM implementation strategies. Students also had a site tour with the project superintendent to get the update of the project progress.

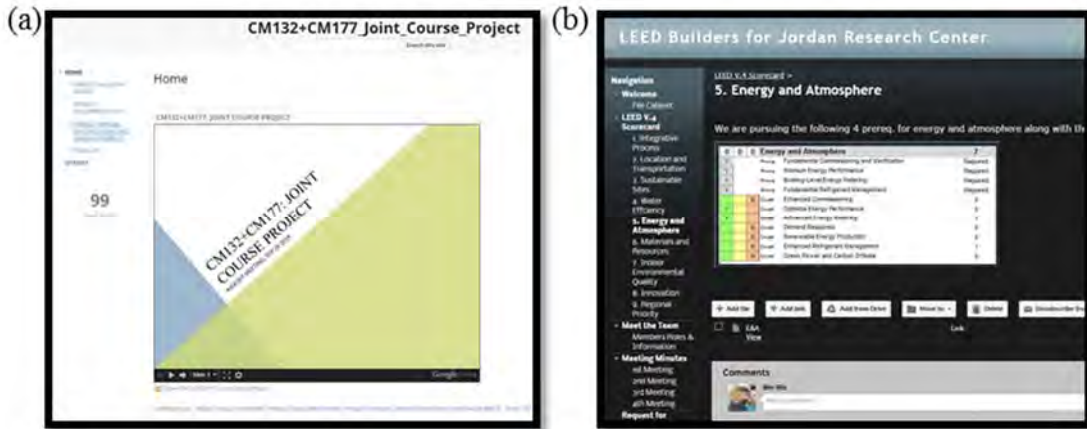


Figure 1. Screenshots of: (a) the joint course project site; and (b) a sample student team site.

4.1 Assessment Results: Direct Measures

Through the joint course project, instructors collected the assessment data following the assessment plan specified in the preceding Table 1. For each direct measure, instructors developed certain metrics and grading rubrics to assess relevant student assignments and activities. For instance, *Model & Design Documentation* is a direct measure utilized to assess *SLO 1: Communication* and *SLO 4: Problem Solving & Critical Thinking*. Associated student assignments/activities included creating the schematic architectural and structural Revit model, performing massing- and building element-based energy simulations, conducting daylighting analysis, calculating water efficiency and recycled contents, and running design analysis reports, to name a few. Another direct measure, the *Autodesk BPAC*, provided a comprehensive assessment of students' fundamental knowledge in building physics and high performance design criteria through a series of well-designed, very relevant learning modules. It also evaluated essential problem-solving skills utilizing BIM applications to accomplish sustainable design goals. The assessment results of direct measures were summarized in Table 3.

Table 3. Assessment results of direct measures: student performance distribution.

Direct Measures	Performance Levels	Student Performance Matrix (% of students)			
		SLO 1	SLO 3	SLO 4	SLO 11
Model & Design Documentation	Low ($\leq 70\%$)	25.0%	—	25.0%	—
	Medium (71% ~ <90%)	27.3%	—	27.3%	—
	High ($\geq 90\%$)	47.7%	—	47.7%	—
Team Presentation	Low ($\leq 70\%$)	0.0%	0.0%	0.0%	—
	Medium (71% ~ <90%)	100.0%	100.0%	100.0%	—
	High ($\geq 90\%$)	0.0%	0.0%	0.0%	—
Team Final Report	Low ($\leq 70\%$)	0.0%	0.0%	0.0%	0.0%
	Medium (71% ~ <90%)	86.2%	86.2%	86.2%	86.2%
	High ($\geq 90\%$)	13.8%	13.8%	13.8%	13.8%
Team Google Site	Low ($\leq 70\%$)	55.2%	55.2%	—	—
	Medium (71% ~ <90%)	44.8%	44.8%	—	—
	High ($\geq 90\%$)	0.0%	0.0%	—	—
Autodesk BPAC	Low ($\leq 70\%$)	—	—	0.0%	0.0%
	Medium (71% ~ <90%)	—	—	69.7%	75.8%
	High ($\geq 90\%$)	—	—	30.3%	24.2%

As indicated by Table 3, each direct measure had three performance levels: *Low*, *Medium* and *High* with corresponding scoring thresholds. Student performance distribution, in terms of the percentage of

students that fell under one of the three performance levels, was then marked. This table offered immediate insights of each learning outcome in a quantitative manner. More importantly, it captured the specificity that the instructors would appreciate in order to develop action plans to improve student performance in particular areas.

4.2 Assessment Results: Indirect Measures

Instructors used both *Entry* and *Exit Surveys* as indirect measures in this joint course project. Surveys, providing their subjectivity or even biases, remain as great means to understand students' attitudes and reflection on the project-based learning experience. The *Entry Survey* was relatively simplistic and aimed at a quick grasp of students' background. Therefore, the analysis was focused on the *Exit Survey* that was conducted online with institutional Qualtrics service. Out of 29 students from the two classes, 24 completed the survey.

The survey had both quiz-like multiple-choice questions as well as open-ended discussions. The goal was to qualitatively evaluate students' perception towards BIM implementation in the sustainability domain, and their confidence in leveraging the knowledge and skills attained from this project to deal with common issues encountered in real world project delivery. A quick example is illustrated in Figure 2, which indicates that the joint course project had a significant positive impact on students' understanding of fundamental concepts of BIM and green building.

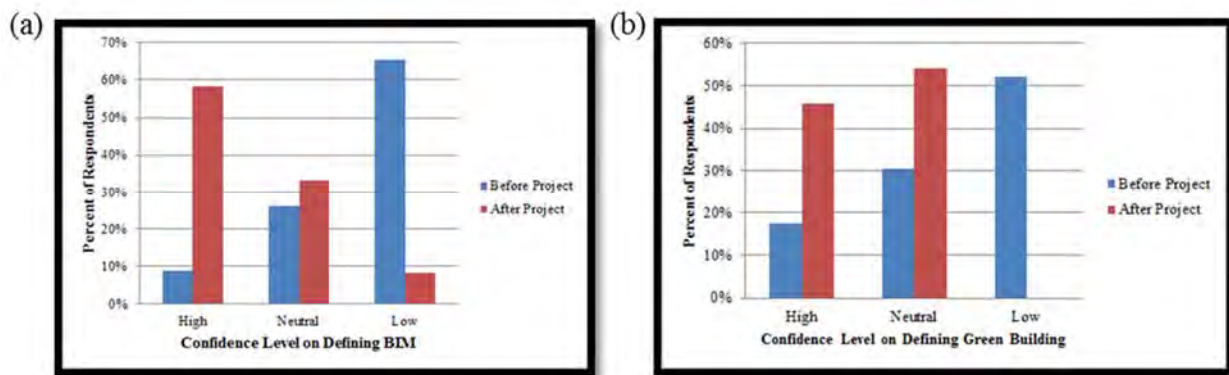


Figure 2. Exit survey: students' confidence in defining (a) BIM and (b) green building before and after the joint course project.

The *Exit Survey* also used Likert scales (1 to 5 where 5 denotes best performance) to evaluate team performance against several typical team effectiveness indicators, in comparison with a parallel self-evaluation. The results were presented in Table 4. It is very consistent across all performance indicators that on average, students rated themselves higher than the rest of the team. The instructors also reflected on individual interviews with project teams through the joint course project, and found out that when conflicts arising, students often attributed the defaults to their peer team members instead of taking the responsibility and making efforts to improve the team performance. It seemed that there was a lack of leadership among the students, which was concerning the instructors since it was essential to the students' professional career.

4.3 Discussion

The last part of the survey requested the students to identify both successes and failures of the joint course project, and offer constructive feedback on potential improvement. The most commonly cited success was the fact that they were able to complete the project on time with satisfactory quality, considering the major of them had never used any BIM applications. They also acknowledged that project-based learning was able to uncover issues that were atypical in conventional lectures and enhanced their working knowledge of BIM in green building projects. The biggest failure as they consistently pointed out was the asynchronous

class periods of the two courses, which as their claimed, was “the biggest inconvenience” that undermined their overall learning experience. The students also cross fired the technological cumbersomeness resulting from the outdated computers and persisting glitches of the Autodesk Energy Analysis plug-in.

Table 4. Evaluation of team project performance: self vs. rest of the team.

Project performance indicators	Survey results in mean Likert scales (1-5)	
	The rest of the team	Self
Planning & Execution	3.46	3.52
Effectiveness	3.67	3.83
Time Commitment & Contribution	3.67	4.04
Collaboration & Communication	3.54	3.83
Overall Accomplishment	3.58	3.74

The instructors, on the other hand, regarded the students’ feedback as partially legitimate. Despite the recognized obstacles, a major challenge perceived by the instructors was students’ unwillingness to get out of their comfort zone and learn something new. Significant efforts were needed to keep them motivated, and there were constant kickbacks and negotiations taking place throughout the joint course project.

5. CONCLUSION

Project-based learning has seen increased application in construction and engineering curricula. This study adopted its pedagogical principles in an exciting joint course project that investigated the synergies between BIM and green building. The study creatively positioned the project goals in alignment with the program assessment needs. As BIM continues its momentum, competencies, including the knowledge, skills and abilities (KSAs) in BIM, need to be developed among students in construction and engineering disciplines. This study provided a timely example of developing effective measures in project-based learning to enhance student learning outcomes in BIM implementation in the sustainability domain. The authors would like to continue similar pedagogical innovations to cultivate desired BIM competency of the future construction workforce.

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BIM COURSE DEVELOPMENT AND ITS FUTURE INTEGRATION AT UNIVERSITY OF INDONESIA AND INSTITUTE OF TECHNOLOGY BANDUNG, INDONESIA

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ABSTRACT

Building Information Modeling (BIM) sets a new standard in Architecture Engineering and Construction (AEC) industry globally, replacing conventional CAD documentation. Until recently, BIM movement in Indonesia has not been as vigorous as in western countries. As part of ASEAN, Indonesia will enter the ASEAN Economic Community in 2015 where the trade of goods and services, including AEC industries, are open to all market in South East Asia. This emerging globalization brings us the awareness about the need to incorporate BIM into architecture school curriculum. This paper looks at 2 BIM courses held at Department of Architecture University of Indonesia (UI) and Department of Architecture Institute of Technology Bandung (ITB), their fundamental student learning outcomes that has been reached, and samples of student's work. Lastly, we discuss the improvements as well as future integration can be made based on differences in curriculum emphasis and common prominent issues in both universities.

Keywords: BIM course, BIM curriculum, students, projects, Indonesia, ASEAN

1. INTRODUCTION

As we move towards the world's modernity, Architectural Engineering and Construction (AEC) industry faces current issues: Globalization and Ecological awareness (Gegana, Handjarinto, & Pandjaitan, 2011). Modeling (BIM) sets a new standard in AEC industry as design method and project documentation that can handle those current issues with its capability of Integrated Project Delivery (IPD) (Gegana G. , 2015). Until recently, BIM movement in Indonesia has not been as enthusiastic as in developed countries. However, the globalization in construction teamwork is unavoidable. Indonesia, along with other ASEAN countries, will enter ASEAN Economic Community in 2015 that comprises five core elements: (i) free flow of goods; (ii) free flow of services; (iii) free flow of investment; (iv) free flow of capital; and (v) free flow of skilled labor (ASEAN Secretariat, 2008) (ASEAN Secretariat, 2014). Neighboring ASEAN countries also has started to adopt BIM to their AEC practice. The most advanced BIM adoption is now done by Singapore that has Singapore BIM Guide that regulates BIM deliverables for building permit (Building and Construction Authority, 2013). These situations make steady increase in the demands of BIM skilled personnel as well as competition pressure in Southeast Asia market. Therefore, it is important for educational institutions in Indonesia to contribute in the education of future graduates who understand and able to operate within a BIM defined framework, to make AEC consultants in Indonesia remain competitive in Southeast Asia market.

The main purpose of this study is to look and compare at 2 different BIM curricula from University of Indonesia (UI) and Institute of Technology Bandung (ITB), their learning outcomes, assessment criteria, and samples of student's work. In this study, BIM course from each university is reviewed and student's works samples are presented. Later, the overall courses and work samples are tabulated for integrated examination. Based on those differences as well as common prominent issues, we discuss the future integration for BIM study with other courses, its direction, and future improvements.

2. BIM COURSE AT UNIVERSITY OF INDONESIA

Department of Architecture UI's curriculum encourage students to explore their design concept. Since 2007, BIM lesson at University of Indonesia has been started as a part of Computer Aided Design (CAD) Presentation course. It is a 3 credits elective course that can be taken by second year students and up. Although it is an elective, the course serves as digital application of students' prior knowledge in Architectural Communication Technique, a mandatory studio course for first year students.

2.1 Course Objectives

The course aims the students to be able to explore CAD and BIM application to generate comprehensive, pre-professional architectural documentation and digitally visualize their architectural idea, both individually and in teamwork. The course contents include the following issues: 1) 2D drafting, 2) 3D modeling, 3) project documentation/ quantification, and 4) rendering/ visualization.

2.2 Learning Method

The learning method is mainly based on workshop in computer lab once a week and individual practice. Knowledge and skills are taught in class directly in each class session. Students directly apply knowledge and skills taught in class by doing their assignment within class meeting and at home, as well as discuss their problems with facilitators in the class.

Since 2010, the workshop is divided into 3 sessions. In the first session (week 1-4), students learn to make 2D project documentation using CAD application. In the second session (week 5-7) students learn to model in BIM application: ArchiCad to learn basic structure modeling. In the third session (week 8-14) students learn in a group to make integrated 2D project documentation with 3D visualization and quantification in BIM. For the whole course, students work for a case of Final Design studio project.

2.3 Course Outline

The CAD Presentation course outline can be seen in Table 1 below.

Table 1 CAD Presentation course outline at University of Indonesia

WEEK	TOPIC	SUB-TOPIC
1	CAD Introduction	AutoCAD user interface and features: layers and units; 2D tools
2	Documentation standards	Symbols, annotating, and dimensioning tools; Blocks and library
3	Orthographic projection	Project exercise: floor plan
4	Layout and printing	Viewport, layout, and plotting
5	Introduction to BIM: ArchiCad	User interface and features: layers/ objects, stories, units; Integrating CAD drawing (floor plan) to ArchiCad; Structural elements
6	Structural elements	Beam, floor, and vertical openings; structural plan
7	<i>MID-TERM submission (individually)</i>	<i>Floor plans of 3-4 stories public building BIM structure model: structural plan and isometric</i>
8	Collaboration Introduction Basic elements I	Splitting works and combining files; Exterior and Interior walls, curtain walls Wall openings: doors and windows
9	Basic elements II	Floor/ slab, roof, ceiling plan
10	Circulation and furnishing	Stairs, ramp, furnishing, and landscape
11	Detailing and annotation	Dimensioning, text, and space elements
12	Project documentation	Doors and windows schedule, layout and printing
13	3D visualization	Daylight, artificial lighting, and rendering
14	<i>FINAL project submission (teamwork)</i>	<i>Project documentations of 3-4 stories public building: Plans, elevations, sections, and elements quantification; 3D visualization: renderings</i>

2.4 Learning Outcome 1: 2D CAD Documentation

At the end of this phase, students must be able to implement basic knowledge and skills of CAD application in their prior knowledge of orthogonal projection drawing and construction drafting. The class is divided into teams of 3-4 students. Each team choose a case of 3-4 stories public building from their senior's Final Studio project to be drawn in AutoCAD application individually. The output is floor plans for all floors. Evaluation is based on architectural/ construction drafting codes and order: precision, dimensions and scales, symbols and annotations, and layout.

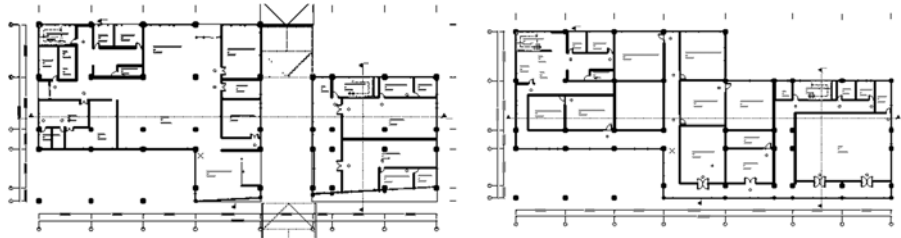


Figure 1 Result of CAD floor plan in session 1

2.5 Learning Outcome 2: Individual Basic BIM Model

In this 2-3 weeks phase, students learn the basic and concept of BIM to make a simple BIM model: structural model. The session is started by the explanation of BIM concept, followed by the explanation of tools in BIM software and workshops to practice. First, students continue their project by integrating CAD documentation (floor plan) that they have made before into ArchiCad as the reference to make BIM structural model individually. The evaluation is based on model accuracy and cleanliness.

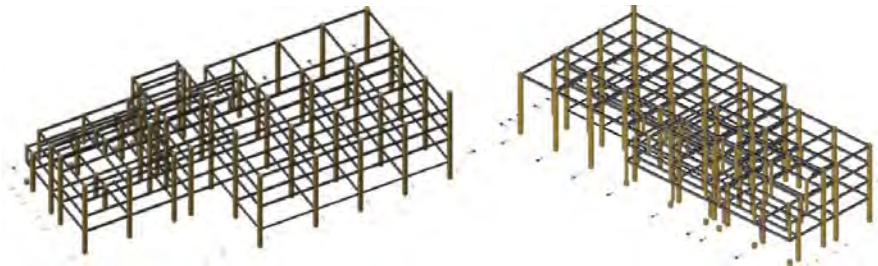


Figure 2 Result of BIM structure model in session 2

2.6 Learning Outcome 3: Teamwork BIM Model and Documentation

In this phase, students are to create an integrated architectural documentation, both of all orthogonal projection drafting (floor plans, sections, and elevations) as well as elements quantification for construction phases and 3D rendering visualizations to impress the clients by utilizing BIM application. This session is started by the explanation of collaboration in BIM by combining different BIM models.

The students work in group of 3-4 people and continue their project to be integrated documented in ArchiCad and comprehend the relationships between all drawings: floor plans, ceiling plans, structural plans, sections, elevations, and 3D. They can split the work by levels or scope such as interior and exterior. There are 2 evaluation criteria for final assignment.

Evaluation of 2D documentation and quantification is based on standard architectural/ construction drafting codes and order: BIM model precision, dimensions and scales, symbols and annotations, and layout. Evaluation of 3D visualizations based on rendering and lighting quality of images, communicative images, and creativity in taking camera angle and objects order. Quantity of images that passed over the minimum requirement also will be additional marks. All drawings have to be organized as the pre-professional project documentation.



Figure 3 Result of project documentation and visualization in session 3

2.7 Grading Criteria

Grades depend on effort, ability, and creativity to explore the applications to create proper 2D documentations and rich 3D visualizations in each assignment. Students deserve C if students have conducted sufficient effort to fulfill all task requirements. C+ shows extra efforts to communicate project documentation. Grade B- shows the ability to result pre-professional documentation with few minor drawbacks. Students will get B if they have clear and comprehended drafting order and 3D rendering. Grade B+ shows extra efforts to result either better quality of 2D drafting or 3D renderings. Grade A- shows professional quality with few minor drawbacks in either 2D drafting or 3D images. Grade A will be afforded if they have demonstrated the ability to fully-explore the applications to result excellent professional quality of documentation and 3D renderings.

2.8 Course Evaluation and Future Development

CAD Presentation is the only course that exposes the students to digital architectural documentation and visualization. At the first, the course was divided into 2 sessions: CAD and BIM, each had 7 weeks. However, we realize that the tools in BIM are more complicated than CAD and need prior knowledge of building science to comprehend. As a result, since 2010, the portion of CAD session is being shortened in favor of BIM to comprehend elements relationship and important features of BIM.

Despite of our effort, we still realize that not all aspects of BIM, such as sustainable analysis and custom content modeling, can be covered in one design computing course. As sustainable issues become more eminent in design practice today, the department's curriculum emphasis of design exploration also encourage the students to explore their design to achieve optimum building performance. Regarding to this, there is a plan in near future to impart BIM lesson in Building Physics course as well so the students will be able to perform conceptual building performance analysis during their design process.

3. BIM COURSE AT INSTITUTE OF TECHNOLOGY BANDUNG

Institute of Technology Bandung, lives up to its name, is renowned for technology specialization, including in architecture. The department's commitment to integrate BIM into its curriculum was represented by the integration of BIM lesson to the existing Computational Studio course since 2004 and, ultimately, by the establishment of Introduction to BIM course in 2014. Computational Studio is a 3 credits mandatory course for the third semester students while Introduction to BIM is a 3 credits elective course that can be taken afterwards. In this paper, we will specifically discuss the new Introduction to BIM course.

3.1 Course Objectives

The Introduction to BIM course aims to introduce students to the basics of BIM operation, as well as its main benefits in comparison to the conventional CAD method. These benefits are: 1). Provision of accurate and integrated documentation of drawings and other information within a project, and 2). Facilitation of cooperation across teams of different disciplines by use of its work-sharing feature.

3.2 Learning Method

The learning method is mainly based on workshop in computer lab once a week and individual/ team work practice. Each workshop module has short introductory lecture, explanation of specific tools in BIM application: Revit, and followed by a hands-on workshop session, for the tools implementation.

Based on the course's objectives, the workshops are divided into two major sessions. The first session (week 1-8) focuses on the students' individual learning of basic element modeling. The second session (week 9-14) focuses on BIM's collaborative aspects. Students work individually for a 2-stories house project during the first half semester and in team for a high-rise apartment project during another half.

3.3 Course Outline

The Introduction to BIM course outline can be seen in Table 2 below.

Table 2 Introduction to BIM course outline at Institute of Technology Bandung

WEEK	TOPIC	SUB-TOPIC
1	Introduction to BIM in the construction industry Revit Architecture	Evolution of information technology in architectural design; Design method using BIM technology; BIM principles and workflow, user interface and key features of Revit Architecture
2	Setting up project	Topography modeling, Image references Datum: project location, grid, elevation
3	Basic component modelling	Column, Walls, Openings: window, doors
4	Circulation and roof	Circulation: Stairs, ramp, Roof types
5	Revit Content Creation	Revit Family creation and editing: System, Loadable, and In- place
6	Curtain Wall	Curtain wall system
7	Mass modelling and editing	Mass modeling and editing
8	<i>MID-TERM Presentation (individually)</i>	<i>BIM model & documentations of 2-stories house: Floor plans, elevations, sections, room schedule, and 3D</i>
9	Intro to Collaboration	Introduction to Collaboration, principle of worksheet Project workshop with PT. Intiland Development, Tbk.
10	Project Workshop	Project workshop
11	Project Workshop	Project workshop
12	Collaborative Management	Clash detection with Naviswork; Exercise on project and rectification
13	Collaborative Management	Project modification and elaboration
14	<i>FINAL project submission (teamwork)</i>	<i>Project final: BIM model of high-rise apartment Course feedback</i>

3.4 Learning Outcome 1: Understanding BIM and Individual Project

The first part of the course talks about the principles of BIM, as well as the proper application of its tools, including each of its relation to its respective real construction project counterparts. Detailed explanations of each building element's parameters and its real world samples are shown up.

The students are asked to submit their personally modeled version of the case study given after receiving the CAD version of the model. The assignment is graded based on the accuracy of their building information as compared to the information of the original BIM model.

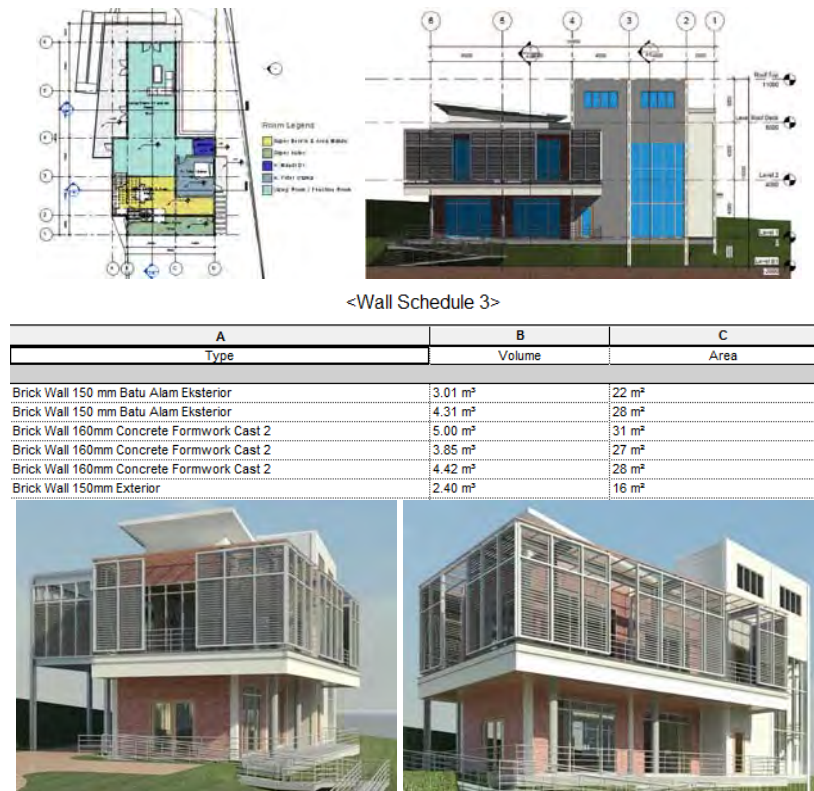


Figure 4 Sample case study of individual project assignment

3.5 Learning Outcome 2: Collaborative Project

By the start of the second part of the lecture, which focuses on the teaching of the collaborative aspects of BIM, students are expected to have a solid understanding of basic element modeling in BIM, so as to function in a team of BIM enabled consultants. Students also learn about clash detection process as the primary backbone of a collaborative process in BIM. During the second part of the course, we invited Indonesia's PT. Intiland Development Tbk to lecture on the collaborative aspects of BIM and explain the current application of BIM in their organization.



Figure 5 Lecture by Gerry of PT Intiland Development Tbk (left) and case study of clash detection presented (right)

The class is given an apartment project sample from the consultant to be remodeled in Revit Architecture. Students are divided into groups of four to five persons per team. As can be seen in Figure 6 below, group identities are assigned to allow for cooperation as follows: alphabet (A-C) to represent the individual apartment tower, number (1-9) to represent individual teams. Grading is given based on each teams' appropriate alignment to the central file of the apartment, which contains the basic level and grids, as well as the podium model of the apartment.

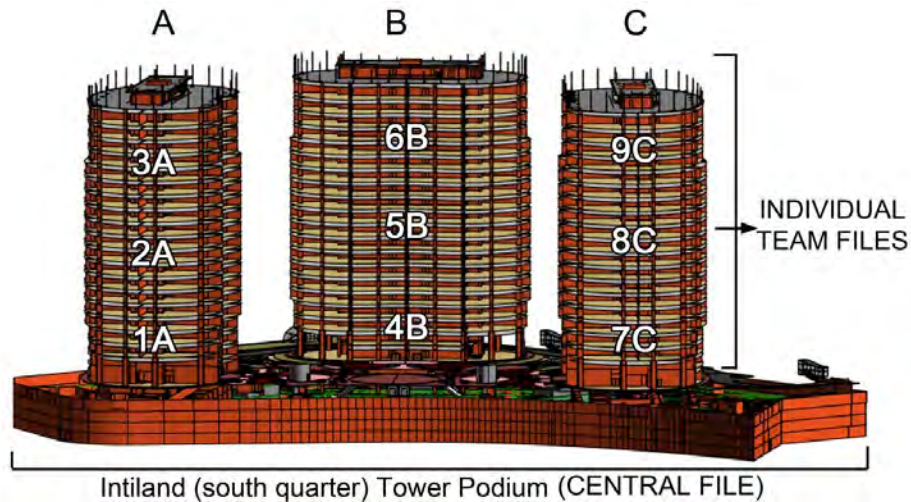


Figure 6 2nd session's model result showing each team's responsibilities and relation to the central file

3.6 Grading Criteria

Grades are given based on the project submission status, comprehensiveness of drawings, and visual appropriateness. Students deserve C- if students submit their project with a few notable inconsistencies to the drawing standards, and/or incomplete components in their projects. C shows minor inconsistencies to the drawing standards, and/or incomplete components in their projects. Grade B- shows minimum comprehensive set of drawings, as is required in the project terms of reference. Students will get B if they fulfill the minimum comprehensive set of drawings with notable improvements such as additional legends, schedules, detail groups, and higher quality renderings. Grade A- shows minimum comprehensive set of drawings with additional explanatory drawings to express better understanding of the modeled building design such as exploded isometric, 3D-Sections, component details. Grade A will be afforded if they are able to produce professional quality, well-documented set of comprehensive drawings, with only minor inconsistencies, or incomplete elements.

3.7 Course Evaluation and Future Development

The new Introduction to BIM course is one of three courses in School of Architecture ITB that exposes students to architectural design computing. As some basics modelling have been integrated into Computational Studio, the course's highlight can be expanded up to content creation and collaboration. We are hoping that we can allocate more time to teach additional features of BIM such as energy and lighting analysis in our future BIM course. One of our future plans for the course includes having a joint class with ITB's Department of Applied Physics to enhance comprehensive performance analysis and material usage efficiency of the final design also multi-discipline collaboration.

4. BIM COURSES COMPARISON

Table 3 BIM course comparison between University of Indonesia and Institute of Technology Bandung

	University of Indonesia	Institute of Technology Bandung
Course Name	CAD Presentation (elective – 3 credits)	Introduction to BIM (elective – 3 credits)
Related CAD	-	Computational Studio (prerequisite); Parametric Design
Emphasis	Design exploration	Building technology
Course Objective	<ol style="list-style-type: none"> 2D drafting, 3D modeling Documentation/ quantification Rendering/ visualization 	<ol style="list-style-type: none"> Accurate, integrated documentation and information within BIM model Project collaboration
BIM app	ArchiCad	Revit Architecture
Method	Workshops/ projects	Workshops/ projects, Guest lecture/ case study
Duration	14 weeks (including exams)	14 weeks (including exams)
Learning Outcome	Individual drafting: Floor plans of 3-4 stories building	Individual accurate modeling Model with integrated documentation and quantification of 2-stories house
	Individual simple modeling Structural model and plan	
	Teamwork modeling Documentation of low-rise building	Teamwork modeling Combined BIM model of high-rise apartment
Future Development Plans	Sustainable design Integration with Building Physics course to explore high performance building design	Sustainable design Joint class with Dept. of Applied Physics to analyze performance and material of final design

As can be seen in Table 3, both universities share some goals but with different approach. The BIM lesson at UI is a part of CAD course, while the BIM course at ITB is continuation of Computational Studio course. In future development to sustainable design area, UI has emphasis for design exploration based on building performance analysis, while ITB emphasize on collaborative analysis of final design.

These differences can be caused by the differences in department's curriculum emphasis. UI encourages design exploration. Therefore, they are more to integrate BIM knowledge into related existing course to enhance the exploration. ITB has emphasis on technology and real world practice based. Therefore, they are more to expand outside, based on real practice case and multi-discipline collaboration.

5. CONCLUSION AND SUGGESTION

This paper has presented 2 samples of how BIM course has been integrated in curricula of universities in Indonesia: University of Indonesia and Institute of Technology Bandung. The result of this study shows how BIM can be integrated on school curriculum by expanding it inwards or outwards, to existing courses or expanding new courses, to inner exploration or open multi-discipline collaboration.

There are rooms for improvements in our curricula. Further studies can be carried out to look at another emphasis such as historical building preservation or urban and infrastructure planning. The collaboration between different universities also can be looked forward.

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BIM PEDAGOGY: FUNDAMENTALS AND EXPLORATION

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ABSTRACT

The introduction of building information modeling (BIM) in a university curriculum can be achieved in many ways depending on university hierarchy, on the department (for example, architectural design or construction management), and even on the skills and preferences of the appointed instructor. What is specifically taught in the class may be dictated closely if for a required course or may be more influenced by the faculty member in the case of an elective.

Architecture 507 is an upper division class designed for the instruction of BIM. Although heavily hands-on and skills-oriented, it also provides a depth of knowledge with lectures, visiting professionals, and readings that go beyond the software. Reviewing the homework assignments given in the class from Fall 2007–2014, it is apparent that these focus on the teaching of software, primarily Autodesk Revit, but over the years including Navisworks, Green Building Studio, Vasari, Solibri, ArchiCAD, and others. Although evolving, the basic assignments were very similar over the years with some additions as the software matured. For example, in fall 2014 the assignments included an overview of BIM using Revit; in-depth instruction about parametric families; creation of a more complex building (2D/3D coordination); scheduling and detailing; rendering and animation; the conceptual modeler and pattern-based curtain walls; BIM analytics; and adaptive components. These are considered by the faculty member as the fundamentals for the course. The course's final project has allowed more exploration. Four types of final projects have made their appearance over the years: contractors' and architects' viewpoints on BIM; BIM + sustainable design; customization (creating plug-ins), and visual scripting using Dynamo. Some of these have gone on to become the basis of new homework assignments. This mix of teaching skill sets for the profession and more exploratory assignments that are more farsighted are hallmarks of the course.

Keywords: building information modeling, BIM, pedagogy, curriculum, Dynamo

1. INTRODUCTION

This paper describes a upper division building information modeling course. The current state of the course for spring 2015 has been outlined and includes a brief overview of the fundamental assignments with samples of student work. It then discusses more thoroughly the final project and how it has changed over the last several years with four examples: contractors' and architects' viewpoints on BIM; BIM + sustainable design; customization (creating plug-ins); and visual scripting using Dynamo. The intent is to provide architecture graduate students with skills that are immediately employable, but also to have them learn more about future potentials of building information modeling that go beyond adding to their current resume.

2. ARCHITECTURE 507

2.1 Course Description

A computer-aided design system is most useful when the structured design inside the computer can be used for something besides merely producing a picture. As soon as the process of computer-aided design is considered as building a description of the object being designed rather than as a process of simply drawing the object, horizons become tremendously expanded.

Ivan E. Sutherland (1973)

Architecture 507 is a three unit elective course that meets on Fridays from 9 am – noon. The course focuses on the quote from Ivan E. Sutherland. Essentially what Sutherland was proposing is a system similar to a fairly recent development in computer software called building information modeling (BIM). BIM is a critical topic in the architecture profession. Learn what it is, how to apply it, innovative uses, and how it relates to sustainable design issues and the AEC industry in general. This course also relies heavily on the knowledge already in the profession: guest speakers will be used to enrich the class content with up-to-date information. It is important that you attend class on-time! In addition to many hands-on computer sessions by the instructor, there will also be guest lecturers from both the profession and the software industry. They have spent considerable time and effort to come talk with the class. Listen, be attentive, and ask appropriate questions. They are valuable resources.

This course is applicable to upper division undergraduate students and graduate students who have a strong background in traditional CAD and three-dimensional modeling. The course applies to the MBS graduate certificate if you are a graduate student. The primary software used will be Revit Architecture and Dynamo. Other programs such as Green Building Studio, Vasari, and Navisworks may also be used. Because of the rapid advancements expected in the technological underpinnings of the course, every effort is made to provide instruction that adjusts to current conditions and is generic to computer hardware and software platforms. Although offered in the School of Architecture, the techniques taught are equally applicable to others with an interest in the applications of building information modeling. Building science majors, structural engineering students, construction management students, and others are strongly encouraged to enroll. It is assumed that students have a basic understanding of 2D CAD and 3D digital modeling. Please contact the instructor if you have questions.

2.2 Grading Breakdown

	Percentage of Grade	Assignments	Number of points
Homeworks	70%	Homework 1	20
		Homework 2	10
		Homework 3	20
		Homework 4	10
		Homework 5	10
		Homework 6	10
		Homework 7	10
		Homework 8	10
Final Project	20%	Part 1	20
		Part 2	20
		Part 3	40
Participation	10%	Pop-quizzes	varies
		Questions on readings	varies
		Other	varies

2.3 Course Schedule: A Weekly Breakdown

	Lecture	Homework	Required Readings (see other software references online)
Week 1 January 16	Introduction to BIM		Routledge - <i>Application</i> – one of the professional firm case studies (designLAB, ZGF, CASE, or Mortenson Construction)
Week 2 January 23	Understanding Families		Routledge – <i>Introduction</i> and <i>Chapter 1: BIM overview</i>
Week 3 January 30	Creating Parametric Components	HWK 1 due	Routledge – <i>Chapter 2: Stakeholders and BIM's many roles</i>
Week 4 February 6	Advanced Parametric Components	HWK 2 due	
Week 5 February 13	BIM as a Database, Interoperability		Routledge – <i>Chapter 3: Data exchange and interoperability</i>
Week 6 February 20	BIM in the Profession: Construction	HWK 3 due	
Week 7 February 27	Rendering and Animation	HWK 4 due	Routledge – <i>Chapter 5: Beyond basic BIM (read the subsection on Computational design) and Conclusion</i>
Week 8 March 6	Conceptual Modeler and Parametric Pattern Based Curtain Walls	HWK 5 due	Wiley – <i>Forward</i> and <i>Chapter 12: Analytical BIM: BIM Fragments, Domain Gaps, and Other Impediments</i>
Week 9 March 13	Introduction to Parametric Adaptive Components	HWK 6 due	Wiley – <i>Chapter 13: One BIM to Rule Them All</i> and <i>Chapter 14: Component-Based BIM</i>
Week 10, March 20, Spring Break			
Week 11 March 27	Introduction to Visual Scripting	HWK 7 due	Wiley – <i>BIM Analytics</i> (read one of the following chapters: 5, 6, 7, 8, 10, 11)
Week 12 April 3	Visual Scripting - attractors	HWK 8 due	http://bimcurriculum.autodesk.com/unit/unit-8-computational-design (especially 8.3.1 about attractors) http://autodesk.typepad.com/bpa/2013/08/more-fun-with-dynamo-for-bpa-automatic-shading-design.html
Week 13 April 10	Visual Scripting – solar control	FP, part 1 due	Wiley – <i>Chapter 16: BIM, Materials, and Fabrication</i>
Week 14 April 17	BIM Customization		Wiley – <i>Chapter 1: Smart Buildings / Smart(er) Designers: BIM and the Creative Design Process</i> <i>AECbytes -Got Macros.pdf</i>
Week 15 April 24	BIM in the Profession: Architecture	FP, part 2 due	Optional: Routledge – <i>Chapter 4: BIM implementation</i>
Week 16 May 1	Course Synthesis		Optional: aiab095712 - AIA BIM contract documents.pdf National Building Information Modeling Standard (NBIMSv1_p1.pdf)
FINAL, May 8, 8 – 10 am, Final Project, part 3 due			

2.4 Short Overview of Homework Assignments

Each assignment usually ask for several pages of 11”x17” print-outs and a Revit file to turn in. The intent is to provide a good overview of the fundamentals of BIM. Unfortunately, there is not time to cover some other important items that are related towards working in an office environment, but issues like standards, naming conventions, and the idea of work sets are discussed in class.

Homework 1: *BIM Overview: Introduction to Revit Architecture*



Figure 1: Yiyu Chen, Spring 2014. Notice the addition of a garage, street, driveway, and sidewalks to the Autodesk Revit getting started guide. This workshop is intended to immerse the students in Revit.

Homework 2: *Understanding Families*

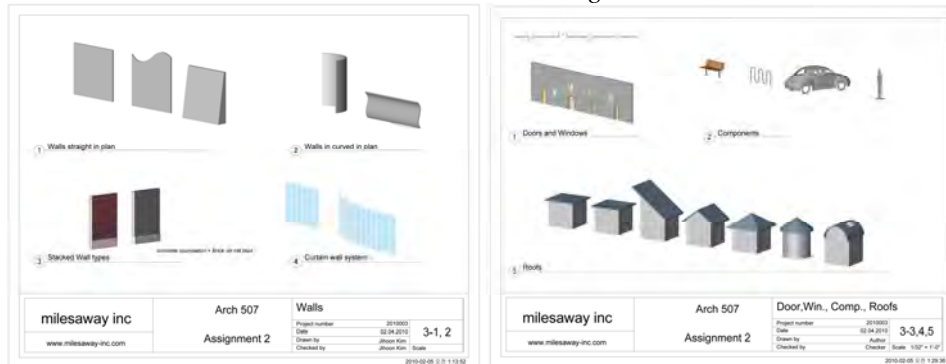


Figure 2: Jihoon Kim, Spring 2010; loadable, in-place, and parametric components

Homework 3: *Your Building: 2D / 3D Coordination*

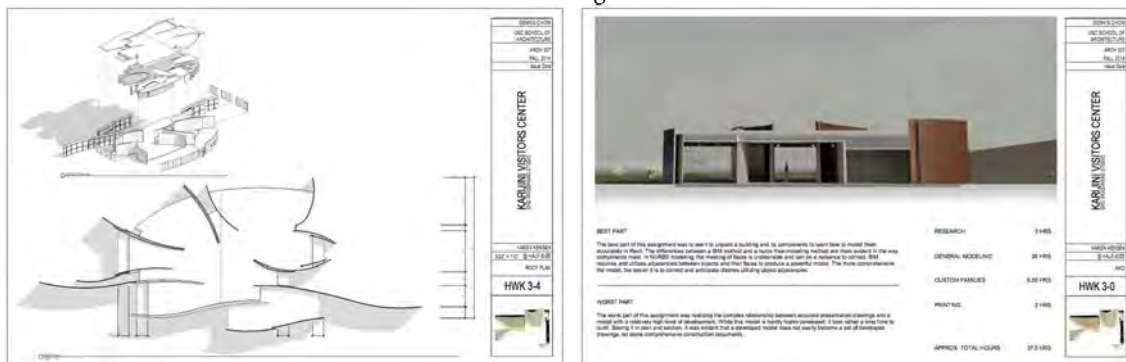


Figure 3: Dennis Chow, Fall 2014; modeling a building from scratch

Homework 4: BIM Scheduling and Detailing and Homework 5: Rendering and Animation

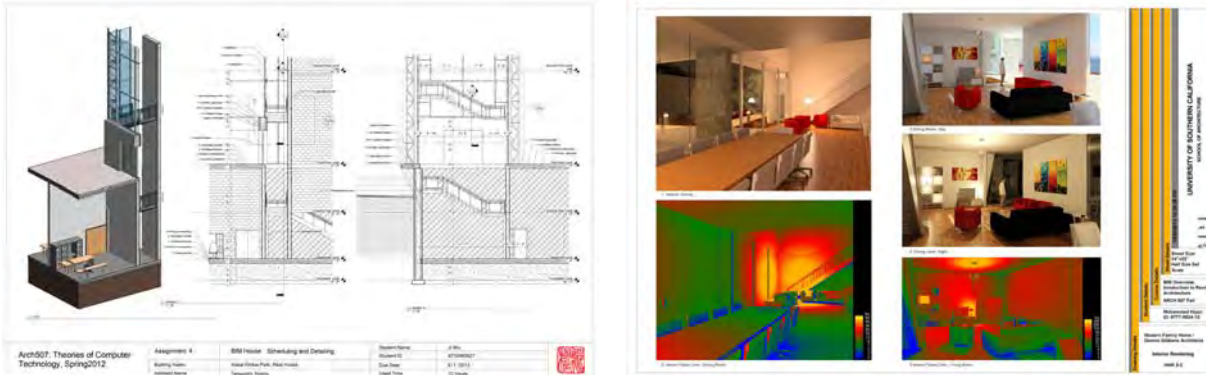


Figure 4: Ji Wu, Spring 2012 and Figure 5: Mohammad Hijazi, Fall 2013

Homework 6: Introduction to the Conceptual Modeler and Pattern Based Curtain Walls

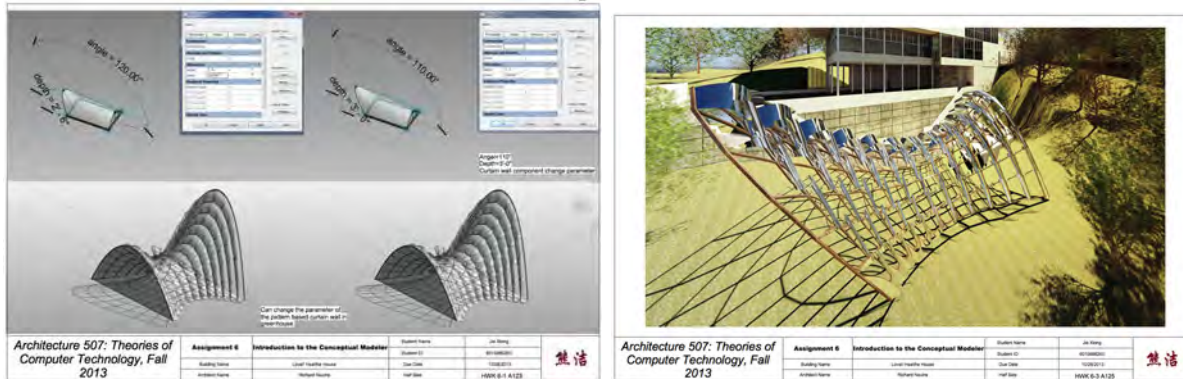


Figure 6: Jie Xiong, Fall 2013

Homework 7: Parametric Modeling: Adaptive Components

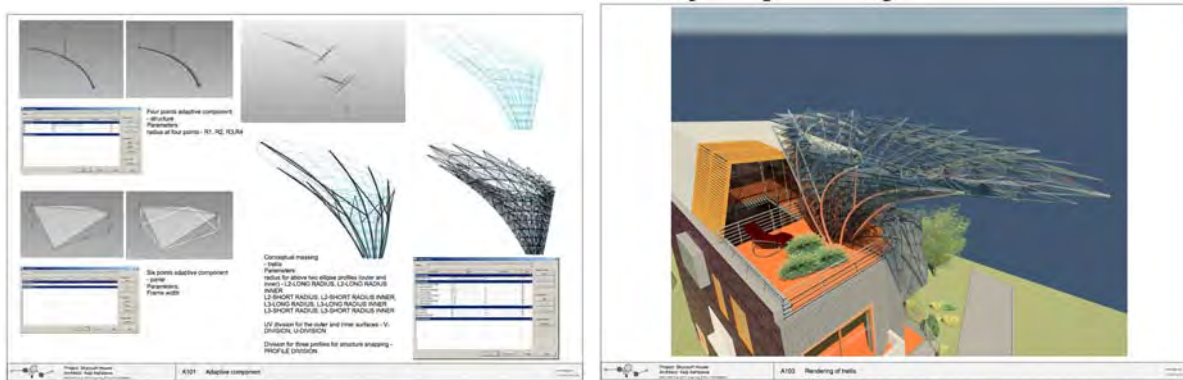


Figure 7: Yuening Zhou, Fall 2013

Homework 8: Varies

The subject matter of homework 8 has varied over the course of several years. Topics have included Navisworks (clash detection and construction sequencing), Vasari (conceptual energy and wind studies), Solibri (model checking), ArchiCAD (another BIM program), and even in some cases, the assignment has been canceled to allow more time for the final project. Currently the assignment is BIM Analytics with a focus on using Revit with Green Building Studio. This is based on a previous final project.

3. FINAL PROJECT

The framework of the homework assignments focuses on teaching the fundamentals of BIM with Revit as the main software used. The final project provides a longer period of time (generally 3 or 4 weeks) to explore a topic in more detail. Four types of final projects have made their appearance: contractors' and architects' viewpoints on BIM; BIM + sustainable design; customization (creating plug-ins); and visual scripting using Dynamo.

3.1 Contractors' and Architects' Viewpoints on BIM

One stumbling block in seamless integration of BIM in the AEC industry has been gaps in the transfer of information between the major players. The students interviewed a key BIM coordinator at an architecture firm about a specific project that they have completed or was near completion. They then interviewed another person at the construction firm that worked on the same project. They reported on how the BIM model was created and then passed on to the next stage of its development, what problems occurred, and how to improve this process.

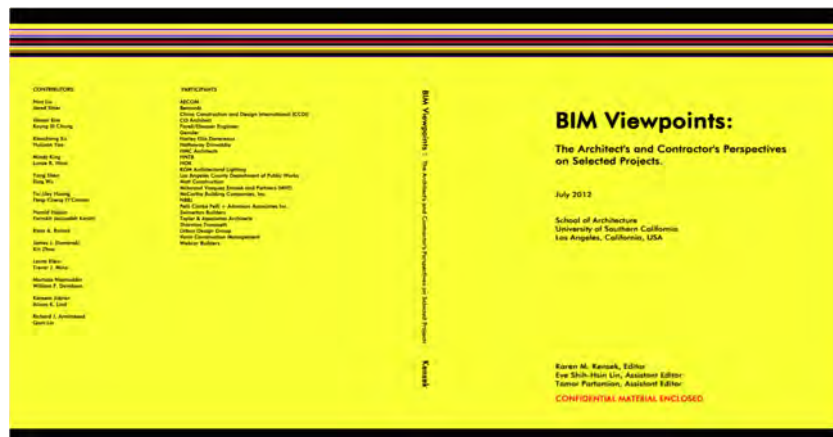


Figure 8: Spring 2010, note that a few firms wanted their interviews kept confidential for liability reasons

3.2 BIM + sustainable design

Different versions of this project have been offered, some in Vasari, others in Revit. They have also made use of the Autodesk Sustainable Design Curriculum and Autodesk Building Performance Analysis Certificate (BPAC) programs to give the students a background in green design. Now only selected modules are assigned, not the entire certificate program as the time to complete it is too long.



Figure 9: Chao Yao, Spring 2014

3.3 Customization (creating plug-ins)

A plug-in is used to improve the productivity of a software program. In this part of the customization final project, the students used the Revit API (application program interface), to create a new plug-in. Along the way, they learned some C# to write the code, how to use Visual Studio to create a dll, and how to create an addin file so that Revit will implement the plug-in.



Figure 10: Plug-ins that calculate the size of a rainwater cistern based on location and roof area (Ethan Barley, Andres Lin-Shiu, and Tyler Tucker) (left) and display the heat gain of different types of windows with and without shading (Chris Daubert, Ty Harrison, and Andrew Reego) (right). Spring 2012.

3.4 Visual Scripting using Dynamo

Visual scripting tools (e.g. Grasshopper for Rhino and Dynamo for Revit) allow users to create customized, flexible, and powerful form-generating algorithms by making connections among a collection of graphic modules without the need to learn how to write code. Forms are automatically created based on flexible numerical parameters rather than a single pre-determined value. This capability is extremely valuable in early stage design, as designers can manipulate one or more parameters to explore design alternatives rather than manually rebuilt the model each time. Although the Rhino/Grasshopper environment is currently further developed along these lines than Revit/Dynamo, the latter does allow for certain features that are different from the former. Overall, in both, visual scripting allows for designers to have even more control over their designs and provides a mechanism for form generation parametrically. The intent of part 1 of the final project was to demonstrate basics of Dynamo by learning how to create an attractor script and manipulate an instance parameter.

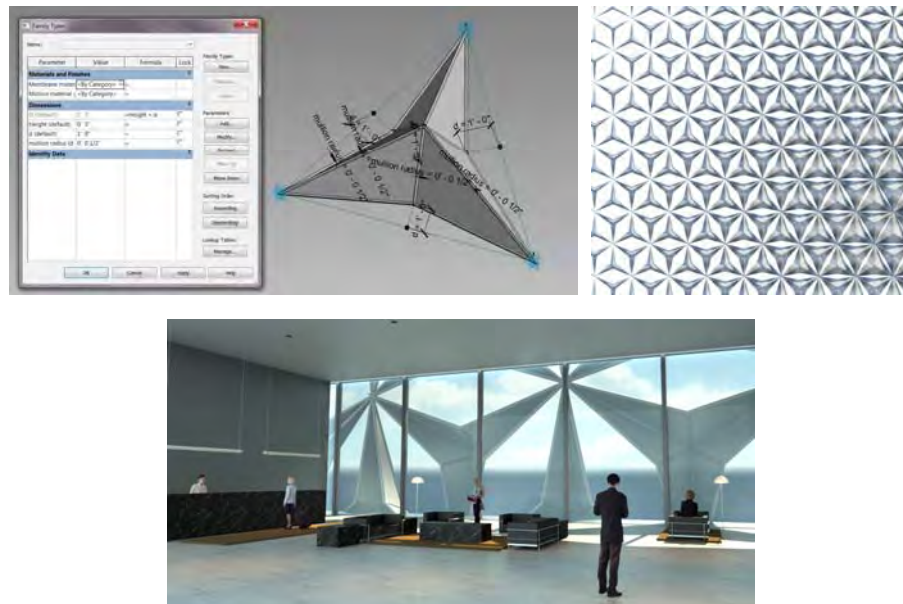


Figure 11: Ilaria Toldo and Dennis Chow, Fall 2014

Part 2 of the final project expanded the attractor idea from part 1 by using the sun's location reported in Revit to Dynamo as the attractor element. The solar shading devices responded to the location of the sun. Further explorations of this part of the assignment would include additional emphasis on day lighting, heat gain, and glare. Another future enhancement would be the use of the Green Building Studio package/component in Dynamo.



Figure 12: Aditya Dharane and Mohammed Aljammaz, Fall 2014

Part 3 of the final project focused on creating interactive, parametric geometry in Dynamo based on Zach Kron's bridge (<https://www.youtube.com/watch?v=pgPLIFSqI6Y>).

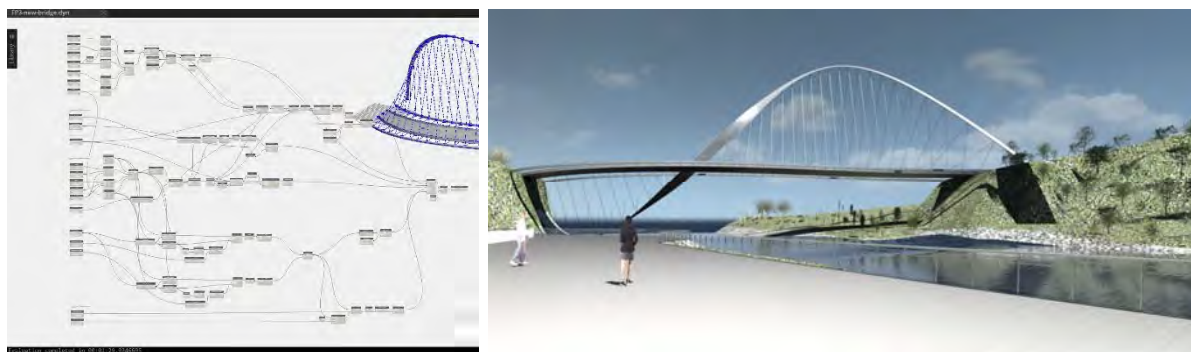


Figure 13: Ilaria Toldo and Dennis Chow, Fall 2014

4. CONCLUSION

This paper concentrates on one elective class and how it balances the fundamentals of BIM (homework assignments) with a more exploratory final project (that sometimes becomes a homework assignment). A separate required class on professional practice also has topics in BIM. The BIM assignments in that class focus more on communication and have the architecture students complete exercises in Revit Architecture, MEP, and Structure in addition to a team project in Autodesk Glue or GTeam. Interested students can also take a class in construction management in the School of Engineering that presents another viewpoint. However, the next step to consider is what other types of courses should be offered: BIM management, facilities management, construction, BIM analytics and interoperability, etc.? Or will building information modeling be subsumed within the architectural curriculum similar to CAD and 3D modeling, which are sometimes no longer taught as discrete topics but learned independently by the students?

ACKNOWLEDGMENTS

Thanks to my students who enthusiastically test my new assignments.

Process and Structure: Performance Impacts on Collaborative Interdisciplinary Team Experiences

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ABSTRACT

Does a team's process or its structure have a greater impact on its performance? In a recent study investigating interdisciplinary student teams assembled for a design-build charrette, results indicated that both process and structure influence team dynamics and by extension the end product. Teams with no prior experience working together were given two weeks to complete a proposal for the addition of classroom and assembly spaces to an existing elementary school. Team members represented both the design and construction disciplines and were in their final semester of undergraduate studies, each having completed their discipline's core technical course work. A Request for Proposal (RFP) was issued for the project requiring each team to submit a building information model for the owner representative's use prior to and after the team presentations and interviews. Students developed their proposals within a charrette context, contributing their discipline specific knowledge and expertise early in the project through openly shared information. Working in a charrette environment requires teams to form quickly and establish roles, responsibilities, and workflow if the team is to be successful. The goals of the project were to improve student understanding about the integration between the disciplines of both team structure and process and how, when integrated early in the project, each could affect the final outcomes. This paper focuses on team process and reports on the results related to information exchange, protocol, information sharing, and standards. Discussion about the importance of establishing a framework to support the team's structure is included as a link between process and structure. Results from this study can be used to inform future curriculum development that supports student success in the 21st century as more design and construction programs seek to integrate collaborative interdisciplinary team experience utilizing BIM.

Keywords: interdisciplinary teams, BIM, design-build, charrette

1. INTRODUCTION

C5 is an interdisciplinary design-build project designed as a collaboration between architecture, interior design, and construction supported by the use of building information modeling. The name C5 derives itself from a mantra developed to define the project containing 5 "C's": Collaborate, Create, Construct, Capstone Charette. Guiding the development of C5 is the premise that BIM enhances collaboration in the design-build process and that collaboration depends on five key principles applied to all team members: 1) interactive communication, 2) full involvement, 3) mutual trust, 4) shared risks and rewards, and 5) teamwork (Design-Build Institute of America [DBIA], 2012).

1.1. Literature Review

Collaboration is the norm for how academic, business, and creative ventures should be executed in the 21st century. Although the definition for collaboration may vary across domains in the balance of

function and social inputs, the essence of collaboration depends on the ability of a team to interact for the purpose of successfully accomplishing the team's goal. One definition from the business management literature describes collaboration as a process of decision making among interdependent parties that involves joint ownership of decisions and collective responsibility for outcomes (Liedtka 1996). Collaboration facilitates a shared understanding about the purpose of the team and its reason for existence to work on a common goal toward task accomplishment. Additionally, it is important that the organization of a team's members provide a structure to facilitate a process that supports collaboration.

The distinction between team process and team structure provides a baseline for better understanding of the aspects that contribute to effectiveness within a team environment. Group structure has both a direct and indirect influence on effectiveness. The indirect link to effectiveness is achieved through the influence of group structure on group process (Gladstein, 1984). Group structure is the arrangement among people based on roles and responsibilities, whereas group process defines the specific modes of interaction between two points of activity in time. The early work of Gladstein (1984) on team building and collaboration introduced a model of effectiveness in which she predicted that group process is the antecedent to group effectiveness.

An understanding about the relationship between technology, structure, and communication to encourage an effective communication process can contribute to improving team interactions and performance. Team management factors facilitate standards for team interactions, such as information exchange. Standards for the team serve to 1) establish and communicate expected performance to all team members, 2) establish and communicate roles and each role's responsibility for information contribution in the exchange, 3) provide a point of reference for conflict resolution and/or reduce conflict, and 4) ensure a platform for team members to contribute technical competency in a normative manner that fits within the team's understanding of roles and responsibilities (Malhotra, Majchrzak et al., 2001)

It is important that teams working in a collaborative project delivery method, such as design-build, exchange information at many different levels and stages from early design through construction. A variety of BIM tools support the mechanics of exchanging information utilizing a common language (IFC) or with the use of proprietary plug-ins, however even with the technology support, gaps in information exchange still exist. It may appear that data and information are interchangeable but there is a distinct difference between them. Data is defined as a collection of empirical observations or facts. In contrast, information is a collection of facts or observations for use in making decisions or drawing conclusions (Smith, 2009). According to the National BIM Standards (NBIMS) information exchange is a process in which a project team establishes what information will be exchanged and the format for exchange between team members (National Institute of Building Sciences [NIBS], 2012). The Project Execution Planning Guide (Computer Integrated Construction Research Program [CIC], 2010) includes the act of defining information exchanges as one of four steps to be completed by project teams in creating and implementing a BIM Project Execution Plan. To be effective the information exchanges should be created early in the team planning process and establish a mutual agreement about 1) the model elements to include by discipline, 2) the level of development for each model element, 3) any additional information or attributes important to the project, and 4) discipline specific deliverables (CIC, 2010). The team process of defining information exchanges is a critical step for teams to collaborate and have success in meeting the project goals.

Information sharing is closely related to information exchange; however, sharing information is considered a principle necessary for success in a design-build (DB) or integrated project delivery (IPD) project, whereas information exchange is a process established to share information. Project delivery methods with less integration between disciplines typically stifle information sharing as individual entities hold separate contracts for design and construction services. Sharing information as a DB principle facilitates the alignment of design and construction professionals and reduces redundant work resulting in time savings (DBIA, 2012; NIBS, 2012).

With information exchanges established, teams should define a procedure for file transfer protocol and their communication protocol. Establishing protocols will support collaboration and define the team's document management process to include file folder structure, permissions and access, folder

maintenance, folder notifications, and file naming convention (CIC, 2010; Eastman, Teicholz, Sacks, and Liston, 2008). The Architecture/Engineering/Construction (AEC) CADD and the NBIMS are standards adopted by the industry that set forth the expected content, format, and graphical representations in BIM models. Standards such as ISO, LEED, ADA and ASHRAE are just a few other industry standards utilized to guide the design and construction of the built environment.

1.2 Purposes

Research about collaboration among interdisciplinary student teams using BIM is an important topic for educators in the design and construction disciplines. As buildings become more complex, the ability for project team members to collaborate increases. As a consequence, efforts to educate tomorrow's AEC professionals are evolving to integrate interdisciplinary team experiences with instruction about interdisciplinary collaboration.

The current study focused on three elements identified in the literature as important attributes of successful teams. The research investigated the process and structure of a team, and how the two impact collaboration. Components of the construct team process included information exchange, protocol, information sharing, and standards. Essentially these are the mechanics of the team and how it operates as a team. Questions were designed to measure a team member's perception about the team process. For example, "It is important that team members agree upon a format for the exchange of technical information." In contrast, the team structure construct included items that measured participant's perceptions about the roles, responsibilities, project knowledge, and technical expertise on a team. "Clearly defined responsibilities for each role is important to ensure positive team dynamics" was one of the items included about team structure. The current study sought to answer the following research questions:

- 1) Is there a difference in student perceptions about the importance of team process compared to team structure?
- 2) Which individual team process components do interdisciplinary teams identify as impacting collaboration?
- 3) Does a team's process or structure have a greater impact on its performance?

The results from this research would serve to inform the instructors in the AEC disciplines that are involved in teaching collaboration. In particular, the results would help determine if the current instructional model and strategies for teaching interdisciplinary collaboration are appropriate or sufficient to developing students' collaboration skills.

2. METHODS

2.1. Study Design

An exploratory study was conducted with undergraduate students (15 female; 15 male) enrolled in either the senior level commercial construction, interior design, or architecture course in the College of Architecture at the University of Oklahoma. Students were recruited and volunteered to participate in an online survey. Participants included 11 Construction Science, 12 Interior Design, and 7 Architecture of which 24 students reported a grade point average of 3.0 or higher. Twenty-eight of the 30 study participants reported having at least one internship experience and all 30 participants reported having experience working in teams during their academic studies in the College of Architecture. No distinction was made between interdisciplinary or single discipline team experiences, but 26 of the 30 reported working in teams at least 4 times. Ten of the students reported working in teams more than 10 times in their course work.

The study was designed to investigate the relationship between team dynamics, structure, and process utilizing a 44 question online survey administered after completion of an interdisciplinary course project. Students were provided with a web link to the survey and time to complete the survey in class. There was no pre-intervention survey to measure student attitudes about teams; however, student teams were required to complete a questionnaire about ten factors previously identified as impacting collaboration.

2.1.1. Context

The C5 interdisciplinary design-build project was organized for students in the final semester of their academic career. The composition of each typical student team was balanced with one student from each of the architecture, interior design, and construction programs. The planning and design of the project was also a collaborative team effort with one faculty member from each of the three represented disciplines. The faculty agreed that the best way to teach collaboration was by example; therefore, the decisions were made to recruit industry partners with prior experience working together to actively participate in the project as experts to role model for the student teams. The faculty believed that through the industry partners sharing specific examples of successful collaborative experiences, including their typical structure and processes, students would gain a real-world perspective and valuable knowledge about best practices and lessons learned from an integrated project approach. It was expected this type of industry partner would demonstrate the principles of mutual respect and trust between the team members.

The goals of the C5 project were to improve student understanding about the integration between the disciplines of both team structure and process and how, when integrated early in the project, each could affect the final outcomes. Ultimately, students would have an improved understanding about the roles and responsibilities of each discipline and, in turn, their overall team structure. The students also would understand where there were possible gaps and overlaps in their team's knowledge and skills, giving them a better opportunity to fully understand and implement a process for the team to follow.

A local community client with a real-world project was utilized. Hillcrest Elementary is an early childhood center educating students in Pre-kindergarten and Kindergarten. The original school was constructed in 1952. Since 1961 four additions have been made to the school. The RFP solicited proposals for an addition of five new classrooms, student bathrooms as needed to meet code for proposal addition, a new entry with secured vestibule, secured reception area, new administration offices, minor interior renovations to the existing facility to bring a somewhat cohesive aesthetic to the interior, below grade safe room that would hold 600 people and site additions of 50 parking spaces and a new parent drop off lane.

2.1.2 Materials

The materials for the charrette consisted of 1) a personality assessment, 2) two team building exercises, and 3) a written 48 page Request for Proposal (RFP). The personality assessment provided a quick interactive activity for students to complete based on four qualities that identified their interaction and leadership style. Team building exercise 1 required team members exchange personal information, along with their academic and professional goals. The second team building exercise listed 10 factors identified as impacting collaboration and students were asked to first discuss each of the factors and then develop a written plan describing how their team would address and manage each factor to optimize collaboration. The RFP provided an overview of the project, project owner's requirements, and a detailed list of deliverables. Additionally the RFP included exhibits (or links to exhibits) of the existing building drawings, site survey, location map, estimate summary sheet, and geotechnical report. Digital photographs of existing building and site conditions were also provided. All deliverables were submitted electronically through the on-campus course management system. Students were required to have a personal laptop with Revit 2013, SketchUp Pro, Assemble, Microsoft Project, Adobe Photoshop, and Microsoft Office.

2.1.3 Procedures

The first day of C5 was scheduled as an eight hour intense meeting with team building exercises, introduction of the project by the community client, industry partners' presentation and role playing demonstrations on team building and professional collaboration skills, release of the request for proposal (RFP), and time dedicated for the teams to work together and begin making decisions about the project. During the work time the faculty and industry partners had the opportunity to observe and advise the student teams through the beginning stages of their collaborative design efforts. The students not only had the opportunity to learn from both their professors and professional industry advisors, but began to learn from each other within the controlled collaborative environment. The faculty and industry partners worked with each team during the initial eight hours to define their goals for the project as each team focused on outstanding performance. Teams were also required to discuss individual expertise and identify each team member's responsibilities during the first session.

A second meeting between the faculty and students took place midway through the project to evaluate the students' progress and address any issues with team dynamics, structure or processes. Within the two weeks of the project, the three faculty members maintained collaborative office hours where individual teams could meet with the faculty and discuss any issues or ask questions about the project.

The architecture and interior design students formed the design team and worked together in a collaborative teamwork approach as the prime designer. The design team's first responsibility involved translating the owner's programme during early design in an iterative manner between the two disciplines. With a common understanding of the space requirements, adjacencies, and project constraints the design team then discussed with the constructors the results from their pre-design activities, at which time, the constructors completed an analysis and provide recommendations for consideration by the project team. Based on the project team's agreement from the pre-design phase, the design team continued developing the project's design in the schematic design. The architects and interior designers worked closely together to coordinate the structural system, building enclosure, and mechanical/electrical/plumbing (MEP) systems in a manner that provided spaces that would function for their intended use and provide a healthy environment for its occupants. The constructors provided ongoing design review and feedback about the project's constructability, costs, and risks. BIM was utilized throughout the project by all team members to facilitate interactive communication and decision making between team members.

During the final segment of the project, the student teams submitted and presented their project proposals to the clients, industry professionals and faculty members. The minimum deliverables required from each team included precedent studies, programme analysis, concept development, code analysis, site plan, floor plans, interior and exterior perspectives and elevations, preliminary specifications, basis of estimate and schedule, constructability review, conceptual cost estimate, preliminary construction schedule, site logistics plan, risk analysis, safety plan, all organized in a proposal booklet and synthesized in digital presentation slides with an oral group presentation. Each team was required to handover a building information model (BIM) with the project proposal. Requirements for the model included complete and accurate model elements ranging between level of development (LOD) 200 and LOD 300.

2.2. Data Analysis

Descriptive statistics were used to answer the research questions. The co-researchers were domain experts and also taught two of the three courses involved in the project. Survey data was extracted from Qualtrics as an exported file and imported to SPSS for analysis. A total of 30 students participated from the 38 recruited resulting in a 79% response rate.

3. RESULTS

Results reported in this paper are based on the participants' responses to 24 questions. Of the 24 questions, 12 questions inquired about team process and 12 questions about team structure. Each

construct included 4 components for which 3 questions specifically addressed each component. A Likert scale of 1-5 was used with 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree. Within each set of component questions there was one question designed with a reverse scale. Table 1 displays the aggregate mean and standard deviation for the team process and team structure components measured by the survey.

Table 1 Team process and team structure data

Construct	Component	Aggregate Mean and Standard Deviation (by component item)	Aggregate Mean and Standard Deviation (by construct)
Team process	Information exchange	3.76 (.963)	4.0 (.698)
	Protocol	4.05 (.609)	
	Information sharing	4.18 (.637)	
	Standards	4.03 (.585)	
Team structure	Roles	4.12 (.863)	3.93 (.842)
	Responsibilities	4.19 (.809)	
	Project knowledge	3.61 (.905)	
	Technical expertise	3.79 (.791)	

Based on the data in Table 1, the researchers were able to provide the answer to research question 1, which indicated that there is a slight difference in student perceptions about the importance of team process compared to team structure. The results revealed that the aggregate mean (4.0, SD = .698) for team process is slightly greater than the aggregate mean (3.93, SD = .842) than team structure in the current study. The team process by component displayed in Table 1 provided the researchers with additional data to answer research question 2 investigating which individual team process components do interdisciplinary teams identify as impacting collaboration? Based on the results, students perceive information exchange as having the least impact on collaboration. The aggregate mean (3.76, SD = .963) for information exchange equates to students neither agreeing or nor disagreeing that information exchange has an impact on collaboration. In contrast, the participants agree that protocol, information sharing, and standards impact collaboration. The researchers were unable to provide an answer to research question 3, investigating whether or not a team's process or structure has a greater impact on its performance, based on the data collected for the current study.

Figure 1 depicts a model representing the relationship between components based on the results. Collaboration is at the top indicating the team's goal with industry standards providing the basis on which all other components build. Although the results indicated a neutral attitude about information exchange, the participants perceive protocol as an important component of collaboration therefore it is combined with information exchange in figure 1.

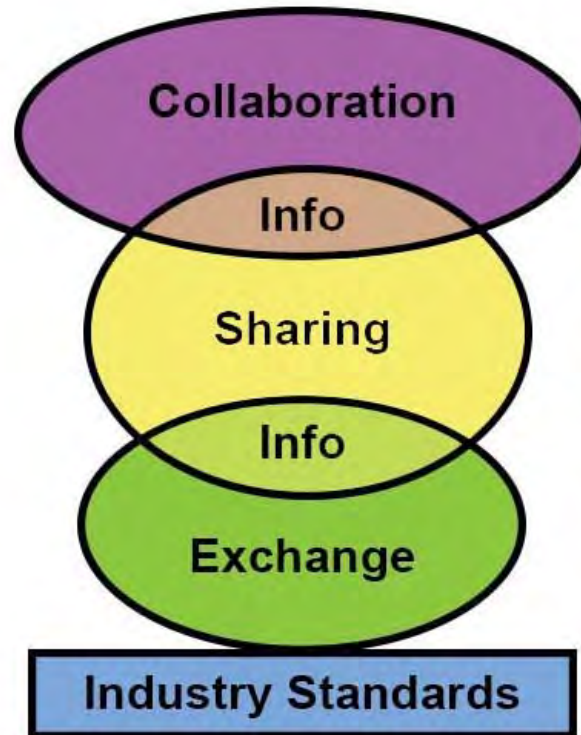


Figure 1 Team process model of components

4. DISCUSSION AND IMPLICATIONS

The distinction between the importance of team process and team structure are slight based on the current study results; however, the results initiated additional questions about each construct and the possibility of interdependence between components and constructs. As reported in the study design section above, 28 of the 30 participants reported having real-world industry experience and all of the participants had previous experiences working in teams during their academic studies at the OU College of Architecture. A tentative conclusion may be made that because participants had experience with both industry and teams, the students understood the impact of team process on collaboration. Drawing the conclusion that previous experiences created an understanding about team process led to further questions about the quantity and quality of student experiences compared to the type of experience, whether industry or academic. Further research that discerns between type, quantity, and quality of student domain experiences relative to team performance would provide empirical evidence that could be used to evaluate the effectiveness of the current instructional model used by educators teaching students about design and construction team collaboration.

C5 is expected to continue annually as a project in the spring semester of students' senior year; therefore the researchers anticipate opportunities to study student experiences and their relationship to team process, structure, and performance. There is anecdotal evidence however that indicates gaps between the students' perceptions about team process and their approach to ensure a process in which the team utilized industry standards to establish protocols for information exchange. Based on observations during the charrette and discussions with students post proposal submittal, the faculty believe there are opportunities to improve student team performance.

5. CONCLUSIONS

The students' that participated in the C5 project are better prepared to utilize BIM as members of a collaborative team in their future professional endeavors. The students' understanding of the other disciplines on their team improved and in turn they learned to respect and trust each other's contributions to the project. The hope is that the students moved into their professional careers with a better understanding of each profession's strengths and weaknesses, including their own, and a greater respect for each discipline. In addition to the students' increased knowledge about collaboration, the C5 faculty members increased their knowledge about each discipline and are better prepared to teach in an interdisciplinary college and collaborative environment.

Additionally, students further developed their technical expertise and gained a better understanding about how BIM can enhance interdisciplinary team collaboration. Although traditional capstone projects are completed individually, C5 provided an added component that further reinforced the idea that a collaborative effort is required to successfully design and construct a building. Ultimately C5 provided students with a simulation of what they can expect in their future professional roles as design-builders. The academic environment provided students with an opportunity to practice their professional roles with peers who represent the roles of future team members. Buildings are ultimately created by a diverse team of professionals, and better buildings can be created when the team members are able to escape their individual professional silos and collaboratively work together based on mutual understanding and respect.

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TOWARD ADOPTION OF BIM IN THE NIGERIAN AEC INDUSTRY; CONTEXT FRAMING, DATA COLLECTING AND PARADIGM FOR INTERPRETATION

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ABSTRACT

In an effort toward aligning the Nigerian Architecture, Engineering and Construction (AEC) sector to the international benchmark of practice in adoption of Building Information Modelling (BIM), this research aimed to understand the Nigerian AEC context assessing the current state of art in the Architectural firms. The research consisted of: creating a survey to collect data on distance mode; adapting different researches and methods in this field to the local context using European and North American protocols as the basis; helping to inform the discussion on future directions and serve as a basis for developments, based on an assessment model specifically defined for a developing Country and the interpretation of the collected data. Part of the research was a review of literature and case studies to appreciate BIM and its potential to the Nigeria AEC sector. It has been realized that BIM among other means has potential to minimize curb corruption in the construction industry which is a worrisome ongoing issue and a slackening factor for the economic growth. As one of the objectives, a conceptual framework was developed based on the Succar's (2009) BIM maturity matrix: this was considered as the basis for the development of the online questionnaire. It involved assessment of technology, processes, policy and functional targets. The assessment conducted through the survey was explanatory and descriptive by itself. It involved 101 architectural firm registered in Nigeria distributed across selected four cities of Lagos, Abuja, Kaduna and Kano where more than 60% of the firms in the country are located. An online questionnaire survey - based on FluidSurveys™ tool – was used to administer the survey. The study opted for a three steps analysis: (i) to classify the firms into a 3 level scale based on staff employed; (ii) to assess data by analysing the responses in each category against the BIM maturity models using cross tabulation; (iii) to define the level of each category in its prospect to the BIM adoption using a descriptive analysis. It was found that most of the medium and larger scale firms are significantly catching up toward the BIM practice, but the small scale firms are having setbacks especially in the aspect of process and policy adherence. However, among all the groups, the level of technological workforce toward BIM and digital technology at large was found appreciable.

Keywords: BIM, Nigeria, AEC, BIM maturity matrix, adoption.

1. INTRODUCTION

In the wake of the information and digital revolution, the Architecture, Engineering and Construction (AEC) industry is facing a paradigm shift in the use of Building Information Modelling (BIM) and Integrated Design and Delivery Solutions (IDDS) (Owen et al., 2009) aiming to increase productivity, efficiency, value, quality and sustainability, and to reduce lifecycle costs (Arayici et al., 2011). Making these gains needs a corresponding shift in focus and processes. Such a change cannot be ensured by a single unit; it is rather a transition that requires participation from the building clients, designers, builders and product manufacturers. BIM is seen as an enabler that may help the building industry to improve its productivity by ensuring an effective communication and collaboration between all project stakeholders from inception to completion of building projects (Becerik-Gerber and Rice, 2010). Numerous case studies (Eastman et al, 2011) that provide some evidence to support the fact that the use of BIM makes the building process more effective have been reported. According to Succar (2012) BIM has now solidified its position as a promising approach towards addressing the AEC sector's numerous inefficiencies.

Countries like Finland, USA, UK, Australia, Netherlands, Singapore, Hong Kong Norway, Denmark among others have adopted BIM technologies and have experienced significant benefits in construction project delivery (Yan and Damian, 2008; Isikdag and Underwood, 2010; Nederveen et al, 2010; Wong and Lee, 2010; Sebastian and Berlo, 2010). Some of the benefits of BIM technologies as claimed by its proponents are the provision of an efficient communication and data exchange system (Nederveen et al, 2010), auto quantification, improved collaboration, coordination of construction documents, improved visualisation of design (Olatunji, et al, 2010; Sacks et al, 2010), clash detection and cost reduction (Eastman et al; 2011) among others. In view of the documented benefits of BIM, Olatunji et al., (2010) stressed the need for its full adoption across all disciplines and geographical boundaries. Consequently, it becomes imperative for the Nigerian AEC industry, which has been described as a 'sleeping giant' and having no capacity to deliver due to inefficiency and poor service delivery among other problems attributed to it (Kolo and Ibrahim, 2010; Mohammed, 2012) to exploit the widely acclaimed benefits of BIM and achieving continuous improvement needed by its core players. However, despite the potentials and documented benefits, not much has been reported regarding its implementation in the Nigerian AEC industry. It requires examining the prospect of the AEC industry market through its state of art and openness to the information and digital technology. In light of that, this research upon taking to the task, focused generally on survey of the prospect of BIM adoption in the state of art of the Nigeria AEC industry practice, but focusing primarily on the Architectural practice to help with developments within this particular sector.

Aim and Objectives of the Research

The aim of the research was to examine the prospect of the Nigerian Architectural firms' market on its state of art and the openness of the firms to the information and digital technology toward adoption of BIM. To achieved that, a review of literature was vital, and was done focusing on the understanding of the BIM, some case studies using BIM. Thereafter, the study opted for a three steps analysis: (i) to classify the firms into a 3 level scale based on staff employed; (ii) to assess data by analysing the responses of each category against the BIM maturity models using cross tabulation; (iii) to define the level of the willingness and implementation in each category in its prospect to the BIM adoption using a descriptive analysis.

Although several earlier researches were done surveying the impact of the information technology in the Nigerian AEC industries, they mostly focus on either its impact on education (Ogunsote et al., 2008), or towards integrating it to the architectural curricular (Ajufoh et al., 2012). Only few have focused on practical aspects, like Fasheun-Motesho (2002) who studied the adoption and growth of Information Technology in Nigerian Architectural Firms. However, even this study ran short of relating his findings to the current challenges facing the AEC industry, like BIM, and identifying the state of the art in the firms. However, state of art studies of IT issues in any context will become obsolete in the rapidly changing technology environment . As a suggestion for further scholarship, Fasheun-Motesho (2002) has advocated for more studies investigating the prospect of information technology in enhancing the new practices in the industry.

2. BUILDING INFORMATION MODELLING AND THE NIGERIA CONTEXT

Case studies of BIM introduction in different markets

The adoption of BIM has not been absolute or as swift as wished, because of the AEC industry's conservatism to their practice (Khemlani, 2006). Thus, most of it success stories exist as a result of some external issues, like market competition (Liu et al., 2010) or as a result of Government enforcement, like in USA where the General Services Administration (GSA) mandated the use of BIM for any public and significantly funded project in 2007. Similar demands have implemented also, for example, in Northern Europe and in Singapore. Until recently BIM adoption was slow in the United Kingdom, but after the UK Government stated in 2010 that the use of BIM will become mandatory in all Governmental projects in 2016 the development has been very fast. However, Liu, Issa and Olbina (2010) identified that the internal readiness which involved the management willingness and equipment are

among the major factors affecting the adoption of BIM. Based on this view, this research made a survey study of the environment in Nigeria to see what was the prospect within the internal readiness.

Nigerian AEC market and how practices are using IT and digital tools.

Generally speaking, just as being categorised of being a developing country, also Nigeria's level of ICT is developing. There has been efforts by researchers and practitioners in the industry to make the best out of the emerging technology to better enhancing practice. While, the industry itself was increasing awareness and applications in its practice, researchers like Oyediran & Odusami (2005) studied the extent of use of the computers particularly among Nigerian quantity surveyors, and found that about 90% of them use computer for project cost management services (PCMS). Oladapo (2006) studied the influence of Information and Communication Technology (ICT) on professional practice in general and his study revealed significant acceptance rate in the industry. Later (2007), he re-investigated the impediments to the use of ICT in typical Nigerian construction industry settings and identified the cultural issues as a main factors affecting it.

BIM prospect evaluation model

An important part of the research was to reflect from existing maturity models/indices by analysing, testing and then adopting some of the widely-used maturity models. The considered models for these study include; Control Objects for Information and related Technology, CMMI (Capability Maturity Model Integration), CSCMM (Construction Supply Chain Maturity Model), I-CMM (Interactive Capability Maturity Model), Knowledge Retention Maturity Levels, LESAT (Lean Enterprise Self-Assessment Tool), P3M3 (Portfolio, Programme and Project Management Maturity Model), P-CMM® (People Capability Maturity Model), (PM)² (Project Management Process Maturity Model), SPICE (Standardised Process Improvement for Construction Enterprises), Supply Chain Management Process Maturity Model, and BPO (Business Process Orientation Maturity Model). These models conceptualise the relation between process maturity and supply chain operations based on the Supply-chain Operations Reference Model (Stephens, 2001) ; Succar, 2009) in analysing their suitability for the development of a BIM-specific maturity index suggest that most were broad in approach and could collectively form a basis for a range of BIM processes, technologies and policies. However, there are not enough differentiation between the notion of capability and that of maturity. Therefore, finally the Succar's model was considered to form the best basis for the study and after modifications to suit the situation in the context of this research.

3. RESEARCH METHOD

A literature review was carried out for the purpose of articulating issues regarding the concept of BIM in the AEC industry with particular emphasis on the context of Nigeria. The review also aimed at appreciating the different BIM readiness and implementation framework models. BIM matrix by Succar (2009) was adopted and then a conceptual framework was designed for evaluating factors against the firms' state of art. This framework served as the basis of the questionnaire.

The study involved an online survey questionnaire using an online application FluidSurveys™ as the tool for data collection. The link to the survey was distributed via email to Architectural consultancy firms within four selected cities, Lagos, Abuja, Kano and Kaduna. 100 surveys were administered using emails and 40 surveys (40%) were retrieved and used for analysis. This was adequate based on the assertion of Moser and Kalton (1971) that the result of a survey can be considered significant if the response rate is not lower than 30-40%.

Classification of the firms

As stated earlier, the firms were classified to ease the level definition of each scale. Previous researches in the similar context were done by Oluwatayo (2009) who ended up classifying most firms in the medium scale. In this study the classification was based on the number of staff: (i) between 1 to 10 employees was classified into Small Architectural firm, (ii) between 11 to 20 into Medium Architectural firm, and (iii) beyond 20 into Large Architectural firm.

Furthermore, in addition to examining the number of staff, a study of how that was related to technological workforce of digital design technology was done. A chi-square test was used to achieve this.

4. ANALYSIS

Analysing the sizes and scales of the Firms

Table 1 shows how the number of digital design workforce (staff) correlates to the respective size of the firms used for classification, further analysis using Chi-square test of independence was used to validate the relation. This was done to ascertain the relevance of the classification for the study.

This classification allows equal participation of the firms in the study. Because the number of technological workforce, computer literacy and digital design skilled staff is depending on the number of the entire staff, the classification based on the size of the firm can play a vital role in a group study of the firms.

Table 1: Cross tabulation of size of firms by digital design staffs in the firms

Size of firm * Number of Digital design workforce cross tabulation						
			Number of digital design workforce			Total
			1 to 10	11 to 20	Beyond 20	
SIZE OF FIRMS	Small firms	% within size of the firm	100.0%			100.0%
		% within digital design workforce	45.8%			45.8%
	Medium firms	% within size of the firms	71.4%	28.6%		100.0%
		% within digital design workforce	41.7%	57.1%		98.8%
	Large firms	% within size of the firms	20.0%	20.0%	60.0%	100.0%
		% within digital design workforce	12.5%	42.9%	37.5%	100.0%

The Assessment

In this section the primary research question was answered identifying and assessing the current state of the art of the architectural firms based on the designed conceptual framework. Also the questions on the questionnaires were set based on the designed conceptual framework. The findings in this section would be mainly descriptive as it relates to the level definition. As planned the study was based on the classification of the firms, and the analysis cross tabulation was done based on the size of the firms followed by a descriptive analysis in each case.

Small Firms

Table 2 reveals the state of use of the BIM in the small firms and the questionnaires indicated that digital tools were mainly used for sketching, modelling and usually only printed copies were shared for visualisation and presentation which made the use of BIM almost obsolete. BIM was regarded as a technology stream without much consideration to the business process and its implementation lacked performance and improvement strategy with lack of leadership and motivation. Also, less regard is given to the product and service potential of the tools in producing a more comprehensive information rich model. There was lack of any policies, rules, guidelines or standards in use of the digital tools as the perception lay basically on technology and less, or no focus was given to the contractual and regulatory aspects.

Table 2: The summary table of the assessment in the small architectural firms

BIM Maturity Matrix Competency set		0 points	10 points Initial	20 points Defined	30 points Managed	40 points Integrated	50 points Optimised
Technology	Software	0	100	0	0	0	0
	Hardware % Network 1	0	18.2	63.6	18.2	0	0
	Hardware & Network 2	9.1	45.5	36.4	9.1	0	0
Process	Leadership	36.4	9.1	9.1	9.1	27.3	9.1
	Human Resources	45.5	9.1	27.3	9.1	9.1	0
	Product and services	0	100	0	0	0	0
	Contractual	36.4	9.1	9.1	9.1	27.3	9.1
Policy	Regulatory	45.5	9.1	18.2	9.1	0	18.2
	Preparatory	9.1	0	18.2	0	36.4	36.4
	Sub total	182	300.1	181.9	63.7	100.1	72.8
	Percentage	20.2%	33.3%	20.2%	7.0%	11.1%	8.0%
BIM Capability Stage		Pre BIM	Object based Modelling	Model based Collaboration	Integration		

Medium firms

Table 3 illustrates that there is significant intra-disciplinary collaboration using digital models within the medium size firms and tools are mainly used for modelling and visualizations while printed copies still remain the main media for the interdisciplinary collaboration. Apparently BIM in this category was still mainly regarded as a technology stream but with some ideas about the process although reluctantly adhered to with less motivation and lack of leadership. In the aspect of detailed integration of models, there is significant potential to improve collaboration on a digital platform but it is not used by the firms. Rules, guidelines or standards for use of BIM were not regarded but basically lay on individual championship and what was readily available.

Table 3: The summary table of the assessment in the medium size architectural firms

BIM Maturity Matrix Competency set		0 points	10 points Initial	20 points Defined	30 points Managed	40 points Integrated	50 points Optimised
Technology	Software	0	0	0	100	0	0
	Hardware % Network 1	0	0	50	35.7	7.1	7.1
	Hardware & Network 2	7.1	35.7	28.6	7.1	14.3	7.1
Process	Leadership	21.4	14.3	0	42.9	14.3	7.1
	Human Resources	21.5	0	14.3	14.3	14.3	35.7
	Product and services	0	0	0	100	0	0
	Contractual	21.4	14.3	0	35.7	21.4	7.1
Policy	Regulatory	21.4	14.3	0	42.9	14.3	7.1
	Preparatory	7.1	0	0	0	50	42.9
	Sub total	99.9	78.6	92.9	378.6	135.7	114.1
	Percentage	11.1%	8.0%	10%	42%	15%	12%
BIM Capability Stage		Pre BIM	Object based Modelling	Model based Collaboration	Integration		

Large Firms

Table 4 indicates that the use of digital tools in the large firms was relatively consistent with regards to collaboration i.e. Model based collaboration. While still significantly adhering to a set process, there was lack of effective leadership and facilities to support the process. This in turns affected the effective implementation of the available policy elements such as guidelines, contracts and effective training.

Table 4: The summary table of the assessment in the large architectural firms

BIM Maturity Matrix Competency set		0 points	10 points Initial	20 points Defined	30 points Managed	40 points Integrated	50 points Optimised
Technology	Software	0	0	0	100	0	0
	Hardware % Network 1	0	20	26.7	6.7	33.3	13.3
	Hardware & Network 2	6.7	40	6.7	6.7	13.3	26.7
Process	Leadership	13.4	6.7	0	13.3	33.3	33.3
	Human Resources	6.7	6.7	53.3	0	26.7	6.7
	Product and services	0	0	0	100	0	0
	Contractual	13.4	6.7	6.7	0	46.7	26.7
Policy	Regulatory	13.4	6.7	0	13.3	33.3	33.3
	Preparatory	0	0	0	6.7	40	53.3
	Sub total	53.6	86.8	93.4	246.7	226.6	193.3
	Percentage	6.0%	10.0%	10.0%	27.0%	25.0%	21.0%
BIM Capability Stage		Pre BIM	Object based Modelling		Model based Collaboration		Integration

5. CONCLUSION

BIM has the potential to play a vital role in the Nigerian AEC sector. Due to its clarity and transparency benefits, it could help standardisation across the industry which has been a worrisome issue in the Country. Adoption of BIM in the industry is an entire shift in the practice. Generally the cultural transformation has always been a greater challenge than technological transformation, however, the medium and the large firms in the Nigeria AEC industry could easily curb with the known challenges of the BIM adoption if the identified process issues could be recognised as an important issue in the industry. This would improve the buildings and adherence to the policy issues. However, the issues in the small firms were relatively major problems as there is lack of understanding of the process itself or even less of the policies,. The small firms regarded the whole shift just as a technological stream and disregarded its accompanying effects on their business settings. However, all the firms affirmed an enthusiasm for a technological innovation with some resistance to changing their practice.

RECOMMENDATIONS

Acknowledging that the shift in BIM is accompanied by cultural and business transformation in the practice is vital to the adoption in the industry. The government and professional institutes can take the lead in the process. However, education and training have also been identified as important parts of BIM adoption and implementation.(Arayici et al., 2009). The software vendors, professional institutes and firms should encourage dissemination through workshops on regular basis to increase knowledge about the BIM, and at large integrating BIM into the core curricula may improve understanding in the AEC industry.

Further research is recommended to understand how the BIM adoption does change the practice in the industry, what approach to adopt, and other topics to reconcile the issues arising.

ACKNOWLEDGMENTS

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BIM COURSE DEVELOPMENT AND INTEGRATION IN A MULTI-DISCIPLINE CIVIL ENGINEERING DEPARTMENT

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ABSTRACT

An integrated BIM course in the Department of Civil Engineering at the University of New Mexico was implemented during the spring 2012 semester. After its third successful at-capacity semester and refinement, the BIM course has matured as a senior and graduate level course CE491/ CE598. Civil - structural engineers, construction managers, construction engineers, and architects have matriculated into the course with an anticipation of learning the emerging technologies of BIM theory and application.

The course consists of weekly lectures, two projects, two minor and one major research papers, and a midterm exam. The main objective of the course is to provide the catalyst and inspiration to the subset of students, current BIM practices and research opportunities as a professional life-long learning process, and to explore new ideas and methods to use BIM in their future collaborative professions.

Keywords: architectural–engineering–construction AEC, building information modeling - BIM, BIM education, civil engineering education, collaboration, knowledge–skills–abilities KSAs, pedagogy

1. INTRODUCTION

The fall 2013 and spring 2014 semesters UNM matriculated a large number of Brazilian international students; the students quickly populated the available positions in the BIM course, relishing the opportunity to gain knowledge and experience infrequently available to them at their universities. Integrating the domestic and international students into teams on the second project proved to be a successful method to inspire the students to collaborate in learning and working toward achieving their academic goals.

The BIM course lectures are focused on the history, advances, current uses and limitations of BIM; but more importantly it offers the students to engage in developing the mindset of straying from myopic or silo mentality which currently is stifling the adoption/advancement of BIM in the AEC industry (Macdonald 2012). The BIM Summit topics and presenters demonstrate the ability to develop, share and deploy visionary ideas with likeminded individuals, companies and organizations that are looking to advance BIM uses.

2. THE COURSE

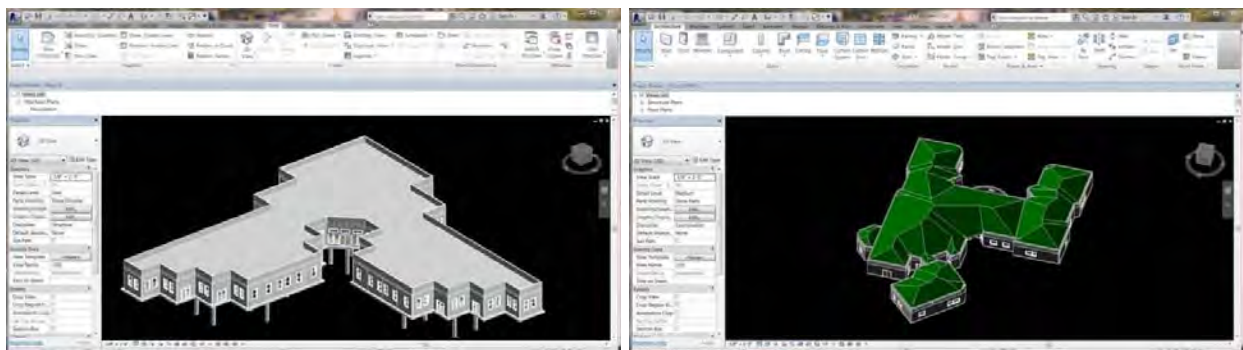
2.1 Course Development and First Project

The course is the first opportunity to gain a rigorous understanding of the need for BIM education other than independent study or internships in the New Mexico region. The BIM Summit provides a learning opportunity for students to see actual discipline specific uses in AEC projects and to collaborate with industry professionals. Universities play an important role to initiate, cultivate Knowledge, Skills, and

Abilities (KSAs) to evolve the next generation of professionals who understand BIM as a process that supports collaborative work (Lockley 2011). After a series of weekly lectures conveying theory, history, current, and future objectives and goals of BIM adoption and implementation within the AEC industry, the students work independently on their first project; an imaginary single-story structure, aptly named “sympathy for the devil”. This first project allowed for the individual students to learn the Revit platform without having any prior experience with modeling or Revit application.

The mixed-use office space design criteria for the first project was specified as an “L” shaped structure with a minimum 75,000 ft.² area. A rubric of small, medium, and large, open space and close space offices was provided for their layout adoption schema. Corridors, column grid location, window openings, controlled entrances and exits complying with basic code and Americans with disabilities act were the main BIM modeling objectives for the project.

The students were introduced to a wealth of online resources and BIM users groups such as Revit city, local BIM 505 user group, and Autodesk’s BIM curriculum website to supplement their respective textbook for the course. The students gained valuable insight and real-world experience in the challenges of modeling and adopting a new applications often encountered in design firms in the AEC industry. The first project was viewed as a success and confidence builder by the students. Samples of the models are shown in figures 1 and 2.



Figures 1 & 2: Screen captures of samples of students’ first project ‘Sympathy for the Devil’

Interdisciplinary learning integrating methodology and etymology from more than one discipline to examine a shared problem or topic is vital to solve today’s complex engineering problems (Schaffer et al. 2008). The first project allowed for individual proficiency development in a quantifiable skill level in the self-paced BIM modeling project. A student must obtain the essential initial modeling skill required to be able to identify future tasks and advance BIM KSAs and determine how they should be developed, and to understand how much time devoted to them in the curriculum coursework to succeed.

The assessments of BIM models constructed by the students were evaluated both in terms of their capacity to solve architectural/engineering problems, regarding the information content level of the BIM/IFC models and their accuracy and organization (Barison and Santos 2010, 2012).

2.2 Research Papers

The academic realm and AEC industry should form partnerships for knowledge transfer in terms of the quality research that is both meaningful and significant to help solve challenges and issues related to BIM implementation and task oriented objectives and others. The students and faculty can both benefit from gaining experience, identifying key research issues and producing significant teaching materials such as papers, case studies, and projects to learn from and share (Barison and Santos 2014).

Changes in the AEC course curriculum academia should engage with industry to promote BIM and collaborative thinking and develop research, teaching and consultancy opportunities and learning teams (Lockley 2011). Moreover, industry must be prepared to provide funding for the academic institutions, devote time to collaboration and visiting the students in classroom/ laboratory environments. They must be prepared to discuss current trends, challenges and scenarios with instructors and students, share generic models and provide current materials for students to enable them to practice the knowledge they have learned in academic course work (Pavelko & Chasey 2010).

Individual research papers offer the students the opportunity to learn through engaging and researching further thorough BIM topics, subjects and case studies, to expand on their individual BIM competencies which are ultimately shared with the class members to advance each other's knowledge collectively. Topics in BIM application, implementation, current and future uses are generally the subject matter for the first and second research papers, while the final paper is concentrated more on achieving a greater understanding of an important topic in their respective degree area of study. Another goal is to gain the understanding of the stakeholders and their respective roles in advancing BIM innovative technologies which includes external for-profit companies which may provide additional resource training opportunities and help identify the current use of innovative technologies such as 3-D scanning point clouds to be integrated into 3-D modeling and other research methods.

Structural engineers tend to concentrate on topics like finite element analysis, validity in model analysis and design, BIM exporting into other application software. Construction managers tend to concentrate in subjects such as bid-build and integrated project delivery (IPD), sustainability and LEED, scheduling and quantifying, operations and maintenance, and facilities management. Architects usually concentrate on visualization, spatial, energy efficiency analysis, and building lifecycle analysis.

2.3 Second Projects – Group Structural Design or Construction Management

The course learning outcomes are to use the knowledge gained in other civil engineering design courses and apply them in a team project based learning environment to successful research the advancement of BIM in the AEC industry. Establish future vision and potential uses advancing the overall quality of BIM education available to students in undergraduate and graduate in AEC, and other interrelated evolving fields such as BrIM, GIS, 3-D Scanning, and others. The course also offers the opportunity to establish knowledge of Graduate level programs at other universities to matriculate into, based on the student's individual desire to complete specific research related to their profession.

Graduate students are placed into a leadership/ project manager role which establishes for most graduate students the first opportunity to directly use management skills to lead a project, internally establish roles, goals and objectives, and document workflow processes, which is essential in the professional work environment which most students will soon enter. Undergraduate students are offered the opportunity to develop team-work skills and abilities using BIM applications and apply their undergraduate knowledge in an inter-discipline project and learning atmosphere (Sabongi 2009). The second project for construction managers and architects diverged from the civil engineers who were focused on structural engineering.

The second project for structural engineers consists of a three-story structure for the three different design teams, which drew from previous structural analysis and design courses to design a fictitious federal courthouse project. The three 2014 structural design teams had different site locations: Miami, FL; Oklahoma City, OK; Seattle, WA. Sustainability, analysis, and design efficiency objectives were incorporated into the second project, along with some unique design aspects like a rooftop helicopter landing pad, third floor secure and sequestered guestrooms, two judge's sleeping chambers, 24 hour full-service chefs kitchen, and an exercise nautilus and weight room. The building also incorporated a second floor administration, records facility, and four-person detention cell for high-value defendants. The first floor courtrooms and layout were based on an architectural layout sketch image (see figure 3) provided to

the students for reference linking and the vertical build template of the structure to be modeled and structurally designed. The models, design analysis, and calculation sheets were assessed based on location design appropriateness, structural feasibility, and LRFD design, see figure 4 for an example of project 2 final structural model rendering.

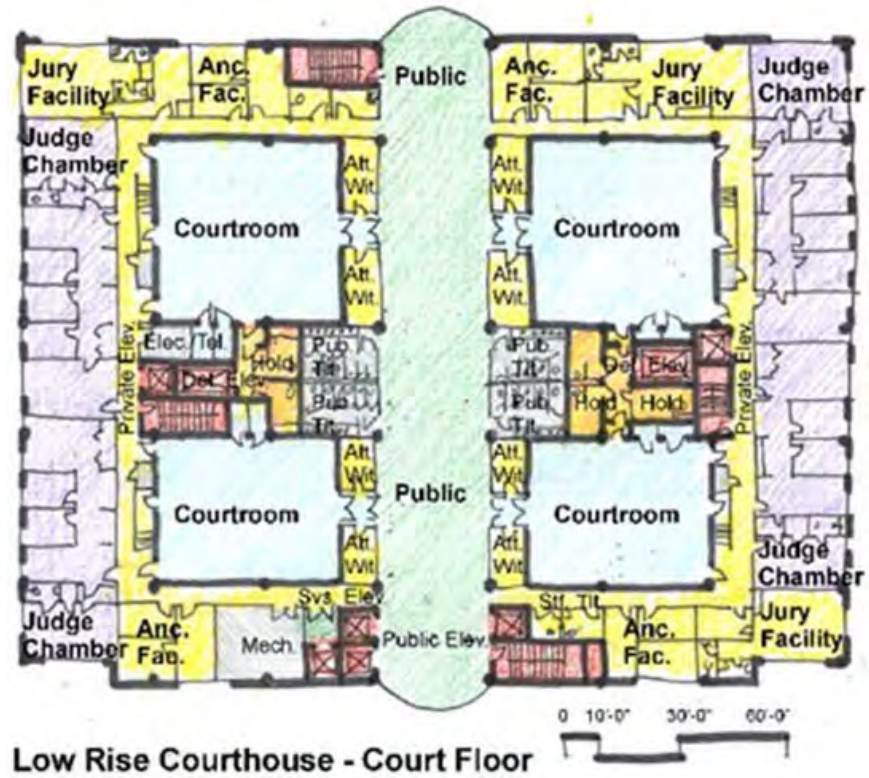


Figure 3: Structural Project 2 Sketch for Design



Figure 4: Structural Project 2 Final Rendering - Miami, FL Design Team

The second project for construction managers and architects consists of being provided the architectural, structural, and MEP Revit medical clinic models from the bSa Common BIM Files and Tools, to be scheduled 4-D, and cost analysis 5-D, and timeline simulation using Navisworks Manage by incorporating Microsoft Project schedule file as desired for ACCE accreditation (Taylor et al 2008).

Source: http://www.nibs.org/?page=bsa_commonbimfiles&hhSearchTerms=%22clinic+and+models%22



The domestic and international students were genuinely pleased with the semester's outcomes and new their new found alliances and friendships developed during the course. This course is having direct impact on motivation, learning skills, and collaboration as the students are actively sought out for employment for their knowledge and BIM skills in the state, and in states surrounding New Mexico such as Texas, Colorado, and Arizona. International students returned to their respective schools to share their newly attained BIM KSAs with other students and faculty ideally as new BIM champions in development.

3. EXTERNAL COLLABORATION – 2014 BIM SUMMIT

The UNM Department of civil engineering hosted the bimSmartfoundation summit on Friday September 26, 2014 with a full-day of presentations, panel discussions, and collaborative sharing of history, current status and future vision of the use of BIM theories in the construction industry and academic integration in course work.

The day's events started with a 7:15 am catered breakfast at the Centennial Engineering Center's (CEC) Stamm Common room which drew over 90 attendees from industry, government, academia, and students from civil engineering, architecture, local community college, technical schools, and local BIM 505 user's group. Michael Gonzalez from the department of civil engineering gave an update of renovations and construction projects at UNM on a short tour from the CEC to the UNM SUB Theater around UNM's Duck-Pond for the morning's presentations.

Dr. Joe Cecchi, UNM Dean of the School of Engineering and Dr. Mahmoud Taha, Chair, Civil Engineering opened with addresses welcoming the attendees prior to the presentations as synergy was developed throughout the morning's presentations.

Thomas Gay traveled from Boston, MA and presented a perspective from the insurance industry's BIM use and need for BIM knowledgeable engineers within the insurance industry and risk management. Tom manages worldwide CAD and GIS services, site plan documentation and engineering document management services for The Factory Mutual Insurance Company (FM Global) and is also FM Global's representative to the buildingSMARTalliance (bSa).

Owners Groups had brief discussions from Steve Fattor at Sandia National Laboratories and Glenn Ballard from New Mexico Public Schools Facilities Authority relating their organizations current BIM initiatives as well how they plan to move forward with BIM on projects in the future.

John Tomaszewski BIM coordinator from UNM Planning and Campus development presented on initiatives being implemented at UNM to garner more useable documentation and facility efficiencies in their operations. He also outlined planning and renovations completed, worked on, or in transition.

After the mid-morning's catered break, Ron Balmer from Bridgers & Paxton, a local mechanical, electrical, and plumbing (MEP) engineering firm presented their company's marked improvement on return on investment (ROI) based on increase BIM use on projects in the last five years. Ron commented on his enthusiasm for future collaboration with UNM and BIM.

BIM academia and educational initiative presentations were conducted by UNM's faculty Michael Gonzalez from civil engineering, Alex Webb from school of architecture, and David Ruff from CNM as each defined how their programs are integrating BIM concepts and modeling in their respective programs and course work.

The afternoon had Michael Gonzalez give a quick tour around the Fine Art department buildings and UNM's featured fountain pool back to the CEC Stamm Common room for an Italian themed catered lunch. After lunch the BIM Summit participants walked across the hall into the CEC's Auditorium for the start of the afternoon's presentations which featured an open panel of invited industry guests for questions and candid lively discussions on various topics in BIM adoption, implementation and integration moderated by bimSmartfoundation's event organizer Birgitta Foster who themed the "Hire Education" a play on Higher Education and the status of BIM locally in New Mexico and the need for BIM skills for market ready graduates. The passion and participation led the panel discussion to carry longer than anticipated which could have gone late into the evening.

Refocusing the event back to presentations was easily accomplished by local engineering firm Bohannon-Huston's Nick Davis as he featured a project using BIM in designing non-building structures and seismic bracing which demonstrated the advanced use of collaborative clash detection and design challenges on massive plant infrastructure and coordination. Running a live model gave the attendees the full scope of the advanced use of BIM in design for structural engineers.

The overall event favorite, Alix Loiesau of VDCO Tech followed by presenting the Real World, Real BIM, Real Value which gave everyone a realistic view of the current stage and future vision of BIM in the construction industry. Alix clearly recharged the attendees with his knowledge of current and future vision and the potential of BIM globally. Alix flew in from Fort Lauderdale, FL to present at the Summit.

After a quick afternoon break, Bryan Cowles of IMAGINiT Technologies showcased some immerging use of BIM with 3-D scanning and automating & documentation of databases. The efficiencies of database management and workflows demonstrated IMAGINiT's advancement of BIM technologies; Bryan flew in from Salt Lake City, UT to present at UNM.

Saving the Best for Last, Birgitta Foster presented the advancement of information exchange and status of the development and implementation of COBie exchange at national and international levels. Birgitta was the formally Assisting Director at buildingSMARTalliance and Facilities BIM Champion for Sandia National Labs, and the current Director of Facilities Integration at VDCO Tech; she specializes in Building Information Modeling (BIM)/Facilities Management (FM) integration strategies. Birgitta is a leading authority, writer, and presenter on BIM for Owners, and continues to examine how technologies can improve Operations and Maintenance, Space Planning, and Asset Management. While serving as bSa's Assisting Director she supported NBIMS-US efforts while overseeing the development of the Introduction to Construction Operations Building information exchange (COBie) course. Birgitta continues to represent bSa-US as the IUG Secretary for buildingSMART International and provides education on COBie nationally and internationally.

The UNM BIM Summit event was deemed an outstanding success by the attendees at the end of the day, who expressed the desire to collaborate and share ideas almost immediately before the overwhelming agreed response to hold and attend the event next year.



Some images from the 2014 BIM Summit event held at The University of New Mexico

The bimSmartfoundation/UNM Summit offers students a direct opportunity to establish connections with the professionals in industry and gain additional insight of the need for advancing KSAs related to BIM and innovative technologies. Many studies have identified the need for engaging academia, AEC industry, and government in outreach to involve in discussion and research associated with BIM interactions and challenges at every level.

4. CONCLUSIONS AND FUTURE WORK

Teaching processes and resources should support the Industry Foundation Classes (IFC) by seeking to understand and comprise of BIM tools applicable for each topic. They should include laboratories and studios, web blogs, routines and documented workflows for processing, access, discussions and project presentations. Since the concept of interoperability is a major obstacle to BIM implementation by industry, the instructor should strive to support open standards (Barison and Santos 2010), and recommend membership in organizations advancing BIM as a standard to be cultivated in industry and users groups locally, regionally, national and internationally.

This course aims to evolve and adapt based on the needs of BIM curriculum changes, requirements and recommendations of the academic literature produced by highly regarded and reputable BIM leaders and SMEs. Integrating advanced 3-D scanning is the next phase in upgrading this course.

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INTRODUCTORY BIM CLASS – DESIGN/BUILDER PROJECT

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ABSTRACT

As Building Information Modeling (BIM) progresses as a necessary component of construction education, learning the basics of BIM development and implementation is considered the first step of understanding for students. An introductory BIM course places students in the role of a design/builder. Each student becomes responsible for the design and the development of a small commercial 2000 sf office building project. As design/builders, they become responsible for the programming, design, development, and completion of the project. As part of the programming discovery phase, student groups investigate and present formal team presentations for the class on 1) Building Designs, 2) Building systems, 3) Interior finishes and furnishings, 4) Storefronts, windows and doors, and 5) Minimum Handicap and Building Code (NC State Code). Using minimal design parameters, students develop individual building standards, construction methods, and furnishings for the project, which result in a preliminary design. After faculty feedback, students' progress in the development of a full BIM model and creation of appropriate 2D and 3D documentation. Based on basic BIM knowledge acquired in the preliminary Revit "Getting Started" project, students create design development level models that include traditional documentation including site development. Evaluation of students addresses building design, design development, modeling capabilities, and inventiveness.

Key Words: Building Information Modeling, Design-Build, Introductory Course

1. INTRODUCTION

1.1 Course Analysis

Design-Build is the combining of the two professions prevalent in the AEC industry. As the construction industry speedily moves towards this method of project delivery (over 60% of all construction projects worldwide use this method), it is important for students to understand its importance as a delivery system. In order to fully appreciate this system, students in our CMGT 3010 Construction Modeling and Information Technology class are given the opportunity to become Design-Builders while strengthening their BIM design graphic abilities. Course Learning Outcomes (CLO), relate to specific Student Learning Outcomes (SLO) based on American Council of Construction Education (ACCE) standards were developed, The CLO are:

1. Create construction electronic models (ACCE SLO 7, 10).
2. Manipulate electronic based software to analyze model's systems (ACCE SLO 10).
3. Prepare and present building design development programming and standards (ACCE SLO 2).

The referenced ACCE SLO (Baccalaureate Degree) are:

1. *SLO 2: Create oral presentations appropriate to the construction discipline.*

2. SLO 7: *Analyze construction documents for planning and management of construction processes.*
3. SLO 10: *Apply electronic-based technology to manage the construction process.*

Student evaluation encompasses a variety of grading rubrics to quantify the abilities of specific tasks pertaining to all assignments. The final direct analysis for the SLOs are:

CLO 1: SLO 7, 10:

Means of Assessment

1. Students created SketchUp Wall Section models to study building construction methods and modeling techniques.
2. Student's "Getting Started" Revit Project.
3. Student's Term Project of Small Office Building using Revit software

Criterion for Success:

Assessment 1: Evaluation Rubric: 75% of students will receive a grade of 24/30 or higher on the SketchUp assignment.

Assessment 2: Evaluation Rubric: 75% of students will receive a grade of 32/40 or higher on "Getting Started" Project.

Assessment 3: Evaluation Rubric: 75% of students will receive a grade of 80% or above on Term Project.

CLO 2: SLO 10:

Means of Assessment

1. Term Project Assignment: Students will develop a minimum of three schedules for the building project. They will include the Door Schedule, Window Schedule, and Finish Schedule. They are also highly recommended to include a Furnishings Schedule, Room Area Schedule, and Planting Schedule.

Criterion for Success:

Evaluation Rubric: 75% of students will receive a score of 8/10 or better for the Schedules scoring in the Final Project.

CLO 3: SLO 2:

Means of Assessment

1. Team Investigation and Presentation Assignment: Students will investigate one of the five project programming discovery issues and make a class presentation.

Criterion for Success:

Evaluation Rubric: 75% of students will receive a score of 80% or better for the Presentation scoring in the Project Programming Discovery assignment.

1.2 Course Program

Students take on the role of a design/builder. They become responsible for the design and the development of a small commercial building project. Traditional architectural program students are taught through various stages of development to research and develop design standards for any given assigned projects. Since our university does not have an architectural program, the instructor has taken on the responsibility of teaching CMGT students rudimentary building programming, preliminary building design standards, and ultimately design development. The instructor is a licensed architect and builder, with extensive building programming experience.

Student teams composed of four students are required to research and present their findings to one of the five building systems needed for programming and design development of their projects. The five investigation areas are 1) Building Designs, 2) Building systems, 3) Interior finishes and furnishings, 4) Storefronts, windows and doors, and 5) Minimum Handicap and Building Code (NC State Code) pertaining to accessibility, egress, toilet room designs and accessories.

Building designs require students to discover small office design examples that include plans, elevations, details, perspectives of buildings. Students are encouraged to use a variety of sources available in the library, as well as visiting existing buildings around town or other communities. Building systems require students to investigate a minimum of three appropriate building systems for the exterior design of the building. Wall sections and details showing differing building sections composition including dimensions and composition sizes are essential for students to develop a modeled wall. Interior finishes and furnishings are investigated to provide multiple examples for all finishes (wall, floor, base, ceiling, trim, panels, etc.) as well as furnishings (storage units, desks, credenza, shelving units, etc.). Exterior Storefronts, windows, interior and exterior doors are researched to provide students with a working knowledge of systems they may incorporate in their designs. Students provide multiple examples and manufacturers for review. Finally, minimum handicap and Building Code (NC State Code) requirements are determined as they pertain to toilet room designs, accessibility, and egress.

Based upon the research, students present their findings to other class members with a formal presentation. Students receive handouts of documented information or web links for further investigation. All presentations are also posted on the class Blackboard site to access through the semester. At the completion of the research component of the course, students engage in a discussion on the minimum programming requirements for the small office project. These requirements include required rooms and sizes, site parking and access requirements, and HC accessibility needs.

The Instructor leads a design development explanation and demonstrates the evolution of bubble diagrams (See Fig. 1). Bubble diagrams are a graphic representation of thinking, problem-solving, and relationship models that graphically communicate the physical planning for student use in developing their designs (Yi-Luen and Gross, 2001). Designing is demonstrated as a process of transforming and merging diagrams, “trying to take a structural diagram, a functional diagram, and a circulation diagram” and “combine them” (Rowe 1987). The elements and spatial relations correspond to physical elements and spatial relations in the architectural problem. Based on this initial discussion, students are propelled into the development of their personal project programming and creation of a spatial relationship model and preliminary design.

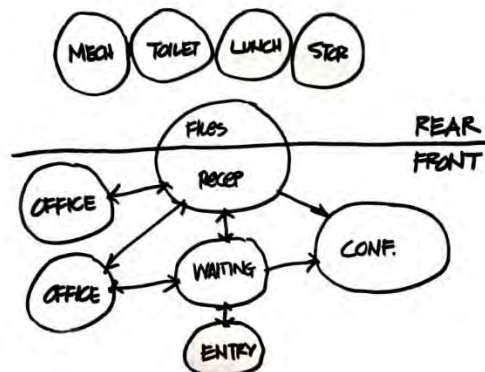


Fig. 1 – Bubble Diagram – Relationship Model

2. CLASS INSTRUCTION – STUDENT DEVELOPMENT

Construction Management students seldom have design courses that assist in understanding three-dimensionality of building and design components. Unlike design students (engineering or architecture), construction students are not exposed to 3D model construction. For this reason to assist our students, students are first exposed to modeling using SketchUp® software. Students use exercises to develop and understand 3D aspects for construction projects. The first assignment provides students with a variety of building floor plans that they use to develop 3D models based on their design decisions. Students learn the basics of SketchUp modeling, as well as the use of materials, components, layers, and sandbox. (See Fig. 2) The second assignment requires the modeling of a wall section developed from existing construction details. Students select one of the five wall sections, and then compose the model of fully developed in all its wall components. Students use construction details to understand the needed materials, dimensions, and quantities need for a six foot section of wall and foundation. Students may use and manipulate 3D Warehouse models for structural components, but are required to model all other components. The exercise is used to strengthen and understanding construction drawings and visualizing the 2D design to a 3D model. (See Figure 3)

The second course assignment introduces students to Autodesk Revit 2014® software. After an introductory lecture that includes multiple examples and visualization models, students are assigned the Revit “Getting Started” (Autodesk, 2010) model assignment. In this step-by-step assignment, students are exposed to all introductory commands and characteristics of the modeling program. (See Fig. 4)

While the above noted assignments are taking place, students develop their preliminary term project floor plans that are submitted for review. After revisions and final review, students develop their Term Project Site Plan and building design in AutoCAD 2014. The process allows the use of a completed contoured site with proper building placement and parking layout. The completed .dwg file is imported into the final Revit file.



Fig. 2 –SketchUp® Assignment 1 – Student Building Example



Fig. 3 –SketchUp® Assignment 2 – Student Wall Section Model

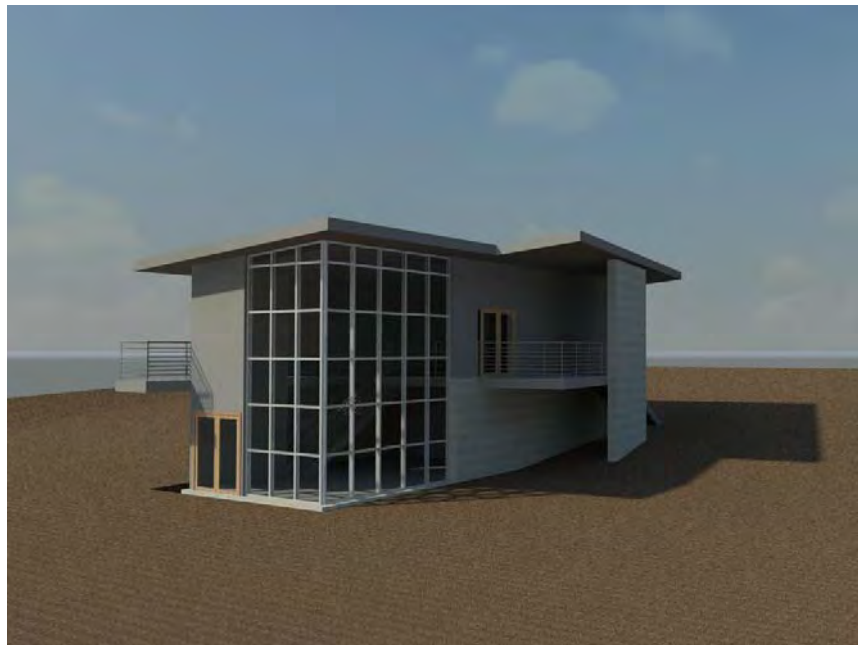


Fig. 4 –Revit® “Getting Started” Student Model

3. FINAL PROJECT

The Term Project includes the design and the development of a small commercial building. Project programming for the Term Project includes the following minimum requirements:

- Building not to exceed 2000 GSF (building only, not including area required for parking, landscaping, etc.)
- Provide one (1) single-person Handicap toilet room.
- Offices for Two (2) Partners (Minimum size = 225 SF each)
- Entrance Foyer
- Secretary / Receptionist Area / Client Seating (Seating for 4-5 people)
- Copy / File Room (Minimum 100 SF)
- Conference Room (Minimum size 250 SF)
- Small Kitchenette area.
- Mechanical Room (Furnace, HW heater, Telephone Board)
- Visually appealing. Do not copy the design of an existing building.
- Addition design components as determined.
- Design will have a crawl space. Therefore, it will be necessary to design for HC accessibility.
- A Minimum of 10 regular parking spaces and two HC parking spaces.
- Enclosed Trash Collection enclosure (8'x8') to match building design in appearance.

With these requirements, each student develops their personalized building design. For most, this project provides them with the first opportunity to make design and construction decisions.

Students use the imported site and building dwg to work within the development of the final building model and completed site with contours. Using this method, the proper building dimensions, as well as window, doors, and interior partitions are already determined, which accelerates the process of constructing the model. During class instruction, the instructor continues to add new techniques in BIM modeling to assist in student development. A class addressing stair and ramp development is expressly provided since they are a requirement for all projects.

With students responsible for their overall design, as well as the construction of the building, each student works within the confines of their decisions. Therefore, all buildings have given requirements, but each student must determine specific design determinants for their project. Therefore, prior to beginning the models, building systems must be defined, and wall systems designed. Students are not allowed to use package Revit® wall systems, but are required to identify and create their own. To ensure that all students are actively engaged in their design efforts, students create an on-going design-construction notebook that documents all products and systems to be used in their project. Areas addressed would include wall systems (interior and exterior), doors, windows, structural systems (floor and roof), finishes, furnishings, and landscaping. This Instructor reviews the documents to verify student active participation in design decisions, rather than to follow the work of other classmates.

With the development of the model, completed construction documents are a condition of the project. Students are expected to complete, at a minimum, the following documents:

- Cover Sheet (Project Rendering)
- Site Plan
- Floor Plan (Fully dimensioned and complete Room / Door documentation)
- Furnishings Plan
- Reflected Ceiling Plan
- North / West Elevations
- South / East Elevations
- Schedules (Door / Window / Room Finish / Furnishings / Wall / Roof Quantities)

- Major Wall Sections

The Instructor encourages the students to construct their models as they would construct the building. In doing so, students must understand their intended structural and exterior wall components. The student determines his required Bottom of Footing (BOF) based on their final grading layout for their building footprint. Since each student project stands by itself, students must evaluate individual conditions. The Instructor provides guidance in the initial site grading to minimize what could become more difficult site conditions based on building placement. Upon a determination of the initial elevations, students proceed with the modeling of the foundation and floor structural system, followed by exterior and interior wall systems placement. Ultimately the structure is roofed using a variety of formats, based on the complexity of the student design. From these basic beginning points, the final development of the project components and final documents are created.

During the creation of the model, the instructor designates once a week BIM Tricks for students to reach beyond the standard basic components of a BIM model. Although students have a comprehensive BIM text to use for understanding BIM commands and attributes, in some instances the documentation is cumbersome and confusing. For applications of advanced attributes, the BIM Tricks assist in clarifying the processes.

Students are encouraged to explore the many capabilities of Revit® by developing additional construction documents or enhancement of those required. Examples, that some students have examined, have included complete HVAC ductwork distribution, plumbing and electrical design, structural roof designs, project energy analysis, furniture design, and enhanced renderings using a third party graphic software package. Example student projects are illustrated in Figures 5 and 6.



Fig. 5 – Student Term Project Example



Fig. 6 – Student Term Project Example

4. CONCLUSIONS

Each semester new enhancements and improvements are incorporated into the student assignments. With the continuing development of BIM software and investigation of other BIM programs, students can create construction electronic models and manipulate the software to analyze model's systems. With the knowledge gained in this class, students enhance their capabilities in newly developed BIM based courses in estimating, scheduling and project management. By using industry developed models, students are developing quantity takeoffs, cost estimates and cost analysis of the projects. In scheduling, students develop project phased construction schedules and full schedules tied to the WBS. This course is to provide the knowledge needed to comprehend the changing use of BIM in the construction industry. An expanded BIM course is planned for students specifically interested in becoming BIM managers in the AEC industry.

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AN EXAMPLE PROJECT-BASED COURSE ON BUILDING INFORMATION MODELING FOR CONSTRUCTION MANAGEMENT

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ABSTRACT

It is widely accepted that the evolution of Building Information Modeling (BIM) is increasingly affecting the roles of construction management professionals in the Architecture, Engineering and Construction (AEC) industry. Teaching BIM in construction engineering and project management (CEPM) curriculum requires more emphasis on learning BIM as a process improvement methodology rather than only a technology. This paper describes experiences of a university course on Building Information Modeling that was developed to educate next generation construction managers to understand BIM and effectively use an existing BIM in plan execution for construction projects. This is a project-based course where students gain knowledge on the implementation of BIM concepts throughout the lifecycle of a project. Findings and lessons learned to date from the teaching experience are documented.

Keywords: Building information modeling (BIM), Construction management, Construction education

1. INTRODUCTION

Building Information Modeling (BIM) is regarded as an innovative approach and integrated process that supports efficient design, information storage and retrieval, model-based data analysis, visual decision making, and communication among project stakeholders (NIST 2004, Krygiel and Nies 2008, Eastman et al. 2008). Although the various definitions of BIM have been given with different focus, most researchers and practitioners believe that BIM is not a product or technology; instead, it is a process which can facilitate project success when utilized throughout the project lifecycle (Autodesk 2003). According to McGraw-Hill's SmartMarket Report (2012), 71% of the Architecture, Engineering and Construction (AEC) industry is using BIM, a rapid growth from 49% in 2009. The biggest challenge to BIM adoption continues to be lack of adequate BIM training. As the importance of BIM is widely recognized in the AEC industry, it is essential for the next generation of construction management professionals to learn BIM while undertaking studies at universities.

This paper describes the experience and lessons learned from a university course on Building Information Modeling that was developed to educate next generation AEC professionals to understand BIM and effectively use an existing Building Information Model (BIM) in plan execution for a building construction project. BIM is cross-listed with both graduate and undergraduate-level codes. ARE 376 is an undergraduate-level elective for both Civil and Architectural Engineering majors, and CE 395R7 is a graduate-level class part of the Construction Engineering and Project Management graduate program in a Civil, Architectural and Environmental Engineering (CAEE) department. The course has had high-interest from the student body. It was first offered in Fall 2010, during which time twice as many students as the capacity tried to enroll. To date, the BIM course has been taught in six unique semesters. The course has attracted students from multiple areas within the CAEE department (Construction Engineering

and Project Management, Architectural Engineering, Structures, and Materials), as well as Mechanical Engineering and Architecture students. Students gain hands-on experience on various aspects of Building Information Modeling (BIM) as well as develop case studies on various BIM-based projects, supported by industry mentors.

This course focuses on BIM as a collaborative process rather than a design tool. There was no requirement for advance modeling since all models used in the course work were provided. Students were asked to use existing models to perform tasks including model-based cost estimating, scheduling and 4D simulation, and design coordination. A process-oriented teaching approach was applied to: 1) emphasize the importance of understanding BIM as a process and 2) provide students with active learning experiences by encouraging self-directed learning and critical thinking throughout the course. The class organization and deployed educational modules are introduced, and lessons learned to date from the teaching experience are documented in the following sections.

2. BACKGROUND RESEARCH

BIM has been gaining wide acceptance and recognition in the last decade, as AEC professionals are facing a new transition from computer-aided design (CAD) to BIM. As a response to this promising technology and to industry needs for relevant skills, academic institutions are exploring strategies and approaches to incorporate BIM education in their undergraduate and graduate curricula. Researchers found that BIM is one of the most challenging and recent trends for Construction Management programs, but BIM pedagogy is not yet consolidated (Johnson and Gunderson 2009; Casey 2008; Wang and Leite 2014). In recent years, more academic institutions have started to incorporate this new technology into their programs to respond to industry needs for these skills. In the United States, schools such as Penn State, Carnegie Mellon, Georgia Tech, University of Southern California, and the University of Texas at Austin have successfully integrated BIM education in their programs, some of which are design programs (i.e., integrated to Architectural Engineering or Design Studio classes). It is important to teach BIM as a design tool in a Design Studio or modeling course; however, as BIM is recognized as “the process of creating and using digital models for design, construction and/or operations of projects” (McGraw-Hill Construction 2012), it should be also taught in construction and facility management. The data-rich nature of BIM enables the model to not only be a digital representation of the design, but to also facilitate model-based quantity take-offs and cost estimating, schedule simulations, design coordination, among others. Therefore, in addition to teaching BIM in design education, it is equally important to teach students the potential of BIM application throughout the project life cycle as well as the knowledge and experience of how to manipulate, manage and make good use of the model.

Teaching BIM in construction management is challenging for several reasons. Firstly, it is critical to help students form a correct understanding of BIM. BIM is not simply new software or a stand-alone tool that supports an individual discipline. Hence, understanding how BIM streamlines the collaboration process of a construction project is much more important than mastering software. Secondly, considering the ever increasing evolution speed of information technology, it is very likely that the “content” taught in class especially the hands-on training on BIM applications will be outdated in the near future. Therefore, it is important for university educators to place more emphasis on students’ ability of self-directed learning. Furthermore, as BIM is still emerging, critical thinking should be strongly encouraged throughout the teaching process.

3. COURSE DESCRIPTION

3.1 Course Overview and Objectives

This course focuses on the skills and information needed to effectively use an existing BIM in plan execution for a building construction project. This is a project-based course where students gain knowledge on the implementation of BIM concepts throughout the lifecycle of a building, from planning

and design, to construction and operations. The main topics covered in the course include: 1) model-based cost estimating, 2) construction scheduling and 4D simulation, 3) design coordination, and 4) photogrammetry-based 3D model generation.

This course is designed to provide construction management students with core concepts of BIM, the knowledge of implementing BIM as a process throughout the project life cycle, hands-on experience with various BIM software, and the opportunity to develop collaboration skills and critical thinking through group projects and individual assignments. By taking this class, students will be able to: 1) define BIM; 2) describe workflow in using BIM in the building lifecycle; 3) describe the process of model-based cost estimating; 4) perform 4D simulations; 5) apply BIM to reduce error and change orders in construction projects; and 6) evaluate and communicate your ideas related to the use of BIM in the building life cycle.

3.2 Course Organization and Educational Modules

This course is cross-listed with both graduate and undergraduate-level codes. It was designed for students interested in construction management and information technology in the AEC industry. Instructional approaches include lectures, hands-on lab-based software tutorials, team-based learning (e.g., lab-based assignments), and individual learning (e.g., reading assignments).

An innovation of this course compared to previous efforts is that the teaching approach and evaluation principle are process-oriented, which means the emphasis is placed on understanding BIM as a new construction management process as well as its impacts on project success. BIM is not only a technology but also a methodology. Especially with information technology booming, BIM products are also advancing rapidly; mastering one or more software should not be the focus in BIM education in universities. BIM courses should, therefore, encourage students to grasp the role of BIM in different project phases so that they know why this tool is used, how it improves the project performance and how it can be further improved. The evaluation mechanism of lab-based assignments is also based on the students' discussion on the process and the further understanding of the tasks based on the practice, rather than the result itself. This section describes the detailed course design and instructional approaches. There are both team and individual evaluations throughout the semester. All lab-based assignments (one per educational module) are carried out in teams. An industry mentored case study is also carried out in teams. Individual evaluations are done through class discussions based on reading assignments, quizzes, and a synthesis report (for graduate students only). Figure 1 depicts the team and individual evaluations, as well as their connections.

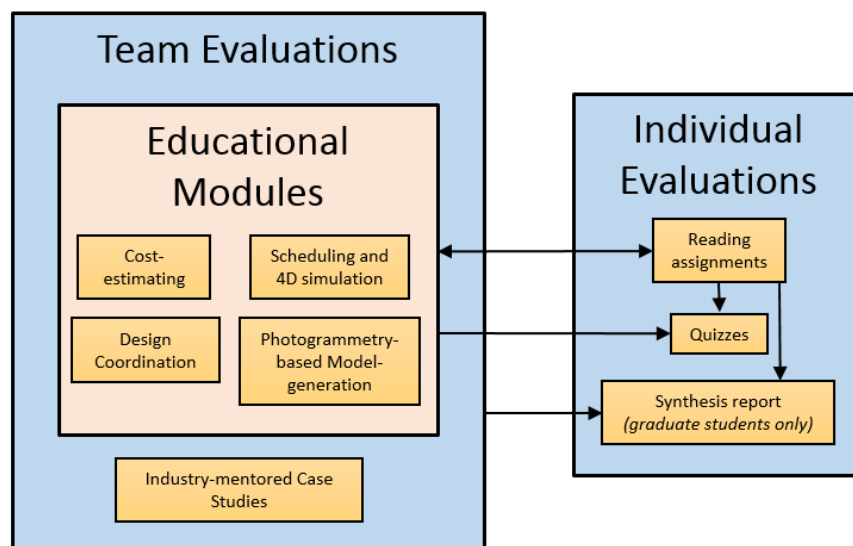


Figure 1: Team and individual evaluations and their relationships

The course content are organized into educational modules covering various topics such as model-based cost estimating, construction scheduling and 4D simulation, design coordination, and photogrammetry-based 3D model generation. As shown in Table 1, every module is composed of four sessions: 1) background introduction - introductory lecture supplemented by additional reading assignments; 2) lab session I - step by step hands-on tutorial lead by a teaching assistant; 3) lab session II - time for questions workshop when students are free to seek help, ask questions, work in groups and interact with other groups; and 4) reflection and discussion – assignment delivery and presentation.

Table 1. Educational Modules

Session	Instructional Approach
1. Background/Introduction	Lecture (topic introduction) + Individual learning (reading assignment and class discussion)
2. Lab session I: tutorial	Lecture (software tutorial) + Team-based learning (hands-on exercises)
3. Lab session II: workshop	Team-based learning (time-for-questions workshop; hands-on exercises)
4. Reflection and discussion	Team-based learning (group presentation and discussion)

These modules provide students with core BIM knowledge, hands-on practice with the state-of-art BIM solutions, and multinational collaboration experience. All lab-based assignments are done in groups. At the beginning of the class, students will be assigned into teams of 2-3. The teams are formed to cover a variety of industry experience levels and background. Teams are also composed of both graduate and undergraduate students.

3.3 Industry Involvement

Guest lectures and the industry-mentored case study assignment provide students a good chance to connect and communicate with industry professionals, learn from the practical experience and strengthen the knowledge learned in class with real world practices.

For the case study assignment, students are asked to directly contact, with the support of the course instructor, one company and develop one case study on a project that utilized BIM in any way. The questions they need to discuss include, but are not limited to: what challenges the project team faced which led to the use of BIM, what technologies were used, why were these technologies pertinent to the problem they were addressing, how was BIM implemented in the project and in which phase of project lifecycle, how did these technologies facilitate project success, were there any measurable improvements, and what challenges were faced in BIM implementation. The teams will address these questions by interviews, site visits, project document analysis. At the end of the semester, the teams present their case studies in a seminar-type environment (see Figure 2). Mentors are invited to attend and, when they do attend, they provide enthusiastic feedback to students throughout the seminar.



Figure 2: Team of students presenting industry-mentored Case Study

Besides mentoring students in case studies, industry representatives get involved in various other ways in the BIM class. Typically, each semester will include 4-5 guest lectures. Each guest lecturer will come from a different company and talk about BIM implementation in their experience, illustrated by projects they worked on. Figure 2a illustrates a guest lecture that is connected to the Design Coordination module. This specific guest lecture starts off with an overview of BIM implementation in this company, followed by a mock design coordination meeting, that is led by two BIM Engineers that perform design coordination as part of their job duties. Figures 2b and 2c illustrate a class exercise developed by a guest lecturer that is deployed after his lecture and is meant to illustrate how 3D representation can enhance multidisciplinary team collaboration.

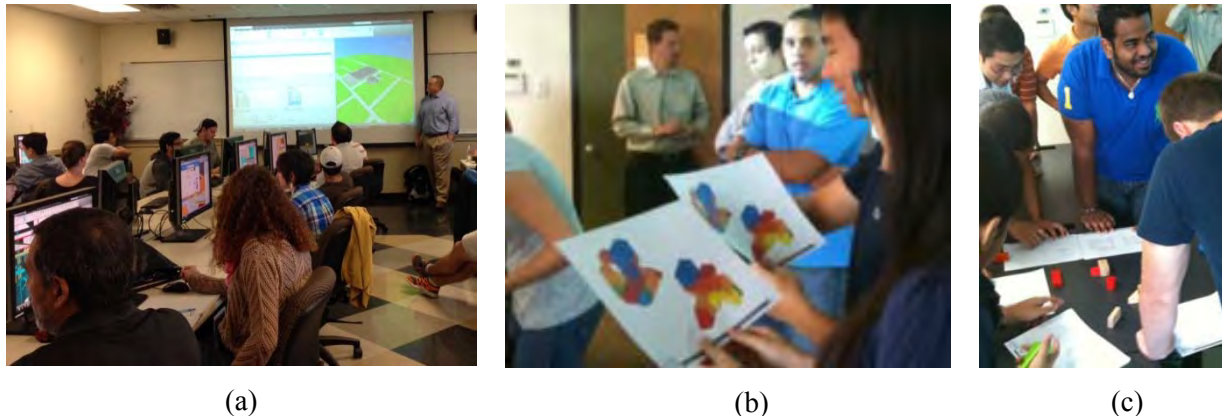


Figure 2: Students in mock BIM-based design coordination meeting (a), and 3D hands-on class exercise (b and c), both with industry mentors

4. LESSONS LEARNED AND CONCLUDING REMARKS

This course emphasizes learning BIM as an integral process which influences the overall project success from various aspects. Understanding the core value of BIM and its far-reaching influences with specific training on innovative and critical thinking is much more important than mastering a piece of software. Reflecting on the course over six semesters, the main lessons learned include: 1) process-oriented teaching and learning, 2) modular structure of the course design, 3) industry involvement, and 4) constant tracking of learning outcomes. For further information on learning outcome tracking in this class, see Wang and Leite (2014).

Process-oriented teaching emphasizes the importance of learning the *process* rather than the *product*, which provides students with active learning experiences by encouraging self-directed learning and critical thinking throughout the course. A combination of lectures, team-based learning and individual learning not only provides students with well-structured knowledge but also enables them to practice working and learning in a collaborative environment supplemented by self-reflections. For emerging technologies and trends as BIM, university education should put more emphasis on “why” and “how” in addition to “what” (e.g., Why is the BIM process better than the traditional process? Why is the software application good or not good? How can you improve it?). Students would benefit more by knowing how to learn and think with a tool than simply knowing how to use it.

The modular structure used in this course establishes a standard format for each educational module but also enables flexibility in terms of course content. Students receive adequate training in each module through lectures, readings, lab tutorials, lab-based exercises and reflection and discussions, while the content of educational models can be updated as required. The three basic modules that are always taught are: model-based cost estimating, scheduling and 4D simulation, and design coordination. Additional modules that have been taught throughout the semesters include: building energy simulation, photogrammetric generation of 3D models, and BIM to the field.

Familiarizing students with industry practice and expectations is also important. In addition to a well-directed course, case studies and guest lectures were also good ways for students to expand their vision and stimulate innovative ideas. This is this university's first BIM class and, through a network of industry mentors and alumni, graduates from the CAEE program (both undergraduate and graduate students) have already been reaping the benefits of this course; several past students have been hired as BIM Engineers or Virtual Design and Construction (VDC) Coordinators, by various general contractors throughout the United States and abroad. Several have already given back, serving as BIM class mentors and/or guest lecturers.

With continuous modification and improvement over six semesters, the proposed process-oriented BIM teaching approach was successfully implemented and well-received by the students. The end-of-semester course evaluation and students' learning outcomes both demonstrate the benefits of this approach. Over the six offerings of this class, the average course instructor rating was 4.7 out of 5.0, ranging from 4.5 to 4.8. The average course rating was 4.5, ranging from 4.2 to 4.7. In summary, this course can be considered a successful educational experience for teaching BIM in construction management programs. The process-oriented teaching approach, the modular structure of course design and lessons learned described in this paper can provide useful insights for educating the next generation AEC professionals on emerging information technologies, such as BIM.

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EXPLORING FLIP FOR BIM: TUTORIALS AT HOME, EXERCISES IN LAB

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ABSTRACT

As BIM uses and practices emerged between 2005-2010, architecture, construction and engineering programs began to introduce these software tools and business practices into their curriculum. While some integrated modules into existing courses, others created stand alone BIM courses. Concurrently, universities began to explore "flip the classroom" style of course design, where students review video taped "lectures" at home and do structured "homework" assignments in class with faculty supervision. The "flip" captured our attention as a means of improving our BIM curriculum. With this technique we could move away from the tutorial-based lab sessions that seemed to lack depth of learning. Our flip entailed having the students do the tutorials "before" lab and then having hands-on workshops in the lab where they work through the exercises with the faculty available to answer questions and focus on concept illustration. Initial challenges with the flip included: 1) students would not do the tutorials without the forcing function of graded assignments, 2) some students would not come to class - doing the "homework" outside of the class instead. This paper presents a refined version of the Flip for BIM curriculum model and discusses the advantages and disadvantages of this model. We discuss how this model supports BIM education and has the potential to synthesize BIM uses, software concepts and BIM skill building.

Keywords: BIM curriculum, Flip the Classroom, Digital Curriculum

1. INTRODUCTION

As BIM uses and practices emerged, universities began to incorporate these software tools and business practices into architecture, engineering and construction programs. While some integrated modules into existing courses, others created stand alone BIM courses (Lee et al. 2013). At the University of Washington (UW), we chose to develop a stand-alone senior elective course entitled Virtual Construction. At Washington State University (WSU), we introduce BIM in the sophomore level construction graphics class. Both classes are taught by Construction Management faculty, are intended to cover the basics of BIM, and introduce students to the new practices emerging in the industry. The UW class is a 3-credits, 10-week course, matching the size of other courses in the program. The WSU course matches other sophomore preparatory courses in a semester long lecture/lab format.

The efforts to develop flip the BIM curriculum began at the University of Washington. Our design of the *new* Virtual Construction class was to split the time between lecture and lab that utilized the newly built "computing classroom" in the Digital Commons of Gould Hall. There, each student has a desktop computer at his or her station in the classroom space. The lecture portion of the class focuses on BIM

uses and practices such as visualization, coordination, 4D modeling and model-based estimating. The lab portion of the class focuses on software concepts and skill building. Given the 10 week course and the breadth of software we cover, we developed 2-3 week "modules" that introduce students to SketchUp, Revit and Navisworks and highlighted key concepts represented in each (such as surface vs solid modeling and object-oriented models). The first version of the lab portion of this course was a tutorial-based BIM curriculum where we introduced the software via in-class tutorials and then had the students work through homework modeling exercises.

Table 1. Tutorial-based lab course schedule (selected days)

Lecture	Date	Topic	Post Lab Assignment
Wed	29-Sep	Introduction - BIM et al	
Wed	6-Oct	Sketch-up Workshop	Sketch-up Model
Wed	13-Oct	Revit 1	Revit Shared Layout
Wed	20-Oct	Revit 2	
Wed	27-Oct	Revit Modeling work session	Mid-Term 3D Model
Wed	10-Nov	Navisworks 1 - Introduction	
Mon	15-Nov	Navisworks 2 - Clash Detective	Navisworks Consolidated model
Wed	17-Nov	Navisworks 3 - 4D modeling	
Mon	22-Nov	4D Modeling work session	Final 3D/4D Model

The challenges we had with this model included dissatisfying inclass sessions and frustrations with students "getting stuck" while doing homework. As a faculty member, walking through tutorials in class felt slow, frustrating and boring. We didn't feel like we were adding to their knowledge in a significant way, and this curriculum was not leveraging our knowledge to help them learn. Most of the students were either ahead and waiting or behind and lost. While we were busy helping individual students troubleshoot their model, others were waiting for the instructor to keep going with the tutorial. We made some attempt to introduce concepts before we began the tutorial, but these concepts often were lost in the busywork of figuring out what button to click next in the tutorial sequence.

Along came the "flip the classroom" movement. Flip the classroom philosophy encourages instructors to have students "watch" lectures at home and then do active exercises in the classroom where faculty expertise can be leveraged to help guide students through problems or highlight strengths of their work-in-progress (Baker 2000; Lage et al. 2001). This captured our attention as a means of improving the BIM curriculum and moving away from the tutorial-based lab sessions. We flipped the tutorials and homework; we had the students do the tutorials "before" lab and then had a hands-on workshop in the lab where they work through the exercises. Faculty were then available to answer questions and focus on concept illustration. In the first year of this effort, we discovered several problems with this model. First, students would not do the tutorials without the forcing function of graded assignments. Second, some students would not come to class, as they would opt to do the "homework" outside of the class instead of coming to lab to do it together. As a result, the most recent version includes graded homework as well as in-class "vignettes" that are due at the end of class. In this paper, we present the most recent iteration of

the curriculum, which is now implemented at both the University of Washington and Washington State University.

2. LITERATURE REVIEW

2.1 BIM coursework in Construction Engineering and Management

There have been a variety of efforts to incorporate BIM in construction education that include stand alone BIM curriculum, interactive teaching modules in construction topic courses such as estimating, and cross-curriculum teaching modules such as integrated studios and capstone projects (Lee et al. 2013). As with any hands-on learning, faculty generally report that BIM enhances student learning of disciplinary concepts (e.g. Sacks and Barak 2010, Richards and Clevenger 2011). The literature also provides a variety of methods to teach software concepts and skills (Dupuis et al., 2008, Lee et al., 2013). We also see that students are strongly interested in learning BIM technology for career development (Woo 2007; Azhar et al. 2010).

In contrast, the major challenges of implementing BIM in construction education include the high level of skill required to use BIM software meaningfully and lack of educational materials (Woo 2007). Information technology requires continual software upgrades and licenses, hardware setup and maintenance, file storage, and training (Kiviniemi et al. 2008). Faculty members' unwillingness to change existing curriculum to incorporate BIM is also a barrier (Sabongi 2009), while the complexity of the relatively new software tools (Johnson and Gunderson 2010); lack of resources including experts to teach BIM, faculty time required to make curriculum changes, support from faculty colleagues and/or administrators, and number of courses in existing programs of study all are hurdles that AEC programs need to overcome to incorporate BIM into our curriculum (Becerik-Gerber et al. 2011; Clevenger et al. 2012).

2.2 Flipped Classroom

Flipping the classroom may address some challenges of implementing BIM in AEC education. The flipped classroom encourages students to take ownership of their own learning, which in turn increases motivation to learn (Lage et al., 2001). By watching lectures or tutorials outside of class, students can review at their own pace, as often as needed, and look to other resources for further exploration. This is less likely to happen in a classroom lecture where the lecture is often linear, generally not repeated, and constrained to a set time period. An additional advantage of the flipped classroom is that students work on assignments in the classroom as a group, which not only allows the instructor to be available for questions, but also allows students to be available to each other. This concept of peer-instruction is one component that can be incorporated into the flipped classroom. Some students will learn certain concepts more quickly than others and thus be able to assist their peers thereby learning these concepts more deeply themselves. Someone who just learned a new concept has the difficulties of grasping it fresh in their mind. Therefore this new learner is in a good position to explain the concept to another student (Mazur 2009).

3. FLIP FOR BIM CURRICULUM

Our design of this Flip for BIM curriculum still includes lecture alongside lab where we utilize "computing classrooms", where each student has a desktop computer at their station in the classroom space. Lectures covered BIM uses and concepts. The lab sessions are structured so that students can work through the in-class assignments at their own pace. This alleviates the problem of some students being frustrated because they are behind others, while others are bored waiting for others to catch up.

3.1 UW Flipped Classroom Structure

At the University of Washington, the lecture portion of the class focuses on BIM uses and practices such as visualization, coordination, 4D modeling and model-based estimating. The lab portion of the class focuses on software concepts and skill building. Due to the limited in class time, we developed 1-3 week "modules" that introduces students to SketchUp, Revit, Navisworks and BIM 360 Glue. We highlight key concepts represented in each (such as surface vs solid modeling, and object-oriented modeling). Here is an overview of the software concepts and the exercises that we perform in each vignette workshop. Our goal is to reinforce learning of software concepts using experiences with the software:

Table 2- UW vignette workshop schedule

Software	Lectured concepts	In-class Exercises
SketchUp	Introduction to BIM	Importing the site plan; Grouping the site plan; Modeling the Building; Assigning colors and textures to the building; Using 3D warehouse to add components; using layers to hide the temporary objects.
Revit I-Basic Modeling Skills	Surface modeling; Groups vs Components	Importing/linking AutoCAD drawings; Creating levels; Modeling walls, floors, roofs, slab on grade, doors and windows; Defining rooms; Hiding elements in views; Using massing and site families; 3D views and Rendering
Revit II- Quantity Take Off (QTO) and Layout Settings	3D Parametric Modeling	Creating rooms and room tags; Creating room schedules; Adding color schemes to floor layouts; Creating material take off and cost estimate for doors; Observing the connection between plan views and cost estimates; Managing sheet layouts.
Navisworks I- Quantity Take Off	Parametric modeling in the context of QTO	Settings for allowing Navisworks to get updates from Revit; Organizing model elements under search sets; Performing QTO for all items; Creating resource catalog and attaching it to items; Performing virtual take off; Using Markup tools; Exporting the workbook; Applying changes within Revit; performing change analysis within Navisworks
Navisworks II- Clash Detection	Creating sets	Appending Revit files; Performing hard clash detection; Grouping the clashes; Distinguishing between modeling errors and valid clashes; Associating viewpoints with each group; Creating a report; Resolving clashes within Revit; Observing the resolution within Navisworks.
Navisworks III- 4D Modeling	3D visualization	Adding schedule to Timeliner; Creating selection sets for 4D modeling; Changing colors and transparencies for better 4D visualization; Adding legend to the simulation; Creating the 4D simulation; Exporting the 4D model; Creating animation; Adding the animation to the simulation; Make adjustments to the animation.
BIM 360 Glue- Clash Detection	4D visualization	Uploading models; Merging Models; using tools panel; Using navigation panel; Comments and Markups; Clash detection and notifying other users; Fixing the clashes in Revit.

3.2 WSU Flipped Classroom Structure

Modeling with BIM software was introduced to students in a sophomore level construction graphics course in the Fall 2014 semester. The course had a lecture portion and a lab portion, each meeting once per week. In the lecture portion, students learned to read and interpret civil, architectural, structural, mechanical, electrical, plumbing, fire suppression, and heavy civil plans using three different project plan sets. Students from both construction management and civil engineering were enrolled in the course. The construction management students were placed into lab sections where they learned Autodesk Revit and civil engineering students were placed into lab sections where they learned Autodesk AutoCAD.

One of the plan sets used in the lecture portion was a 37,000 SF community activity center comprising of civil, grading, architectural, structural, mechanical, electrical, plumbing and fire suppression drawings. In the Revit labs, students were asked to model the activity center building with the idea that by assembling the model in 3D students would visualize building system components. This in turn would help them better understand the 2D drawings (Clevenger et al. 2012).

Students in the Revit labs were asked to review one chapter of a Revit text each week and work through practice problems to prepare for the in-lab exercise. Like the UW curriculum model, the weekly in class assignment was released through the University’s learning management system at the beginning of each lab and due at the end of the 1 hour 30 minute session. Each lab assignment built on the last, and in the final week of the semester, they submitted a final project that was the complete model they had created over the course of the semester. In the final weeks, they had an opportunity to work on the model at home to fix or update any items they may not have completed during lab time. The structure of the Fall 2014 Revit lab was as follows:

Table 3 – WSU Revit Lab Schedule

TOPIC	LAB ASSIGNMENT
Revit interface; Importing images	Import the 2D floor plan image; create levels and reference planes
Walls and Curtain Walls	Create grids; Add walls; Add doors and windows
Floors, Roofs, and Ceilings	Create the floors, roofs and ceilings
Adding Families	Create a custom stacked wall; Space windows as shown on the plans
Stairs, Ramps, and Railings	Create stairs; Add mechanical components; Add site components
Site Modeling; Modifying Families	Create a toposurface; Adjust and array site fencing
Masses and Rendering	Create a conceptual estimate; Create a conceptual model using a mass; Render the model
Modifying Families; Rendering	Model the main entry canopy structure; Render the entry view

Details; Section Boxes; Walkthroughs	Create and annotate details; Create new 3D views using the section box; Create a walkthrough of their building
Drawing Sets; Workflow	Create a sheet layout with elevations and sections; Create worksets
"Something Cool"	Each student was asked to independently find and demonstrate "something cool" about Revit to the class. Students chose any three of those items to incorporate into their final model.

4. FINDINGS AND SUGGESTIONS FOR FUTURE

We found several benefits as well as drawbacks to flipping the classroom. One of the biggest weaknesses of the curriculum was the challenge of getting students to prepare for class. In previous years, when attempting to implement the flipped classroom, we found that some students found it difficult to motivate themselves to watch the tutorials at home. As a result, they would come to class unprepared and relied on the instructor to help them through the in-class exercises. We found this to be true this year as well. Students would not engage in the tutorial and would come to class ill prepared for the exercises. They would then not have had an introduction to the software and felt lost and frustrated. In future iterations, we intend to incorporate short tutorial-based "homework" assignments into the curriculum to help motivate students to watch the tutorials at home and be better prepared to complete in-class exercises as well as create a vehicle for reflection on software concepts. Additionally, there are online tutorials (such as Global eTraining) that allow instructors to monitor student progress as they work through tutorials and provide short quizzes to help students prepare for in-class assignments. For undergraduate curriculum, it seems that some type of tutorial supervision (and credit) is required.

The main benefit of the flip was having direct contact with the students during lab sessions, which allowed the instructors to have a better understanding of individual student needs as well as strengths and weaknesses of the exercises. If numerous students were stuck on one item, it could be addressed to all students with a quick tutorial where everyone walked through the item together in lab while those students who had already worked through the issue could continue working at their own pace.

Having students working at their own pace was both a strength and a weakness. One drawback to allowing students to work at their own pace is that the more advanced students would complete the assignment and leave early rather than following the peer-instruction model by helping other students through the assignment. The remaining students felt rushed due to the time constraint of the lab session and, as a result, did not have time to build their skills or reflect on their learning of the concepts as they could have in longer homework assignments. This is something to explore in future development of the in class exercises. We will explore collaborative learning models where students are encouraged to engage in peer-to-peer learning as well as reflect on the software concepts we seek to illustrate.

We also seek to encourage "reflection", a strong learning mechanisms, where the students learn the software concept as well as the software skill. We still have not resolved the conflict between concept learning and figuring out the software. Students tend to focus on the immediate task of "getting the assignment done", which tends to encourage them to focus on the software skills. However, we feel that the most important take-aways from the BIM coursework should be software concepts, with which they can understand a variety of software packages and apply BIM in appropriate ways. One mechanism we will try in the next iteration is to conduct a post-exercise reflection (perhaps as part of the week's homework), that connects software concepts with uses and skills.

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INDUSTRY-ACADEMIC BIM ALLIANCE: A PRAGMATIC APPROACH TO ENHANCE STUDENTS' BIM KNOWLEDGE

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ABSTRACT

Although the wide adoption of Building Information Modeling (BIM) in the construction industry is still evolving, recent evidence suggests that BIM usage is becoming the mainstream. It was projected that by 2014, over 70% of architects, over 40% of engineers, and over 50% of contractors would adopt BIM (McGraw Hill Construction, 2012). In response to this trend, it is critical that construction students be educated in the application of this important technology. North Carolina A&T State University (NCA&T) has integrated BIM as part of its ACCE-accredited construction curriculum. In addition to a dedicated stand-alone BIM course, the faculty has also experimented with teaching a BIM-integrated senior capstone course in alliance with an industry partner. This paper discusses the alliance formation process and the issues and challenges faced.

Keywords: BIM Application, BIM curriculum, BIM Integration, Industry Involvement

1. INTRODUCTION

Building Information Modeling (BIM) has become a major development in the architectural, engineering and construction (AEC) industry. In fact, it has become a technology of choice among many of these firms. Lee and Dossick (2012) stated that about 50% of the construction industry currently uses BIM and its adoption is expected to grow. Several factors have been attributed to the reasons why this technology is becoming popular in the AEC industry. One obvious reason is an attempt by these companies to improve their productivity while maintaining competitive edge over others. As Ofori-Boadu, Okere, & Kim (2010) put it, "BIM is no longer an option, but a vital part of business performance and success in the AECF [Architectural, Engineering, Construction, and Facility] industry" (p. 1). BIM applications in the AEC industry are widespread. It has been used in various phases of construction to achieve tangible benefits. These include smooth construction operations and decommissioning, increased building values, shortened project schedules, reliable project estimates, project design conceptualization, and improved development of building models and specifications (Ofori-Boadu, et. al., 2010) and to collaborate with members of the project teams (Ofori-Boadu, et. al., 2010; Lee & Dossick (2012). Compared to traditional practices, BIM has also been credited to a reduction in the number of Requests for Information (RFI). It is believed to have helped in reducing field coordination problems as well (Lee & Dossick, 2012). Infocomm international (2011) task force on BIM stated that:

The use of BIM is the backbone of new, leaner design and construction methods such as Integrated Project Delivery (IPD) and Virtual Design and Construction (VDC). The ability that BIM provides to design, construct and operate a building virtually will prove to be an important instrument to increase productivity while at the same time improve the quality of work. Additionally, BIM will be valuable in developing more sustainable buildings and their related systems. As sustainable design becomes the standard and not the exception, BIM's ability to capture and manipulate large amounts of data related to the built environment will prove to be an invaluable tool (p. 2)

In spite of the wide spread applications of BIM, its limitations cannot be ignored. Some of the limitations listed by Ofori-Boadu, et al (2010) include: scalability and manageability of project database, difficulty in sharing BIM information as drawing files, limited capacity of current data management systems, complex work processes, interoperability issues, high investment cost and resistance among members of the project team concerning adoption of one particular BIM system. These limitations were also echoed by infocomm international (2011) BIM task force as the group elaborated on the cost of software and training as well as the challenges of transitioning from drafting to modeling. Compatibility between software was also cited as a formidable limitation.

Regardless of the limitations of BIM, the AEC professionals believe that the technology is here to stay and that its adoption should not be left to chance. Unfortunately, the rate of BIM adoption by the construction industry is still very slow. For those firms who have decided to adopt the technology, it is very essential that a strategic implementation process be taken in order to maximize the full potential of BIM (Ofori-Boadu, et. al. 2010). The authors called for strong organizational and project-based strategies in order to maintain continued success with BIM integration.

2. INTEGRATION OF BIM INTO CONSTRUCTION CURRICULUM

Driven by industry and government requirements for cost-efficient building delivery systems and improved operational efficiency, construction educators can no longer afford to ignore the need to educate construction graduates in the applications of BIM. Taylor, Liu, and Hein (2008) argued that “If education is to prepare students for the coming BIM revolution, its integrative potential among the related disciplines must be explored at educational institutions” (p. 1). In response to the industry needs, some members of the Associated Schools of Construction (ASC) have introduced BIM in their curricula. However the pace of BIM integration into construction curriculum is appalling. In a study conducted on BIM integration in construction curricula among ASC members, Sabongi (2009) reported that less than 1% of survey respondents stated that BIM is taught as a stand-alone course while 9% indicated that it is taught as part of existing course. The author cited few obstacles to BIM integration into construction curriculum, including lack of additional provision to accommodate BIM course as an elective course in an already crowded curriculum. Since Sabongi’s (2009) report, there was an evidence of an improvement in the integration of BIM into construction curriculum, although the pace is still slow. The newer findings, however, were found to be in sharp contrast to Sabongi’s (2009) report. For example, Joannides, Issa, and Olbina (2011) reported that 78% of members of the Association of Collegiate Schools of Architecture (ACSA) and American Council for Construction Education (ACCE) schools stated that BIM was part of their curriculum. They also found that sixty seven percent (67%) of ACSA and fifty three percent (53%) of ACCE member schools reported that their programs have a stand-alone BIM course. Similarly, Becerik-Gerber, Gerber, and Ku (2011) as cited in Lee and Dossick (2012) found in their study that BIM courses were integrated into 57% of the engineering programs and 36% of the construction management programs.

Despite the reported achievements in BIM usage in the industry, many construction programs across the country still lag behind in integrating BIM into their curriculum. This is worrisome as employers consider students with BIM skills as having an advantage over those without BIM skills (Azhar, Hein, & Sketo, as cited in Lee & Dossick, 2012). Clevenger, Ozbek, Glick and Porter (n.d.) stated that “employers who currently use BIM seek students capable in and comfortable with BIM processes, but do not require software expertise” (p. 1).

Few challenges have been documented as reasons for construction programs’ failure to integrate BIM into their curriculum. They include lack of strategies and capabilities to introduce and leverage BIM into existing coursework (Clevenger, Ozbek, Glick & Porter, (n.d). These reasons are congruent with the argument made by Ofori-Boadu et. al (2010) that strategic implementation approach is necessary to assure smooth and effective BIM integration. Some programs also have no qualified faculty in their staff to teach BIM. This is beginning to change as some schools have started to

demand BIM knowledge for new faculty hires (Joannides, et. al, 2011). For those schools that have integrated BIM into their construction curriculum, the popular modes of delivery include offering it as part of subject matters in some of their existing courses, and as a required stand-alone course. Only a handful of schools co-teach BIM practices with industry partners. In order to maximize the students' mastery of BIM practices as seamless as possible, the following advice was offered by Taylor et. al (2008):

...Introduce students to BIM early in the curriculum as part of the subject matter topics. Thus, by the time students get to the required BIM course, they would have been familiarized with most of the terms and select applications” (p. 9)

The authors argued that BIM should not be limited to one dedicated course but rather diffused throughout the construction curriculum.

3. BIM IN NCA&T CONSTRUCTION CURRICULUM

BIM is currently a requirement in the ACCE-accredited baccalaureate construction management (CM) curriculum at NCA&T State University. In 2009, the construction faculty in the Department of Built Environment began to deliberate on the need for BIM integration. A curriculum committee was formed to review the existing curriculum, with the input of the Construction Management Advisory Board. The committee's recommendation was to integrate BIM into the CM curriculum. A senior faculty with expertise in BIM was later tasked with developing the BIM course. In 2010, the course, dubbed CM 256 – Introduction to Building Information Modeling was developed and subsequently gained approval by the University Senate Curriculum Committee. The course is offered as a sophomore level course. Introduction of BIM at this level is crucial to both students and faculty. This would allow students to understand its basic principles and applications by the time they begin to take upper level courses that would further address BIM applications. The course introduces BIM technology to students with particular emphasis on applications to construction industry. The following are Students Learning Outcomes (SLOs) of the course:

- Ability to define BIM and explain the difference between BIM and Computer-Aided Drafting (CAD)
- Ability to explain and discuss the various applications of BIM
- Ability to apply BIM principles to develop simple building models and specifications
- Ability to manipulate a building model to produce different views
- Proficiency in the use of BIM tools to produce basic quantity take-off from a building model.

Because students lack knowledge of how contractors and/or sub-contractors can utilize BIM technology for project delivery, the faculty decided to divide the BIM course materials into two (2) distinct and separate sections during the sixteen week semester. In Week 1 through 9, students are placed in groups (Figure 1) to focus on current project delivery methods such as 2-D paper-based specifications and documents, and BIM-integrated project delivery approach. Other BIM topics such as BIM for Contractors, BIM tools and parametric modeling, Interoperability, BIM for Subcontractors and Fabricators are also introduced during the first nine weeks as well. During Week 10 through Week 16, students are required to demonstrate BIM competency in the weekly Revit modules that include conceptual design, industry practices, creation of floor systems, documentation, wall and roof systems, windows, doors, schedules, quantity take-off, structural components and renderings. Figure 2 and 3 show examples of class lectures and student-produced BIM renderings, respectively. Figure 4 shows final project presentation to the CM faculty and CM advisory board members.

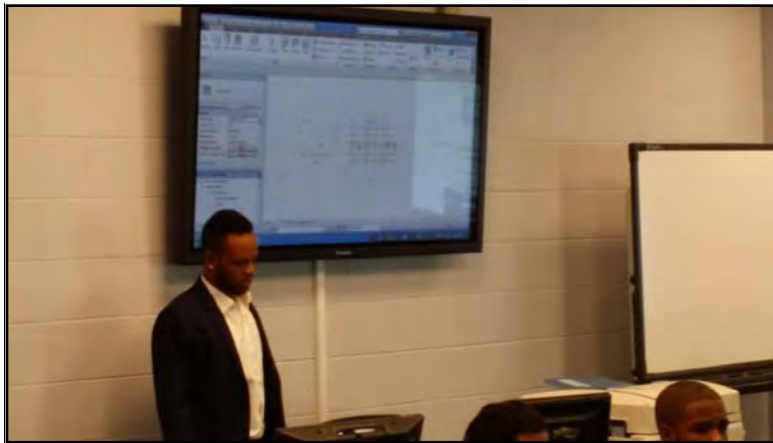


Figure 1: Students in group session

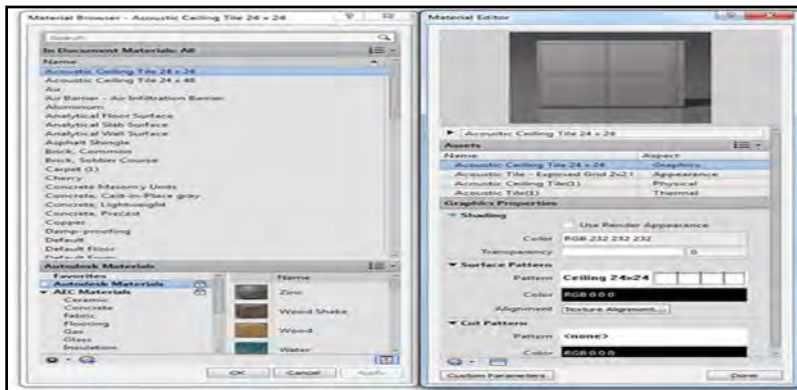


Figure 2: One of the weekly Revit Lecture modules

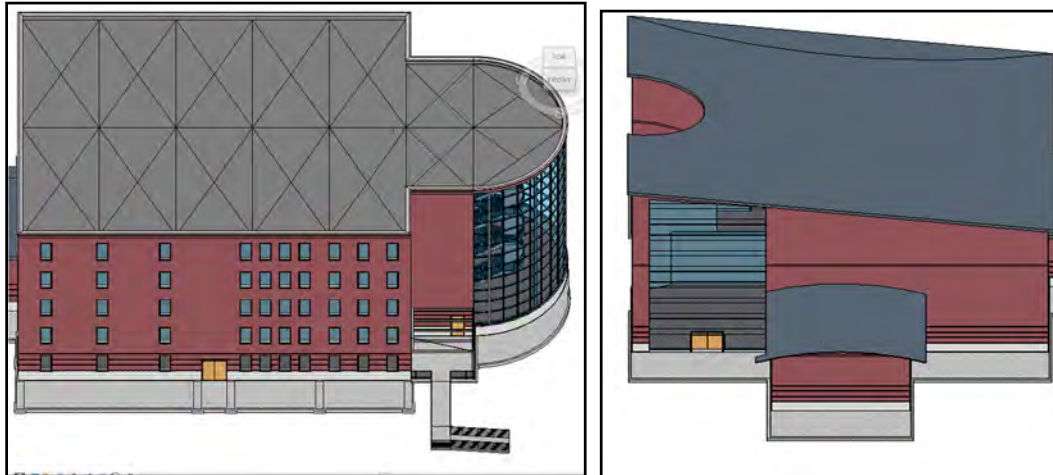


Figure 3: One of the BIM renderings produced by students

Following the success of the course as evidenced from the feedbacks received from the students who have served as summer interns and from those alumni already working in the industry, the faculty began to explore the possibility of implementing BIM in most of the CM courses.



Figure 4: Final project presentation

4. THE SENIOR CAPSTONE PROJECT

The senior capstone course was designed to encapsulate all CM courses that have been offered in the curriculum. The course requires seniors to partake in an assigned construction project with some of the leading construction firms in the country. As part of the required portfolio, students develop a set of construction documents, including production drawings and specifications. Students typically review and discuss contracts, ethics, construction administration and management as they relate to the project. The ultimate goal is to enable students visualize how their various CM courses tie together towards accomplishing a successful project. The course culminates with the submission of a detailed portfolio by each student.

As BIM continues to gain popularity in the AEC industry, the CM faculty began to discuss a paradigm shift for the capstone course. The outcome was to integrate BIM into the course for a semester and assess its success. Its success would determine whether to incorporate it permanently into the course. Seven senior students were enrolled in the class, including four who have completed the introductory BIM course. The BIM's SLOs were the same as used in CM 256.

5. FORMATION OF ACADEMIC-INDUSTRY ALLIANCE

To enhance the students' learning experience, a collaborative academic-industry alliance was initiated with Lend Lease (US) Construction Inc. The objective was to expose students and faculty to a real-world application of BIM technology. Lend Lease (US) Construction Inc. specializes in Health Care facilities and the company uses BIM extensively in all its projects. As part of our planned BIM integration model, the department's chair and some faculty members made initial contact with our CM graduate who works in a senior level position with the company. Some members of our advisory council also helped to seal the deal. After meeting with the company officials, the company agreed to work with the faculty to team-teach BIM applications to our Spring 2013 Senior Capstone students.

A local medical facility building was chosen as the BIM study project. This building is 280,000 square foot with a total projected cost of \$80 million (Figure 5). Figure 6 shows the site logistics for the project. Prior to the beginning of the course, faculty members were invited to the company's project site office for general discussion about the company's involvement. During this meeting a plan of action was developed which outlined specific milestones during a twelve week period. A tour of the project site was also conducted which provided faculty members with the opportunity to observe the project under construction.



Figure 5: Medical Facility used as as BIM study project

6. COLLABORATIVE TEAM TEACHING

The teaching of BIM in the senior capstone course was accomplished through team teaching with the assigned industry BIM expert from Lend Lease. The individual contributed to the lecture/lab through video webinar sessions with the faculty and students. The official class instructor was a senior faculty member with expertise in BIM as well construction management and architectural background. Other faculty members were tasked with specific responsibilities in order to achieve the goals of the alliance. For example, the following tasks were assigned to various faculty members based on their areas of expertise: BIM Logistics Plan analysis, Cost Estimating and Project Scheduling, Structural and Clash Detection Analysis, BIM MEP and Clash Detection Analysis. The department chair and another senior faculty member served as Project Managers with the responsibility of making sure that all plans went smoothly. BIM Integration Management was facilitated by the industry representative who also served as lead instructor. He also facilitated the webinar sessions throughout the twelve week session. Students were given access to the company's project BIM database throughout the duration of the course.

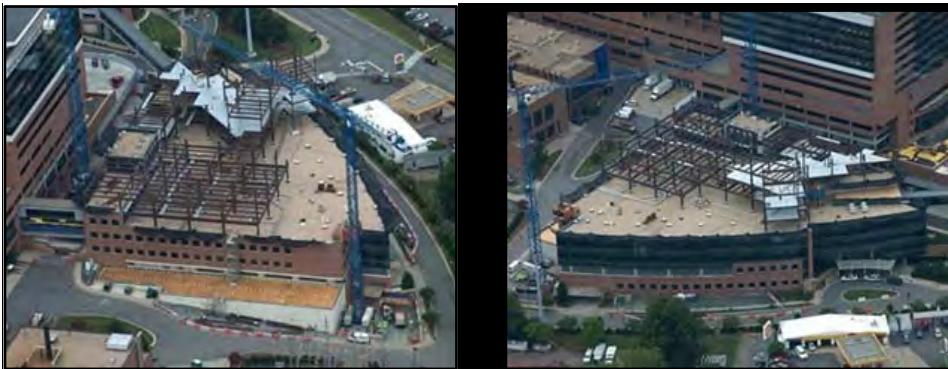


Figure 6: Site Logistics

7. ISSUES AND CONCERNS

There were technical challenges faced during the delivery of the course. Some of them are listed below:

- The computer lab used to facilitate live webinar sessions failed to work as expected
- Issues were found with the computer RAM and file storage, hardware capacity, and speed
- There were problems with computer software compatibility

Technical challenges of accessing several gigabits of BIM-based model data through the university and Lend Lease file transfer protocol (FTP) became apparent very quickly when Lend Lease BIM

Integration Manager “went live”. Actual webinar setup time, file transfer rates, and file data sharing proved problematic throughout the webinar sessions. The faculty quickly learned that industry BIM collaboration requires substantial computing power, robust networks and skilled IT managers.

8. MITIGATION OF TECHNICAL ISSUES

The BIM lead faculty member met with the School of Technology (SOT) IT manager to discuss the issues. The discussion centered on what computer/video equipment was needed to facilitate FTP and webinar access across the university network. The SOT IT manager and Lend Lease manager later found ways to establish log-in protocols for students and faculty. Major problems were found with the SOT computers with respect to their capacities and capabilities to process in real-time, large data sets and live video streaming. To solve these issues, the SOT IT manager dedicated one computer for FTP and webinar access during the live webinar sessions. Students were also placed in three groups, each with a dedicated computer to facilitate file exchanges using FTP. This was a temporary solution, but it did work.

9. CHALLENGES AND LESSONS LEARNED

Four of the seven students who participated in the course had prior BIM experiences gained through the introductory BIM course. The other three students struggled to fully understand the BIM concepts. This is not unusual as one case study of BIM-integrated construction course reported that students had to learn the software on their own as well (Taylor, et. al, 2008). Student class schedules conflicted with faculty schedules. Thus, students had to juggle their schedules in order to work with their assigned faculty members on their BIM project. Faculty schedules also conflicted with the industry webinar sessions. It was quickly learned that adequate schedule provisions must be made by the students and faculty in order to accommodate meeting times for the webinar sessions. CM faculty must also familiarize themselves with the BIM software in order to apply it successfully to their respective courses. This turned out to be more challenging than anticipated in terms of time and learning curves for faculty.

10. CONCLUSIONS AND FUTURE PLANS

The experience and the lessons learned from the industry-supported BIM-integrated senior capstone course have provided the CM faculty with the ammunition needed to assess how BIM should be taught to enhance the students’ knowledge. Although few challenges were faced during this experimental pilot period, they were not considered deterrence towards integrating BIM throughout our CM curriculum. The technical issues were mitigated as temporary solution. The successful integration of BIM technology will however require more computer resources. Thus, moving forward will require BIM technology integration to become an annual SOT IT budget line item. In addition, on-going BIM training for faculty is essential to successful course delivery. Students who have completed the BIM introductory course also suggested that it should be integrated into other CM courses. This has begun to change as faculty members have agreed to obtain necessary training in order to integrate BIM in their respective courses.

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How should we teach BIM? A case study from the UK

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Abstract

Growing industry demand and the United Kingdom (UK) government's 2016 'BIM deadline' have provided a clear impetus for enhanced BIM teaching in UK HE institutions. This paper reports on the approach taken in a large multi-disciplinary School of Civil and Building Engineering. From a number of options, the approach to embed BIM into existing modules was chosen and three categories of BIM Learning Outcomes (BIMLOs) were identified including: knowledge and intellectual aspects; practical skills; and transferable skills. A three-year implementation plan (2014 – 2016) was developed in which 26 priority modules had their existing learning outcomes upgraded to meet the BIMLOs. Partnership with BIM technology providers and practicing professionals, contemporary and research-driven topics as well as guidance documents e.g. BS1192 (2007), PAS1192-2 and BIM Protocol determined the contents of these BIMLOs. Many priority modules were taken by mixed cohorts of students drawn from various programmes, so group work via problem-based coursework is typically used for assessment. A 5-day intensive workshop was organised for final year students providing confidence in the use of web-based video tutorials for constant access to expert training. Streaming such videos into mobile devices enables flexible skill acquisition for 3D, 4D and 5D modelling. Guided self-learning through these video tutorials is now used strategically across the School. Developing and acquiring software and collaboration skills is extended through group-based problem-solving and modelling. New BIM-dedicated modules focus on collaborative working through common data environments (shared workspaces) as well as the auditing and coordinating of BIM models. The approach required long-term vision, leadership, BIM championing and the cooperation of academic peers who were extensively consulted. A feedback mechanism was put in place to capture students' experiences regarding BIMLOs, access to computing facilities and effectiveness of video tutorials. The paper considers the benefits and shortcomings of the approach and the need for appropriate resources, skills and facilities to prepared students for a BIM-enabled world.

Keywords: *Multi-disciplinary cohorts; Embedding; BIM Learning Outcomes; Streamed video tutorials; New BIM-dedicated modules; Leadership and BIM champion; Feedback mechanism.*

1.0 Background: BIM in the UK context

Various BIM initiatives and implementation or regulatory bodies shape the policy, technology and process aspects of BIM in different countries. Wong et al (2010) have reviewed and classified the roles of such bodies for six countries: Denmark; Finland; Hong Kong; Norway; Singapore and USA. In the United Kingdom (UK), the BIM Task Group¹ is a major interest group comprising of experts drawn from the public sector, industry and academia. Its remit covers building the capacity of the public sector to deliver Level 2 BIM by 2016 as part of the Government Construction Strategy (Cabinet Office, 2011). The BIM Task Group (2013a) suggests that BIM is "such a wide open subject with interpretations differing throughout the supply chain that we could have spent a year just trying to define BIM". The Task Group also implies that digital-tool sets (e.g. authoring and collaboration software), are necessary to implement BIM. From the UK's perspective, there are four different levels of implementing BIM (Fig. 1). These are summarily described as: Level 0; Level 1, Level 2 and Level 3 (RIBA, 2012). Of immediate interest in the UK is Level 2, where models are created in BIM applications by specific disciplines before deployment in a shared workspace or common data environment (BSI, 2013; BSI, 2007). The data generated by Level 2 BIM must be compatible with the Construction Operations Building Information Exchange (COBie) format. Level 2 BIM is hence, the minimum desired level (and format) of BIM implementation expected by the UK government by 2016 (CIOB, 2011; HEA, 2013) for all centrally procured projects.

1.1 Teaching BIM: A global overview

An example of a contemporary approach to planning a BIM curriculum can be found in Barison

and Santos (2010a) who reviewed AEC undergraduate programmes in 25 universities, most of which are in the USA. They deduced that BIM was taught by six universities at an introductory level, by 12

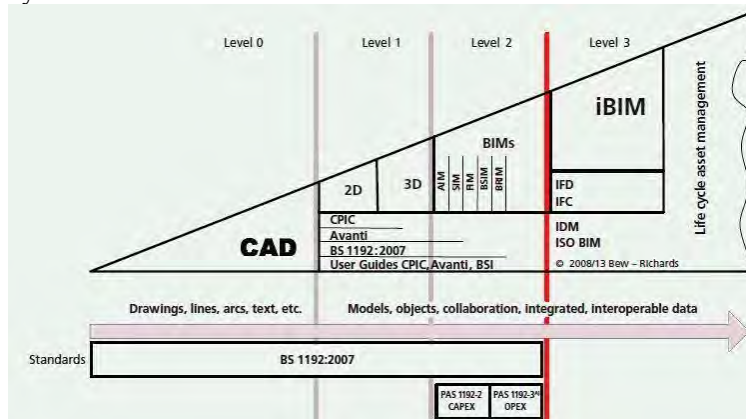


Figure 1: The BIM Maturity Diagram (Source: BSI, 2013)

universities at an intermediate level and by seven universities at an advanced level. BIM at the introductory level did not require any pre-requisites (not even CAD) or high level of computing skills, making it suitable for first year students. Barison and Santos (2010b) have also suggested that there are schools which teach BIM via distance collaboration, the idea being to simulate real-life collaborative working amongst geographically dispersed students of different institutions. They give an example of universities which have implemented this approach to include The University of Nebraska-Lincoln (Architecture) and University of Wyoming (Architectural Engineering). Another example is provided by Becerik-Gerber, et al (2012), where senior level undergraduate or postgraduate level students of Virginia Tech (11 students) and University of Southern California (12 students) collaborated on the platform of a CEM course. A similar multi-institutional but international exercise has just been carried out by Loughborough University in conjunction with Coventry University and Ryerson University, through the ‘BIM-Hub²’ initiative (Poh, et al. 2014).

Teaching BIM has its challenges and opportunities. Becerik-Gerber, et al. (2011) who studied over 100 US-based AEC programmes found inconsistencies in how BIM was adopted and accepted by many institutions, based on cultural, economic and academic differences. There can also be obstacles to BIM integration due to inflexible or tight curricula that cannot withstand elective courses, constraints due to graduation requirements, and even lack of reference materials for teaching (Sabongi, 2009). A BIM capstone thesis can however, give valuable and in-depth skill sets to undergraduate students (Azhar, et al. 2010). On the basis of industry needs, Pikas, et al. (2013) identified 39 key topics on BIM competencies that should be covered by construction management students. It is also clear that as a result of its revolutionary technology (Hardin, 2009) BIM is creating new types of activities and protocols which are not only re-defining tradition AEC roles but creating new career opportunities like ‘Model Manager’ (RIBA, 2012), ‘BIM Manager’ (Barison and Santos, 2010a) as well as ‘BIM Coordinator’ and ‘BIM Engineer’ (Wu and Issa, 2013). These sorts of career opportunities have to be considered and exploited in the training of AEC students and there is no evidence that separate degree programmes are required for these new BIM-specific ‘professions’.

Depending on the nature and objectives of a module, effective learning by students can be achieved by a combination of many methods, including lectures, isolated drill and practice as well as guided self-study (Bransford, et al. (2000) who discuss the principles of ‘how people learn’.

Based on this model, learning BIM can be achieved via teacher-led instruction in traditional lectures and/or lab tutorials, problem-based projects/coursework and use of web-based tutorials for acquiring practical skills in BIM-related software. Such videos can offer a new vista to the learning experience that cannot be obtained from traditional text- based hand-outs. Evidence in literature suggested that video-based training could aid metacognition (Wouters et al., 2007); support problem-based learning (Chan, et al. 2010) as well as increase stimulation, retention and satisfaction of students learning

experience (Choi and Johnson, 2007). By encouraging guided self-learning through video tutorials, students can acquire CAD/BIM skills with a knock-on effect on computer lab sessions, which can then focus on coursework (problem-solving). This is as opposed to current scenario, where substantial amount of time spent by students in lab sessions is dedicated to first, learning how (CAD) software work, leaving lesser time for applying the learning in their coursework. This should eventually speed up the Kolb Learning Cycle (Kolb, 1984).

1.2 Teaching BIM in the United Kingdom

Compared to North America, there is a relative shortage of pedagogical literature and case studies about curriculum development and teaching experiences regarding BIM in UK higher institutions. There some exceptions like McGough, et al. (2013) where a two-staged approach was used to integrate BIM into the Civil Engineering, Architecture and Building Department of Coventry University. This approach involves the implicit introduction of collaborative working skills to first year students, with a reorganisation of a third year integrated project module. The BIM Academic Forum (BAF) is nevertheless playing an important coordinating role through its BIM Academic Framework³ with membership from over 30 UK universities. Postgraduate (MSc) taught programmes of UK universities are often the most visible or most publicised BIM programmes in UK universities' websites. They appear to be used to demonstrate BIM- focused specialisation (Table 1), with evidence of distance learning being a popular (and sometimes only) mode of delivery.

Table 1: Overview of BIM-related MSc programmes in selected UK universities (as of Dec 2014).

University	Programme title	Duration and Mode of Study	Delivery format
<i>Westminster University</i>	Building Information Management	1 Year (FT);	Campus only
<i>Middlesex</i>	Building Info. Modelling Management	1 Year (FT); 2 Years (PT)	Distance learning only
<i>Salford</i>	BIM and Integrated Design	1 Year (FT); 2.5 Years (PT)	Campus, Distance Learning and International Distance Learning
<i>Liverpool (in London)</i>	Building Information Modelling	1 Year (FT)	Campus only
<i>Uni. of West of England</i>	Building Info. Modelling in Design, Const. & Operation	1 Year (FT); 2-3 Years (PT).	Campus only
<i>Northumbria</i>	Building Design Mgt. and BIM	3 Years	Distance learning only
<i>University of South Wales</i>	Building Info. Modelling and Sustainability	1 Year (FT); 3 Years (PT).	Campus only

FT = Full Time; PT = Part Time.

In view of the importance which BIM is expected to play, the UK's Higher Education Academy (HEA) sponsored a report on the infusion of BIM in taught programmes through BAF (HEA, 2013). This report overviewed the impact of BIM on the needs of students, the expertise of staff in schools that teach AEC disciplines as well as essential BIM learning outcomes. The report outlines three types of intended learning outcomes (ILOs) for BIM which are: knowledge and understanding; practical skills and transferable skills. These categories of learning outcomes are supported by Ghosh, et al (2013) who argued that for effective BIM implementation, the pedagogical approach should cover theory, practical experience and use of technology-driven collaborative environments. The HEA report is however rather silent on some issues which have bearing on successful integration of BIM. For example, the steps to be taken to infuse the ILOs of BIM into the specifications of existing modules require a mapping process. Without careful planning (e.g. through a toolkit), duplication of ILOs, over-assessment of students (Boud and Falchikov, 2007) or inconsistencies with accreditation requirements may occur. Additionally, the HEA report does not discuss the need for role-playing amongst multi-disciplinary cohorts of students as a precursor to Level 2 BIM. The sequential order of professional tasks associated with collaborative work via BIM modelling (Shafiq et al. 2013, Gu and London 2010) should be adopted by students in the form of role-playing as exemplified in Becerik-Gerber et al. (2012). Role-playing would be helpful towards acquiring the range of skills necessary for efficient and effective collaboration with respect to UK's Level 2 BIM ambitions.

2.0 Teaching BIM at Loughborough University: A case study

The School of Civil and Building Engineering (SCBE) at Loughborough University has four undergraduate degree programmes and up to five postgraduate taught programmes requiring BIM. The undergraduate programmes include: Architectural Engineering and Design Management (AEDM); Civil Engineering (BEng/MEng); Construction Engineering Management (CEM) and Commercial Management and Quantity Surveying (CMQS). The co-location of these programmes in one School has traditionally allowed the optimisation of multi-disciplinary modules where group work is often used to achieve learning outcomes. Embedding BIM into such a wide array of programmes had logistic implications, requiring coordination and consistency in approach. The leadership of the School therefore identified and empowered a BIM champion (lead author) to facilitate the required changes. The exercise began with extensive consultation of academics about their needs, expectations or concerns. This was the foundation upon which changes to the curriculum was possible. The BIMLOs recommended by BAF (HEA, 2013) were mapped and cross-referenced with the ILOs of 26 existing undergraduate and five postgraduate modules identified for priority⁴ embedding (Table 2). These BIMLOs also serve guide the development of new BIM-specific or BIM-relevant modules introduced to a programme.

In addition to customary texts on BIM which provide theories and conceptual backdrop, there are important documents that are crucial as learning materials and to the learning outcomes of BIM in the UK. These include: regulatory guidelines like BS1192-2007 (BSI, 2007), PAS 1192 (BSI, 2013) and the CIC BIM Protocol (BIM Task Group 2013b); industry standards such as Royal Institute of British Architects (RIBA) BIM overlay (RIBA, 2012), and Royal Institution of Chartered Surveyors' (RICS) new rules of measurement (NRM1) (Wu, et al. 2014). Other sources of BIM knowledge and understanding come from case studies by industry professionals who give presentations on how BIM has been used in real-life projects. Depending on the programme and its focus, acquisition of various practical skills is achieved through data generation from BIM.

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Table 2: Summary of priority undergraduate modules and implementation semesters

	Semester 1: 2013/14	Semester 2: 2013/14
Phase 1	CVA028 (Const. Comm. Mgt 1)	CVB026 (Construction Tech. Management 2)
	CVC037 (Pre Const. Est. Plan)	CVA011 (2D CAD & BIM)
	CVB033 (Health and Safety)	
	Semester 1: 2014/15	Semester 2: 2014/15
Phase 2	CVA014 (Construction Tech. Management 1)	CVA027 (Graphic Communications)
	CVC022 (3D CAD Modelling)	CVB005 (Construction Management)
	CVC039 (Arch. Design Project)	CVC045 (Collaborative. BIM Design Project)
	CVA028 (Const. Comm. Mgt 1)	CVA026 (Building Production)
	CVB037 (Measurement & QS)	CVA030 (Methods of Measurement)
	CVP320 (ICT for Construction)**	CVP335 (Federated Build. Info. Modelling)**
	Semester 1: 2015/16	Semester 2: 2015/16
Phase 3	CVB001 (Structural Design)	CVC019 (Project Management)
	CVC005 (Design Project)	CVD003 (Teamwork Design Project)
	CVD004 (Design Project Management)	CVC033 (Maintenance, Repair and Refurbishment)
	CVC024 (Architectural Detailing)	CVC037 (Pre Const. Est. Plan)
	CVC030 (Advanced Mechanical Services)	CVC028 (Construction Economics)

⁴Criteria for prioritising a module for BIM embedding include: (1) it is taken by a multi-disciplinary cohort of students; (2) it primarily teaches building design and/or construction; (3) it has inherent focus on ITC application: i.e. computing or modelling; (4) it is at a critical stage of learning*(i.e. Part A or Part C

on the programme and its focus, acquisition of various practical skills is achieved through data generation from BIM authoring software, model coordination and auditing, and finally collaboration through shared workspaces. In this regard, long-term partnership with technology providers has been central to acquisition of software necessary for teaching and learning skills in BIM technologies. The core BIM technologies adopted include: Revit suite of products for 3D BIM (Architecture, Structure and MEP); CSI-SAP2000 (Finite Element Analysis); CCS (costing); Navisworks and Solibri (clash detection and auditing); IESVE, as well as 4Projects⁵ and Asite⁶ (common data environments).

In the Civil Engineering (BEng/MEng) programmes accredited through the Joint Board of Moderators (JBM) framework, BIM was added as distinct ‘thread’ or ‘theme’ separate from existing JBM threads namely: Design, Health and Safety Risk Management and Sustainability. This enabled clarity in delivery of BIMLOs for these programmes, providing transparency to the accreditation body and industrial sponsors who have been keen to see BIM in the curriculum. Across the School, a typical undergraduate student is expected to go through four phases of BIM education (Fig. 2).

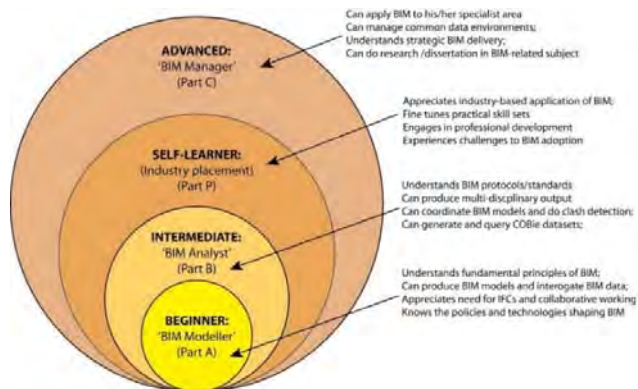


Figure 2: Projected BIM capacity for an undergraduate student at SCB based on Barison and Santos, (2010a)

2.1 Mission BIMpossible: A five-day workshop on BIM

The first phase of implementing the BIM strategy (2013/14) witnessed a 5-day extra-curricular workshop on BIM. Tagged ‘Mission BIMpossible’ the workshop was aimed at final year students and those about to go on industrial placement. The workshop provided over 100 of these students with requisite knowledge and skills in BIM but it was also used to achieve other goals, such as: (a) comparing software for teaching, e.g. Navisworks vs. CATO (for cost estimating) as well as Navisworks vs. Solibri Model Checker (for coordination/clash detection); (b) networking with experts from industry for case studies and site visits; and (c) piloting the use of video tutorials for acquisition of modelling skills. Over five days of Easter holidays, students were able to acquire enough skills to collaboratively re-create the Sir Frank Gibb and (c) piloting the use of video tutorials for acquisition of modelling skills. Over five days of Easter holidays, students were able to acquire enough skills to collaboratively re-create the Sir Frank Gibb Building⁷, a composite (steel and concrete) three storey building using 3D and 4D BIM technology. This group work was supported by as-built CAD drawings and walk-through audits. The success of the video tutorials during the workshop provided the confidence needed for their adoption as a carefully considered teaching and learning resource. In addition to case studies of major projects such as Network Rail, a number of workshop speakers presented topics like (a) Clash Detection using Solibri Model Checker; (b) Common Data Environments using 4Projects; (c) integrated environmental impact and life cycle costing using BRE’s IMPACT; (d) How BIM supports the New Rules of Measurements (NRM1); (e) Linking Revit Structure to SAP2000/Etabs; and (f) Legal issues, standards and protocols of BIM. These topics are now integrated into various modules. In summary, the workshop increased awareness and momentum about BIM in the School of Civil and Building Engineering. The confidence and employability of participating final year students was positively affected by the workshop.

⁵<http://www.4projects.com/2g3glogin.aspx>

⁶<https://www.asite.com/>

2.2 Mass adoption of video tutorials

Video tutorials are now adopted across the entire school to provide constant stream/access to audio-visual instructions for common BIM software (e.g. Revit Series). All students are given free, unlimited access to a web-based learning portal⁸ containing these videos. Current final year students are given 6 to 12 months grace period after graduation, but this grace period will not be necessary in a few years. The videos can be consulted during tutorials on desktop computers or streamed into mobile devices during students' free time. Data was collected on the opinion of students sampled from three programmes about these videos. These students were targeted based on recently taken modules where substantial use of BIM technology was required. The respondents were drawn from the following programmes: AEDM (Part A = 20% and Part B = 34%); CEM Part C (21%) and Civil/MEng Part D (23%). Students were asked to rank the helpfulness of the videos, their confidence after watching the videos as well as the range of topics covered and quality of streaming (Fig. 3).

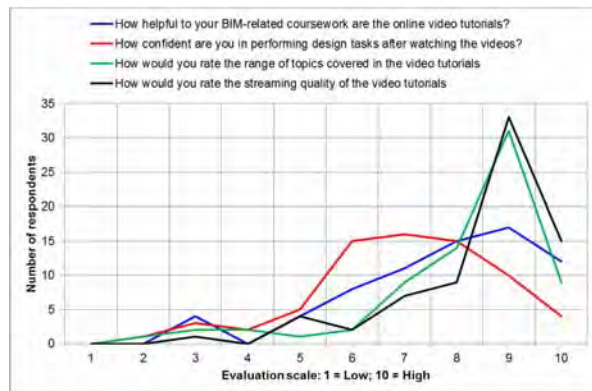


Figure 3: Students' evaluation of video tutorials based on recent coursework

Students were asked about the length of time they would typically spend each time they consulted the videos. It appeared that more students would spend around 30 to 45 minutes watching these videos at any given time. The majority (64%) of respondents claim to prefer watching these videos on their personal laptops compared to 34% who watch them while in computer labs and just 3% who do so from smartphones/tablets. About half of students surveyed stated that they would have to watch a specific video clip twice before understanding the task involved. Only 21% would watch a video clip once and 24% will need to watch a few times. MEng students typically spent longer time (45 minutes to 1 hour) on these videos than AEDM and CEM students (15 to 30 minutes), but this could be due to the complexity of the MEng coursework. Only 11% of students thought paper hand-outs were a better way to learn software than use of video tutorials while 72% thought videos were better and 17% were undecided. There is a general lack of awareness about the different computer labs where BIM software are available on campus. This may however, be linked to the fact that 63% of respondents would rather watch the videos (and perhaps do their coursework) on personal laptops.

3.0 Conclusions and lessons learned

There are a number of options that can be pursued for teaching BIM as suggested in existing literature. The most detailed studies on curricula implications of teaching BIM are based on studies in North American institutions and degree programmes. Although there is scarcity of detailed case studies about similar universities in the UK, BIM is shaped by Level 2 expectations, standards like BS1192-2007 and political deadlines for implementation in UK government projects. Where multi-disciplinary degree programmes are offered in a School or Department, the approach to embed BIM into ILOs of existing modules has advantages and opportunities. To ease the burden of massive changes required for about 30 modules, the School of Civil and Building Engineering adopted a three year implementation plan, culminating with the deadline for Level 2 BIM in 2016. The choice and role of BIM technologies should not be underestimated because the generation and sharing of object-oriented models through.

⁷ The building hosting the School of Civil and Building Engineering

⁸ <http://www.infiniteskills.com/>

digital applications is central to BIM, regardless of the country-specific protocols, policies and professional processes. Many challenges had to be overcome as some academics might take a view that BIM ‘*should be delivered by a BIM expert... on a specific module*’. For proper integration into an AEC programme, it is doubtful that any single person or module can satisfy the multi-faceted scope of BIM. It may be reasonable and practical to have a BIM champion coordinating the learning and teaching of BIM in order to ensure consistency and holistic integration. However, every academic should be capable of delivering at least one lecture on BIMLO1 (Principles of BIM) i.e. what BIM means and how it applies to his subject/module. It is hence, necessary to up-skill more academics without which, BIM capacity will remain in the hands of select few or worse, BIM will be viewed as ‘something someone else should teach’.

In order to avoid overwhelming students with too many types of BIM technologies, it is helpful to adopt a restricted suite of tools, even if IFC concepts are stressed. For the School, one of the advantages of adopting Autodesk solutions lies in its popularity in the UK, where 66% of all CAD/BIM applications are based on its products (NBS, 2013). In addition, there is wide availability of teaching and learning resources (textbooks and video tutorials) on Autodesk solutions. When selecting the software solutions for teaching BIM, the availability of these supporting resources should not be underestimated. The use of video tutorials has in particular helped to deliver training on practical BIM skills to students and has eliminated the need for academics to develop and update hand-outs for computer lab sessions.

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DEVELOPING BIM LABORATORY EXERCISES FOR A MEP SYSTEMS COURSE IN A CONSTRUCTION SCIENCE AND MANAGEMENT PROGRAM

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ABSTRACT

Starting with the 2014-2015 academic year, the curriculum of the Construction Science and Management (CSM) program at the University of Texas at San Antonio includes Building Information Modeling (BIM) courses as part of the degree requirements. One of the courses requiring BIM is the Mechanical, Electrical and Plumbing (MEP) Systems course. This paper focuses on the process followed in developing the MEP Systems course laboratory exercises, the specific topics covered, and the organization of the course during its first implementation under the new format, as well as the differences with previous offerings of the course without the BIM component. It also discusses the perceived benefits of using BIM as part of the teaching process, as well as the difficulties and drawbacks encountered while using the software. In addition to presenting the instructor experiences, the paper also discusses the results and observations stemming from student surveys and evaluations. The student surveys were used specifically to assess the effectiveness of the BIM exercise in presenting the MEP topics. Additionally, the surveys provided student opinions and suggestions on how to improve the BIM component of the course, where as the course evaluations only provided general feedback on the instructor teaching and course delivery. Lastly, the paper discusses future additions, changes and improvements to the course laboratory BIM exercises, as well as changes to the course organization and topics covered in order to ease the inclusion of BIM into the classroom.

Keywords: BIM, MEP Systems, Laboratory Exercises, Course Development

1. INTRODUCTION

Starting with the 2014-2015 academic year, the curriculum of the Construction Science and Management (CSM) program at the University of Texas at San Antonio includes Building Information Modeling (BIM) courses as part of the degree requirements. The inclusion of BIM into the curriculum responds to current technology trends in the construction industry (Azhar, Khalfan, and Maqsood 2012), as well as feedback from the program's Industry Advisory Council.

Under the new catalog, BIM is covered primarily in three courses. First, the BIM software packages and fundamental concepts are first introduced in a dedicated course during the fall semester of the junior year, and then students are further exposed to specific aspects of BIM in the laboratory exercises of the program's Mechanical, Electrical and Plumbing (MEP) Systems course. Finally, students are required to use BIM as part of the program's final capstone project course during their senior year. Figure 1 shows the current required CSM course sequence flowchart starting from the sophomore year, without showing the business course requirements of the program. The first year of the program consists of the base core courses such as sciences, mathematics, and humanities/social sciences.

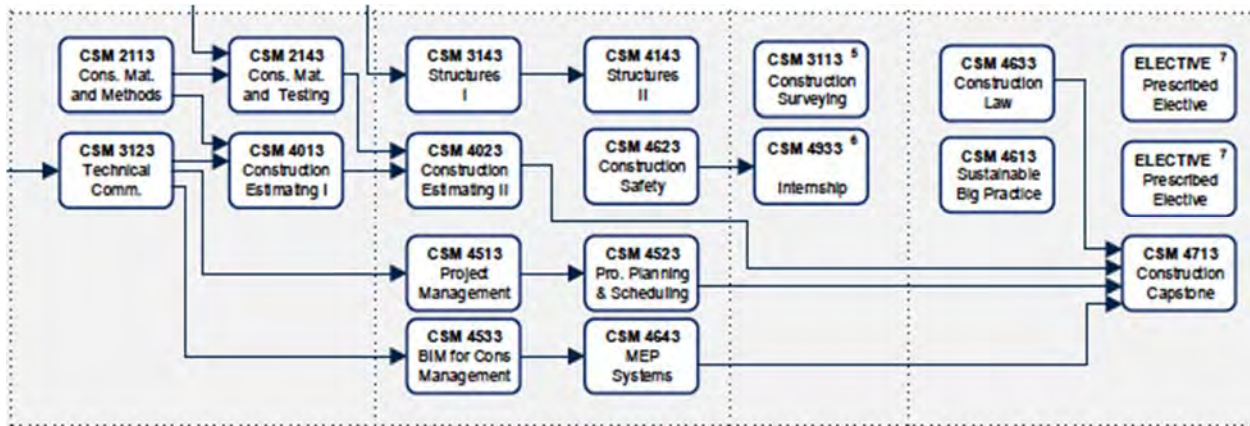


Figure 1 2014-2015 UTSA Catalog CSM Program Sequence.

In the following sections, the authors describe the course general structure, followed by the laboratory structure and topics covered, in both the new class format that incorporates BIM, and the previous class implementations prior to BIM. Then, a description of the general format used for the BIM-focused laboratory exercises is presented, as well as the instructor experiences with the development of the course together with the results and observations stemming from student surveys and evaluations.

Lastly, the paper discusses future additions, changes and improvements to the course laboratory BIM exercises, as well as changes to the course organization and topics covered in order to ease the inclusion of BIM into the classroom.

2. COURSE STRUCTURE

The Mechanical, Electrical, and Plumbing Systems (MEP) course in the Construction Science Department at the University of Texas at San Antonio (UTSA) is structured as a 3-credit hour (2-2-3) course consisting of two one-hour lectures per week, and a single two-hour laboratory session per week. The MEP course goals and objectives are:

- Develop an understanding of the design principles of mechanical, electrical and plumbing systems.
- Develop an understanding of the principles, materials, and equipment used in plumbing/drainage, building electrical systems, HVAC, and fire protection and suppression systems.
- Read and interpret electrical, mechanical, plumbing and fire protection building construction plans and specifications.
- Conduct basic sizing and layout of MEP systems based on the building specifications, loads and demands.

The first two objectives are covered primarily through the lecture presentations, handout readings, and supplemental audiovisual materials, posted on the course Blackboard Learn® webpage, while the last two, more practical, objectives are covered primarily through the course laboratory exercises. Starting with the Fall 2014 semester, Building Information Modeling became an essential part of the course laboratory component, as part of the department initiative to include BIM proficiency and knowledge in the program's graduates skillset.

In the current implementation of the course, the lecture components and order of topics covered are not modified from previous incarnations, but rather the laboratory topics are arranged to follow the lecture subjects: electrical systems, followed by plumbing and fire protection, and finalizing with HVAC systems and building science fundamentals.

In the Fall of 2014, the students taking the course were sophomores to seniors majoring in the Construction Science and Management (CSM) Bachelor program, and the majority of the students enrolled in the MEP course had either taken the program's first construction estimating course, or were taking it concurrently with the MEP class. Prior to the Fall 2014 semester, an introductory course to BIM

was not a requirement of the program, so proficiency with BIM was not required nor expected from the students taking the MEP course at the time. However, a BIM course is now a requirement of the CSM program, and a pre-requisite for the MEP course, for any student enrolled in UTSA’s CSM program under the 2014-2015 UTSA Course Catalog.

3. LABORATORY STRUCTURE

3.1 Current Format with BIM

The laboratory exercises developed during the Fall 2014 semester were designed to introduce and develop practical knowledge in the following construction management areas as they apply to the most common MEP subsystems present in vertical construction:

- Plan reading and interpretation;
- Material quantity takeoffs (QTO);
- Basic system sizing;
- System modeling and layout, and;
- Fundamental principles calculations

Two software packages were used in the laboratory: On Screen TakeOff® (OST) published by OnCenter Software, Inc. (“On Screen Takeoff 3.8.1 User Guide” 2010); and Revit 2014® (Revit) published by Autodesk, Inc. (Bokmiller, Whitbread, and Hristov 2013). OST was used to perform the material QTO during some of the electrical and plumbing related exercises. A detailed description of the development of the OST based laboratory exercises was presented by the author in a previous education conference (Palomera-Arias 2014). Revit was the only BIM software package used during the course, and it was required to perform the system modeling and layout exercises for the various MEP subsystems covered in the course. Finally, system sizing and fundamental calculations exercises were performed in the laboratory manually or using a spreadsheet program such as Microsoft’s Excel®.

There were a total of ten laboratory exercises during the semesters covering the areas described above. The order of the laboratories, as mentioned previously, closely follows the topics covered in the lecture component of the course. Table 1 lists the current laboratory topics, and the specific areas covered in each. All the laboratory instructions, handouts and supporting materials, were delivered, and the student work collected, using the Blackboard Learn® course management system. Students were required to submit a pdf file of their work, and in the case of BIM exercises, the Revit® model file (.rvt) or a pdf of a specific view of the model.

Table 1 Current Laboratory Exercises Focus

Laboratory Description	Plan Reading	QTO	Sizing	BIM	Principles
Laboratory 1: Introduction to OST® and Revit®		•		•	
Laboratory 2: Electric Power and Loads					•
Laboratory 3: Power Distribution Systems	○	•		•	
Laboratory 4: Lighting Systems	○	•		•	
Laboratory 5: Electrical System Sizing			•		
Laboratory 6: Plumbing Plans and Pipe Sizing	•	•	•		•
Laboratory 7: Plumbing Layout	○			•	
Laboratory 8: Fire Suppression Layout	○			•	
Laboratory 9: HVAC Forced Air Systems Layout	○			•	
Laboratory 10: Heating and Cooling Loads			•		•

Legend: •-explicit focus; ○-implicit focus.

3.2 Laboratory Format without BIM

Prior to the inclusion and use of BIM, the laboratory exercises focused on the following practical construction management areas:

- Plan reading and interpretation;
- Material quantity takeoffs (QTO);
- Basic system sizing;
- Basic material and labor estimating, and;
- Fundamental principles calculations

The main difference between this list and the list presented in the previous subsection, is the substitution of the estimating component of the laboratory with the system modeling and layout using Revit®. Also the number of exercises on each category was different than in the current implementation, with the five topics explicitly covered for each of the four MEP subsystems covered in the course.

4. BIM EXERCISES FORMAT

As shown previously in Table 1, a total of 6 BIM exercises were developed for the course. The first one was intended as an introduction to the software packages that would be used in the course, and provided an introduction to the main 3D model of the building (Figure 2) that would be used throughout the semester for most of the problems. The building presented (West St. Video) is a single-story, open-floorplan, retail building with two small rooms and a single bathroom. It contains full plumbing, including storm drainage, rooftop HVAC with ductwork, automatic fire sprinkler system, and a full electrical power and lighting system with a single electrical panel. A full set of digital plans for the building is available, including architectural and structural plans, at a scale of an eighth of an inch to a foot ($1/8''=1'$) in an 11x17 page format. The building contains most of the systems covered in the course at a relatively low complexity level. The Revit® architectural base model was developed by the instructor based on the architectural and structural plans provided to the students. The model was then distributed to the students using Blackboard® to allow them to add the MEP systems.

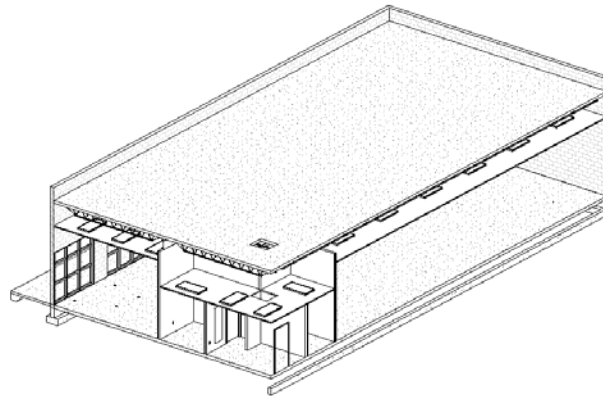


Figure 2 Snapshot of the West St. Video Building Revit® Model Used.

After the introductory laboratory, the other five problems focused on the individual systems, and were structured as step-by-step instructions that guided the student through the process of: (a) setting up Revit® to define necessary floor-plans and 3D views in order to work with a particular MEP system; (b) adding and defining required components to the library such as piping, fittings, ducts, equipment, fixtures, etc.; and (c) placing those components into the provided architectural base model following the provided West St. Video plans. Figure 3 below shows a partial snapshot of the work to be completed by following the “Laboratory 7 Plumbing Layout” instructions. The figure shows the bathroom detail available in the plumbing plans of the West St. Video Building, and the resulting 3D model of the same space on Revit®.

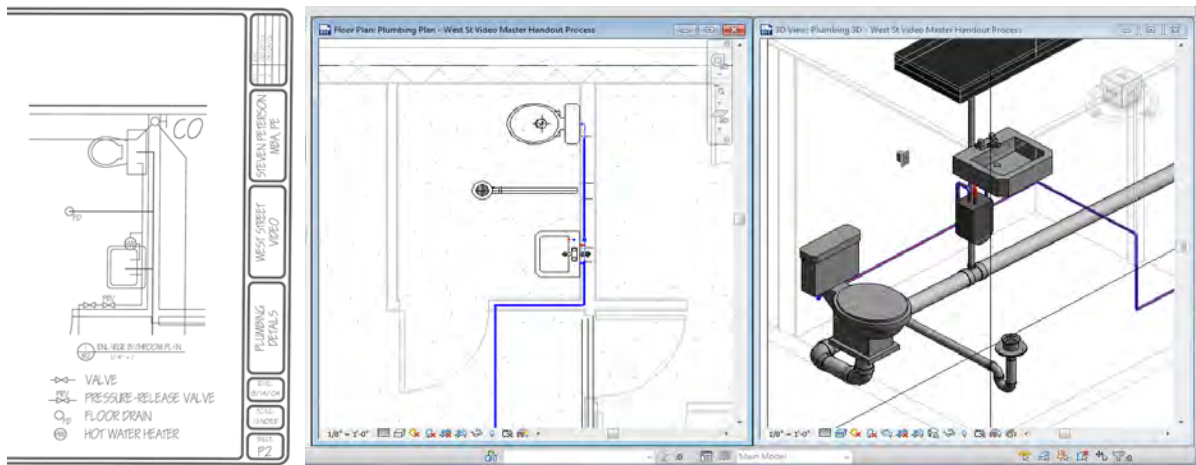


Figure 3 a) West St. Video Plumbing Plan Bathroom Detail. b) Revit® 3D Model of Bathroom Plumbing.

Similar exercises to the plumbing were developed for the fire suppression, and HVAC systems. Electrical systems were slightly different as they focused on generating “electrical plans” and “electrical circuiting” rather than 3D models of conduits and wiring layouts. Devices and lighting were placed on the architectural model, but only “electrical” connections were made between devices. Figure 4 below shows the generated electrical lighting 3D model (with HVAC and ductwork showing) with the corresponding Revit® produced lighting electrical floor plan. Notice the lack of a 3D model for the electrical circuit connections between devices as shown in the floor plan.

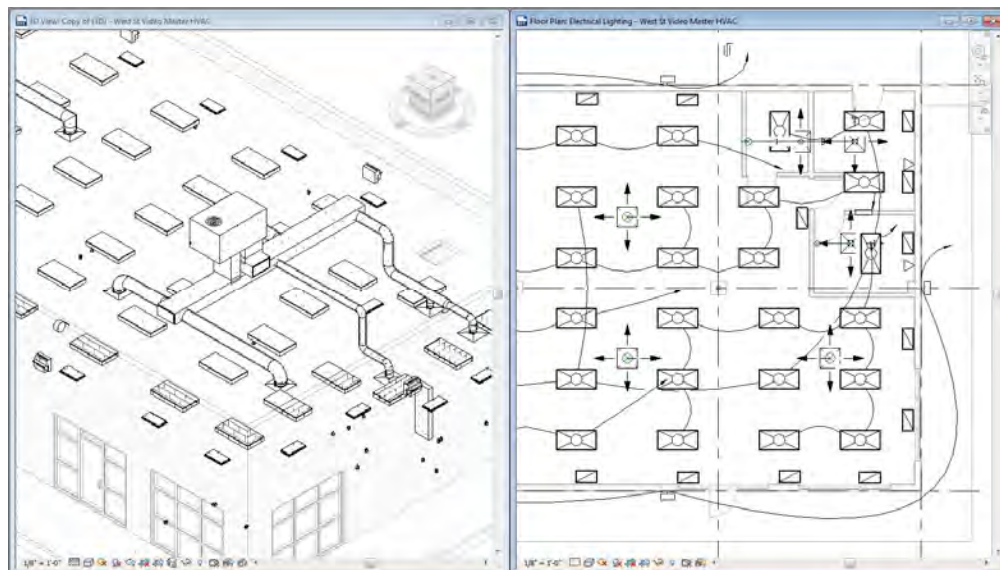


Figure 4 Revit® Lighting and HVAC Model with corresponding Electrical Plan.

5. DISCUSSION

5.1 Student Evaluation

The University of Texas at San Antonio follows a two-tier course evaluation procedure where students complete an online evaluation of the courses taken during the semester. This evaluation is used for administrative review purposes as well as assessment, and provides only a general measure of the

course effectiveness and the instructor’s teaching effectiveness without providing details on the individual course components.

In order to evaluate the perceived effectiveness of the BIM laboratory exercises, students were asked to complete an online survey on Blackboard® independently of the University’s online course evaluation. The supplemental evaluation was used to ask the students questions regarding the topics listed below:

- Usefulness and appropriateness of using BIM in a MEP course (Table 2).
- Student proficiency with BIM software and effectiveness of laboratory problems (Table 3).
- Laboratory problems organization and difficulty (Table 4).
- And, appropriateness of the building models used in the exercises (Table 5).

A total of 30 questions were asked, twenty-nine covering the topics above in a multiple selection scale format, and an additional question to provide written feedback on the laboratory exercises. Approximately 35 students were enrolled in the course, and the survey response rate was close to 50%.

Based on the feedback received, the majority of students feel that it is a good idea to have BIM as part of the course, and that the problems were conducive to learning. However, the model and laboratory handouts and problems could be improved, especially on the electrical systems part of the course. Also, the students strongly feel that a previous BIM course is essential prior to taking the MEP course.

Table 2 Students Responses Regarding BIM Use in an MEP Course.

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Do you think using Building Information Modeling, as part of the MEP System Course is a good idea?	27%	47%	20%	0%	7%
Does laboratory exercises, BIM or otherwise, should be part of the MEP course?	27%	60%	0%	13%	0%
Should an introductory BIM course be a requirement for the current MEP Course?	67%	27%	7%	0%	0%
How relevant were the BIM exercises to the CM profession?	13%	73%	13%	0%	0%
Does understanding BIM as it applies to MEP systems might help in your future CM career?	27%	73%	0%	0%	0%

Table 3 a) Student Perceived BIM Proficiency and b) Effectiveness of the Labs.

Question	Advanced	Average	Basic	Beginner	Clueless
At the beginning of the class, how would rate your knowledge and proficiency of BIM software?	0%	7%	7%	47%	40%
After completing the MEP class, how would rate your knowledge and proficiency of BIM software?	7%	40%	20%	27%	7%

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Did you learn something useful from the BIM exercises?	7%	93%	0%	0%	0%
Using BIM in the laboratory, does it help understand MEP systems better?	13%	47%	27%	13%	0%
Using BIM in laboratory exercises, does it help understand how MEP systems are layout/routed?	20%	67%	13%	0%	0%
Using BIM in the laboratory exercises, does it help understand what components and pieces are needed?	13%	73%	13%	0%	0%
Using BIM helps understand electrical system better?	7%	40%	53%	0%	0%
Using BIM helps understand plumbing and fire suppression systems better?	7%	73%	20%	0%	0%
Using BIM helps understand HVAC systems better?	20%	60%	20%	0%	0%

Table 4 Student Responses Regarding a) Laboratory Format and b) Difficulty.

Question	A Lot More Needed	More Needed	Just Right	Little Too Much	Way Too Much
How do you feel about the number of BIM exercises done over the semester?	0%	20%	67%	13%	0%
Is one week to complete each exercise enough time?	0%	27%	67%	7%	0%

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Ignoring the software learning curve, the tasks that you were asked to complete during the BIM exercises were difficult?	7%	27%	53%	13%	0%
In regards to the BIM software used in the labs, is the software user friendly?	7%	40%	0%	40%	13%
Using REVIT is a distraction from understanding MEP systems?	0%	33%	13%	27%	27%
Does the content of the BIM exercises complement the lecture materials?	20%	40%	27%	13%	0%
Do the instructions provided in the lab handouts were easy to follow?	0%	53%	7%	33%	7%
Does the instructions provided in the labs were sufficient to complete the exercises?	7%	53%	27%	7%	7%

Table 5 Students Responses Regarding Appropriateness of Building Models Used

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Do you think the building model used (West St. Video Building) was a good choice?	27%	47%	27%	0%	0%
Was the other building model used (Kamp for Kids Basement) a good choice for electrical exercise?	13%	40%	47%	0%	0%
Should the same building be used for every exercise?	47%	27%	13%	13%	0%
Do you think that adding more detail to the building models, such as furniture, finishes, doors and windows is relevant while working with MEP systems in BIM?	0%	20%	27%	47%	7%
When working with a particular MEP system, should the model not have any other MEP systems on it?	7%	13%	40%	20%	20%
When working with a particular MEP system, should the model already have all the other MEP systems on it?	7%	13%	33%	40%	7%
If the same building model is used for all the exercises, should the MEP systems be added sequentially throughout all the exercises?	47%	53%	0%	0%	0%

5.2 Advantages

One advantage of using BIM during the MEP course is the understanding and visualization of the system layout over two dimensional plans and drawings. The students are able to visualize layout issues not evident without prior experience, or good intuition, from a collection of plans and riser diagrams, including changes in elevation, overlaps, and special location of components in relation to other building components such as doors, windows, ceiling, etc. Also, subsystems can be easily classified and identified, and the relative scale of the components is clear from the BIM model.

5.3 Challenges

One of the main problems encountered using the BIM software package was the learning curve associated with the software, which was accentuated by the fact that most of the students enrolled had no previous exposure to the software. Another caveat of the software relates to the working files size and the computer laboratory storage policies, which requires the use of external portable drives in order to allow students to work on the same project on different computers at various times during the semester, when the software is not installed on their personal laptops. Also, the instructor needs to plan accordingly to introduce the software package itself to the students, especially if it is the first time students are exposed to it.

Also, from the modeling perspective, Revit® requires extensive workspace setup, such as library loadings, systems definitions, and routing preferences to name a few, which requires a considerable amount of time and effort, as well as MEP systems knowledge, before the software can be used effectively. Also, the requirement of another software package (Navisworks®), in order to run clash detection of systems in a building, requires additional class time, and possible resources, to take full advantage of the promises of BIM.

6. CONCLUSIONS AND FUTURE WORK

Starting with the 2014-2015 academic year, the curriculum of the CSM program at UTSA encompasses BIM as part of the degree requirements. As part of this new requirement, the MEP Systems course was modified during the Fall 2014 to incorporate BIM as part of the laboratory exercises.

The laboratory exercises developed during the Fall 2014 semester are the first step in the ongoing process of incorporating BIM into the MEP course offered in the Construction Science Department at UTSA. During this first stage, only the basic 3D MEP systems modeling capabilities of Revit® were explored. The BIM exercises were designed as step-by-step instruction that guided the students through the process of adding MEP systems into an existing architectural model, as a way to recreate an existing 2D plan set.

The advanced capabilities and features of the BIM software package, such as automatic quantity take off, or schedule generations, to name a few, were not explored. Furthermore, clash detection of MEP systems and structural systems, which is one of the most important benefits, and drivers, for the use of BIM during design and construction of buildings, was not covered. These omissions would be the next logical additions to the laboratory exercises.

Finally, the order on which the MEP systems are covered in the course needs to be modified to reflect the prevalent (historically) coordination of MEP systems, and to facilitate the modeling of these systems in BIM: HVAC, followed by plumbing and fire suppression, and ending with power and lighting systems.

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USING REAL LIFE EXAMPLES OF BUILDING CONSTRUCTION FOR STUDENT PROJECTS TO IMPROVE THEIR UNDERSTANDING AND CONCEPT OF BIM IMPLEMENTATION

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ABSTRACT

Building Information Modeling (BIM) is an emerging trend in construction industry and a desired skill for construction management students as they prepare for their professional careers. Recent surveys showed that university level BIM education of architecture, engineering, and construction programs in the United States has increased dramatically in the past several years. Structuring a course that would properly address the industry's demand and required skill is a considerable challenge. This paper presents the introduction of the coordination process of a real life building construction project for the BIM course in a construction management program. The course is structured as a lecture-lab combination where the fundamental concepts and implementation issues are discussed in the lecture portion. In the lab sessions, the students are asked to complete individual projects and present them in different formats. The purpose of this paper is to provide a sample term project for delivering BIM content to students by engaging the involvement from industry practitioners and utilizing real life experience. In addition to the term project demonstration, other important aspects that should be addressed in the BIM implementation process for construction management will also be discussed. Especially items that receive limited attention at the current BIM courses and construction curriculums according to industry practitioner's feedback. For example, collaboration issues amongst AEC, influence of different project delivery methods on BIM implementation, knowledge of BIM standards, contracts, agreements, and challenges surrounding them, relationship between BIM and new emerging technologies, and challenges with the generation gap while implementing BIM.

Keywords: BIM Education, Industry Involvement, Term Project Example

1. INTRODUCTION

As Building Information Modeling (BIM) becomes a standard practice in the Architecture-Engineering-Construction-Operation (AECO) industry, many universities and colleges offering construction related programs integrated BIM components into their programs (Sacks and Pikas, 2013). Johnson (2009) reasoned that BIM is likely the most recent trend to be addressed by construction education programs and one of the most challenging one at the same time. In addition, the relationship of BIM and the project delivery method, Integrated Project Delivery (IPD), were discussed for a more efficient collaboration with BIM (Becerik-Gerber and Kent 2010). Wright explored the integration of best practice of BIM and

Integrated Project Delivery (IPD) into the current undergraduate construction program. (Wright 2012) Recent research indicated that BIM adoption is increasing in both academia and the AEC industry (Joannides et al. 2012, McGraw-Hill Construction, 2013). Based on the survey distributed to members of Associate School of Construction, as of 2008, less than 1% of the construction programs had a stand-alone BIM course while 9% incorporated BIM as part of the existing courses (Sabongi, 2009). By 2013, 54 % of the programs had dedicated and fully developed BIM classes included in their curriculum while 52 % claimed BIM content was embedded in conventional courses. The same study also recommended that an enhanced and more proactive partnership can be the solution to advancing BIM education and BIM acquisition in the AEC industry (Wu and Issa, 2013). As the demand for graduate construction students with BIM skills is increasing, it is important for the current construction program to provide an effective course that can help students achieve the corresponding knowledge and skills. However, there are many BIM platforms and business processes that can be used in the construction industry. It is almost impossible for the instructor to cover all different platforms and business processes in one course. In addition, it is ineffective to teach all of the possible knowledge, concepts and skills in one course as technology changes every day. As a result, the most effective way to teach the students is by educating them about current/typical challenges on construction projects, problems that can be solved and being solved by experts using BIM, and the industry need for utilizing BIM technology for effective design, preconstruction and construction management. In order to achieve this goal, partnership is built between the Construction Program at University of Texas at San Antonio and the BIM experts from local construction companies. Front-line practices were introduced to the students as guest speakers. In addition, the students' term project is evaluated by both the instructor and the industry practitioners. Real-time feedbacks were given to the students during presentation. The purpose of this paper is to provide a sample term project assignment that reflect the support from industry practitioner in delivering the BIM content to students and helping them analyze different career opportunities by exposing them to various industry experiences.

2. CLASS COMPONENTS AND COURSE STRUCTURE

The “BIM for Construction Management” course was offered as three-credit hour elective course. A survey was conducted at the beginning of the class to evaluate the students education level and background. The results showed that the class was mainly composed of senior and junior construction majors who has already completed basic construction courses such as plan reading, estimating, scheduling, and project management. Since it was the only BIM course in the curriculum at the time, the course was designed to cover a wide variety of BIM topics such as clash detection, constructability, design, visualization, model based quantity take-off (QTO) and estimating, and 4D scheduling.

The course assessment consisted of one midterm exam (10% of the grade), one final exam (10% of the grade), homework projects (30% of the grade), quizzes (10% of the grade), and two term projects (40% of the grade). Since all the lectures and lab sessions were conducted in the computer lab, students had access to computers loaded with BIM software throughout the semester. Exams and quizzes were conducted online through Blackboard Learn 9.1 in multiple choice and open ended question formats. The homework and project assignments carried a larger weight of the final grade due to the requirement of hands-on learning and excelling in the use of various BIM and other software packages. The software utilized for this coursework is Autodesk Revit 2014 and Autodesk Navisworks Manage 2014. Other complimentary software packages such as MS Excel, MS Project, and Primavera P6 were also utilized by students without any specific instructions.

Each course session started with a lecture and followed by the lab exercises. The lecture portion was utilized to teach introductory BIM concepts, BIM Execution Plans, implementation processes, case studies, and demonstration of specific steps to use the software. The lab portion provided students with hands-on skills. In the lab sessions, the first half of the semester was focused on Autodesk Revit 2014, a design modeling platform famous in A/E community for creating design models. The purpose was to provide basic modeling skills, teach database structures, and explain the process of coordination among different trades for a typical

construction project. A term project was assigned after all the Revit tutorials were finished in the class. The second half of the semester was focused on the trade coordination utilizing Autodesk Navisworks Manage 2014, a model aggregation platform well-known in the industry for BIM coordination and collaboration. The purpose was to allow students to run clash detection, conduct 4D scheduling, and color code models of different trades . For more information about term project 1, please refer to Liu (2014).

2.1 Term Project Example

The students were given two term projects during the span of one semester. One project was based on the design software Autodesk Revit, and the other project was based on the construction coordination/collaboration software Autodesk Navisworks Manage. In this paper, we are addressing the construction coordination/collaboration term project that simulate the MEP overhead coordination process between contractors and subcontractors. A well-known local general contractor respected for their BIM expertise and leadership provided all the uncoordinated shop models and fabrication models from their trade partners, and the design models from their design team. The project is located at UTSA campus so the students had a chance to visit the site and had a better understanding of the real project and the model. The project information is shown in Table 1.

Table 1. Project Information

Project Owner	University of Texas-San Antonio
Project Name	North Paseo Building 1
Project Value	\$36,000,000
Delivery Method	Construction Manager a Risk
Challenges	<ul style="list-style-type: none"> • Complex mechanical piping and equipment • Complex technology and data systems • Concrete structure and tight ceiling spaces • Owners wanted As-built BIM Model
# of People involved in coordination	19
Coordination Time	8 months
Coordination Cost of work for GC	\$40,000 (Total BIM COW: \$83,587)
Results	<ol style="list-style-type: none"> 1. On time, on budget delivery 2. Smooth MEP Installation. Happy Subcontractors-Teamwork! 3. Transparency in project for Owners

The term project assignment was described as follows.

Developer ABC has recently had a development plan for a new office building. As a project manager in a Design-Build company, you have received 3D BIM drawings for its architecture, structure and MEP disciplines. You are required to build the project animation, 4D schedule for your BIM model and do coordination between your structure and MEP disciplines by performing clash detection. Download Architecture.nwc, Structural.nwc, Plumbing.nwc, Mechanical.nwc, Fire Protection.nwc, Hydronic Piping.nwc, Lighting.nwc files from blackboard, and use these sets of models for this project.

Required Elements:

- a. **Clash Detection:** Run clash detection for your structure and MEP disciplines, cloud your clashes, write comments identifying problem with possible solution, and save them as view-points. Make folders in the “Save Viewpoints” window and name your folders according to the disciplines (for example “Structural vs Plumbing”). Make at least four folders for four different clash detections. In each folder, save at least 15 clashes with markups. (25 points)

- b. *4D Schedule*: Create an abridged construction schedule consisting of at least 50 line items. You can choose to build the schedule within Naviswork Timeliner or create the schedule in MS project or MS excel (csv file) and import to Timeliner. For each task, you have at least the planned start and planned end date. Choose ‘Construct’ for your task type and make sure you have the right simulation period in your ‘Simulate’ tab. After you simulate the construction schedule successfully in Timeliner, export this 4D schedule to an .avi file with name “lastname4Dschedule.avi” (15 points)
- c. *A 3D Walkthrough Animation*: Create a walkthrough animation using your model in Navisworks highlighting some exterior and interior features. Then export this animation as “lastnameWalkthrough.avi” (10 points)

Project Deliverables

- Save your finished Naviswork file as “LastnameTermProject2.nwd”
- lastname4Dschedule.avi
- lastnameWalkthrough.avi
- Submit the above three files to Blackboard. If your file is too big for uploading to blackboard, you can choose to submit a CD/DVD containing all your files
- lastnamePresentation.ppt

The requirements that were created allowed the students to choose their own trades for preparing their clash detection reports. For example, if they are specifically interested in mechanical discipline and would like to work for a mechanical subcontractor in future, they can use the mechanical shop models to run clash detection with structure, plumbing or any others discipline models. They would understand the relationship and common conflicts between mechanical disciplines with other trades. Even if the course allowed them to choose their trades based on their own interest and experience, the skills they learned from this exercise can be implemented to any other trades too.

Due to the size, footprint and height of the building, the coordination process is sensibly cut into packages as per floor or zones. Seldom we see the MEP coordination for the entire building being done altogether unless the size of the building allows construction teams to do so. Keeping that thought in mind, the students were provided with only the second floor models for their assignments to mimic the real coordination scenario. The models used for the term project are shown as in Figure 1.

2.2 Student Deliverables Examples

The students were given three weeks to finish the above project. In addition to the submission of their deliverables, they were asked to give a 15 minutes presentation to the class. Other faculties from the Department of Construction Science, BIM practitioners from the general contractor company who sponsored the project and the instructor were served as judges for their project qualities. Some of the students work were shown in Figure 2 and Figure 3.

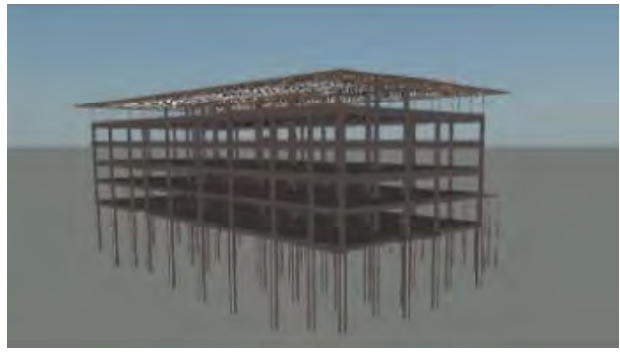
2.3 Student Feedback

At the end of the semester, student evaluation was conducted to measure the content and delivery of the course. The evaluation was a standard online student evaluation performed for every course offering at the university. A response rate of 88.24% (15 out of 17) was recorded for the online evaluation. The evaluation questions and the combined results are presented in Table 2 below. Based on the results of the students’ evaluation, it can be concluded that students gave many positive feedback to this class.

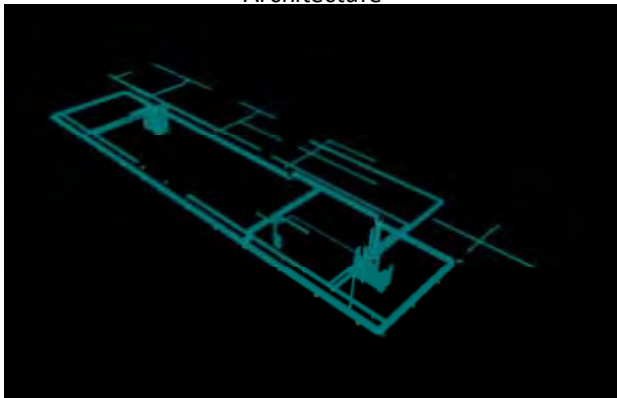
As presented in Table 2, the course received an overall rating of 4.53/5.00. Most students gave very positive feedback to this class. Although some students complained about the fast teaching style, most students expressed their appreciation for the term project, the lab practice, and the industry practitioners’ involvements.



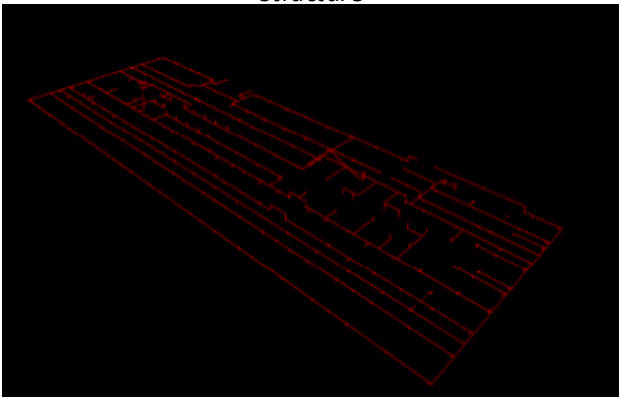
Architecture



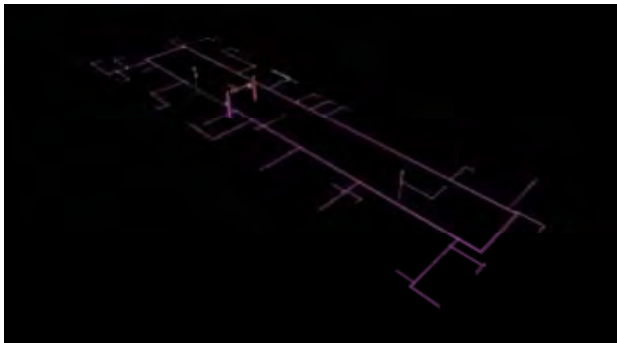
Structure



Electrical and Communication



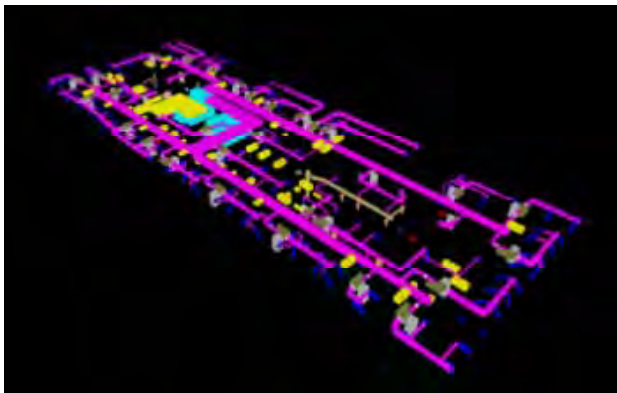
Fire Protection



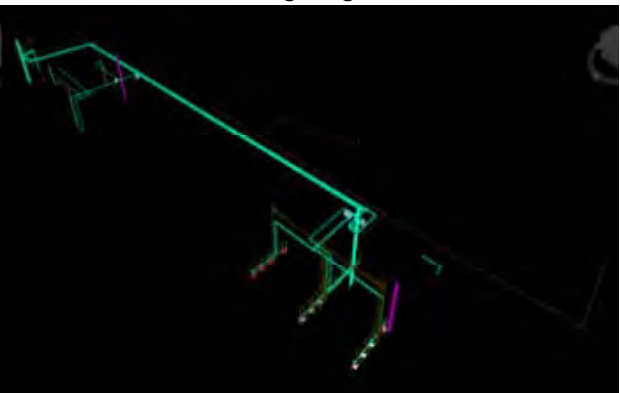
Hydronic Piping



Lighting



Mechanical



Plumbing

Figure 1. BIM models from Different Disciplines

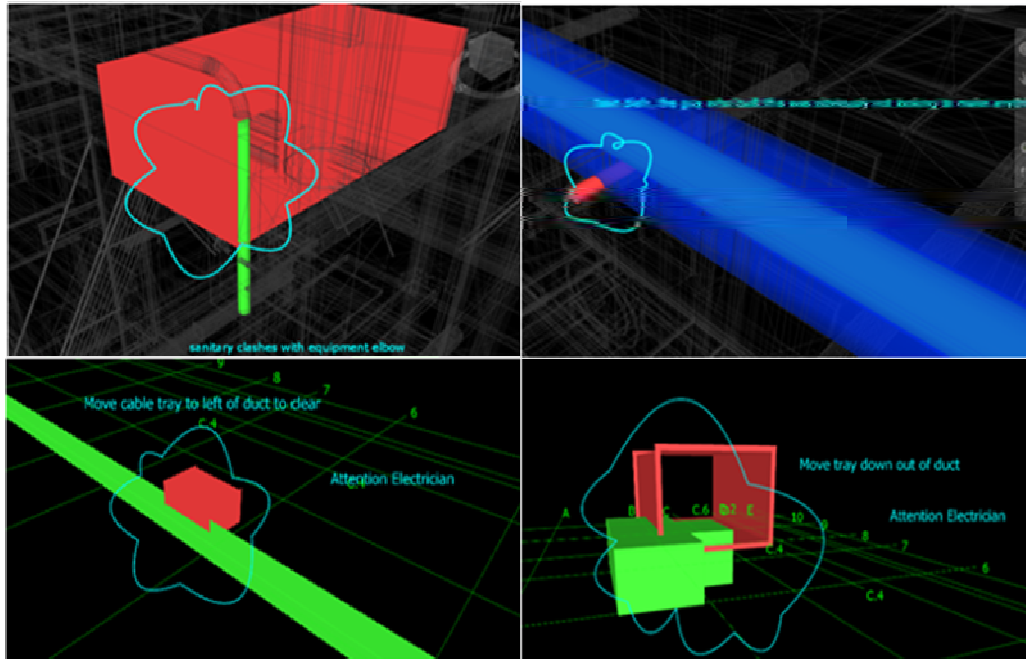


Figure 2. Clash Detection Examples

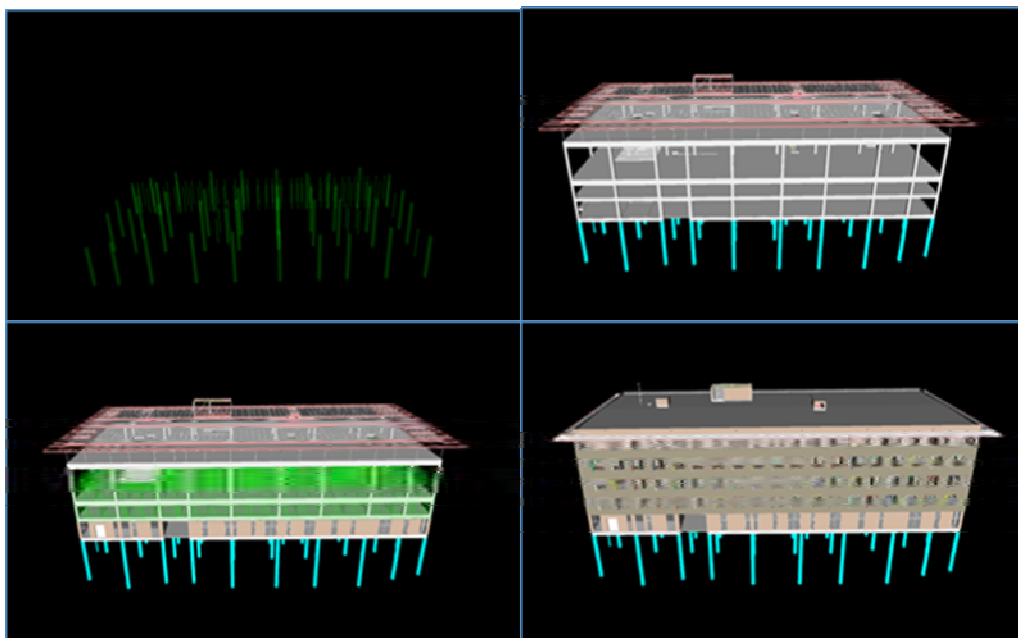


Figure 3. 4D Schedule Example

1. DISCUSSION

The BIM coursework is a great platform for the construction science students to learn about the BIM software and its usage in performing tasks such as clash detection, 4D modeling, running quantities and creating walk-throughs. However, in construction management industry, the goal of using BIM (at the minimum) is to coordinate work of multiple disciplines (architecture, structure, systems), use models for budgeting through-out preconstruction, optimize and communicate schedules by performing construction simulation, use model for constructability and value engineering, and use it at the field for quality control.

Table 2. Combined Student Evaluation Results

	Student Evaluation	
	Scale	Combined Score
The instructor clearly defined and explained the course objectives and expectations.	Strongly Agree=5.00 Strongly Disagree = 0.00	4.53
The instructor communicated information effectively.	Strongly Agree=5.00 Strongly Disagree = 0.00	4.47
The instructor was prepared to teach for each instructional period.	Strongly Agree=5.00 Strongly Disagree = 0.00	4.73
The instructor encouraged me to take an active role in my own learning.	Strongly Agree=5.00 Strongly Disagree = 0.00	4.53
The instructor was available outside of class either electronically or in person.	Strongly Agree=5.00 Strongly Disagree = 0.00	4.73
My overall rating of the course is:	Excellent =5.00 Poor = 0.00	4.53
My overall rating of the teaching of this course is:	Excellent =5.00 Poor = 0.00	4.53

In order to accomplish these goals, there are many aspects of BIM implementation and current industry challenges that students must provide opportunity to learn. However, due to limited time allowed in the classroom environment, it is not possible to cover all of it. Below are the recommendations on the some key topics that are important for BIM implementation and needs to be covered in the classroom setting:

1. Collaboration vs. Project Delivery Methods: BIM is a team sport. In order to successfully implement BIM processes and accomplish the goals, each team members (A, E, and C) needs to collaborate with each other. However, the level of collaboration is usually dictated by the Owners and project delivery method utilized. Design-Build and IPD provides the optimum platform for collaboration amongst AEC and allows them to utilize BIM to its full potential. CM@R project delivery methods rely on either strong direction from Owners to use BIM or qualified AEC team members with desire to collaborate and utilize BIM for successful execution of the project. Traditional CSP delivery method does not allow any room to collaborate, and if BIM is utilized, it's in very silo approach which can lead to much repetition of work
2. BIM Contracts: In an owner driven BIM project, all the AEC project stakeholders are usually tied with some form of formal agreement regarding BIM that reciprocate to Owner's BIM Execution plan/guide. Some example of these plan/contracts are AGC Consensus docs, AIA BIM addenda, etc. Students should be provided with a fair knowledge of these contracts, agreements and BIM execution plans/guides.
3. Generation gap: Construction industry has traditionally been rigid, conservative, and risk averse which has been primarily focusing on slimming operational costs and raising profit margins. If left handful of companies, majority of US construction firms will reflect those traits. That philosophy and formula bleeds into how project managers, subcontractors, field superintendents, architects and engineers are being seasoned. Students of this new technology generation needs to provide opportunity to learn about challenges the generation gap has to offer and learn how to face it when implementing BIM . Case studies in terms of how those challenges have been met in the past must be discussed.
4. New Emerging Technologies: New technologies are being introduced in the society on a daily basis. We have been putting more focus on innovation and continuous improvement. This holds true in construction industry as well. BIM is becoming a norm on how A/E provides design services and contractors provide preconstruction and construction services. New emerging technologies such as laser scanning, drones, use of I-pads at field, barcoding, 3D printing, etc. are being utilized with BIM being

backbone to support them. Students should provide opportunities to learn about these new emerging technologies and how AEC's are using it. However, most importantly, as BIM practitioners, students need to learn to keep their mind open towards new technology and anticipate change in current processes/software/technology they learn in class. As technology is evolving every day, student should be taught to keep an open mind to accept change with an eagerness to learn. The BIM class is only a starting point of their journey.

2. CONCLUSION

As Building Information Modeling (BIM) become more and more popular in the construction industry, it is important to train the construction management students with these knowledge and skills to better prepare them for their professional careers. This paper presents the introduction of a real life coordination project to the BIM course of a construction management program. The project is on the university campus, the general contractor's BIM experts were invited to support the students learning process. From the students' evaluation, this course was highly evaluated by the students for the instructor and the external experts' effort. This term project can be a sample project to other construction program for BIM coordination and 4D scheduling purpose.

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BUILDING A BIM-BASED PLATFORM TO SUPPORT DELIVERY OF CONSTRUCTION METHODS AND VIRTUAL CONSTRUCTION COURSES AT DIFFERENT UNIVERSITIES

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ABSTRACT

BIM Software tools that support the development of Virtual Construction using 4D and 5D models continue to improve in functionality and operability making it possible to produce more informative simulations linking the visual progression of construction with time and cost impacts. Their use in educational settings has contributed to accelerate the students' understanding about construction planning and scheduling because it provides a three-dimensional representation of the geometry and of the assembly sequence of the elements to be constructed over time as well as information about the type and use of the required resources. Colleges and universities have been gradually incorporating the use of BIM software and concepts into course components or into their curricula at large and have developed specific courses on the subject.

With the continuous advancement of technology a constant challenge for course instructors of construction planning and scheduling related courses is to design course content in such a way that the essential technical and managerial aspects from the construction point of view maintain a proper balance with the rapid and continuous change of the BIM-based tools as well as with their nature.

In order to meet these challenges on a continuous basis and with minimum efforts the authors have joined their efforts to create a BIM-based platform based on the development of a term project and virtual prototypes that supports the delivery construction planning and scheduling courses through the use of Virtual Construction techniques at the two universities in which they teach. This paper describes the approach taken by the authors in developing virtual prototypes to efficiently incorporate the use of Virtual Construction in their courses. It also describes the results obtained so far and outlines the immediate next steps. The virtual prototypes contain elements with Level of Development (LOD) of 300 and 350 for composite walls, roofs, slabs and foundation, including detail modeling of formwork and rebar. Students are able to split these elements according to their own construction strategy, as opposed to the imposed software constrains for object manipulation, and match them with elements of their own schedule Work Breakdown Structure (WBS) and local professional practices.

Keywords: BIM, Construction Methods, Virtual Construction

1. INTRODUCTION

The planning of a construction project is a key element for the successful delivery of a facility. Planning mainly relies in defining a construction strategy, which consists in selecting the adequate construction methods according to the context of the project. In order to make a cost-effective selection of the construction method, it is necessary to fully understand the complexity, risks, cost and other implications that each available construction method has to offer to the project. Such awareness is acquired through years of experience, which is not possible to replicate in a classroom.

Traditional courses in construction planning and scheduling expose the student to the theory and practice of the different construction methods relying on lectures, reading materials, pictures and videos, book illustrations, and occasional visits to a construction site for observation. Given the dynamic nature of a construction method and the very limited (if any) previous exposure of the student to construction site experiences the use of graphic material enhances dramatically the potential for improving the students' understanding of the subject. In addition, computer simulation software such as CYCLONE (Halpin 1992), SIMSUPER5 (Salazar & Einstein, 1986), STROBOSCOPE (Martinez, 1996) have been used in the past to support the delivery of these courses providing a dynamic and quantitative tool to assist students in the analysis of different configurations and assessment of the benefits derived from the selection of a given construction method and associated resources. As Information Technology has continued to evolve over time multimedia elements such as time-lapse photography captured through webcams in construction sites have been gradually incorporated in support of construction planning and scheduling courses.

The advent of Building Information Modeling software tools has dramatically enhanced the ability to communicate the interaction between the site and the building identifying temporary and permanent resources layouts through powerful 3D visualization at the different stages of the construction process thus allowing for the creation of 4D (3D + time) models. In addition, it is possible to quantify the cumulated and partial cost impacts over time to generate 5D models. Virtual Construction (VC) consists in creating a performance digital model of a facility; it relies strongly on Building Information Modeling (BIM) tools. VC is an extensive concept, which includes the design, construction, and operation stages of the life cycle of a facility. VC is about virtual prototyping

Virtual prototyping does not replace the years of construction experience, but it can provide a deeper understanding of the construction method, The use of VC with 4D and 5D models in educational settings has contributed to accelerate the students' understanding about construction method selection (Huang et al 2006), (Li et al, 2008), (Salazar/Alvarez/Gomez, 2011), (Kunz & Fisher, 2012), (Salazar /Alvarez/ Gomez, 2013), (Clevenger et al, 2014), (Maghiar, 2014), because it represents the geometry of the elements to be constructed, as well as their assembly sequence along the timeline allowing identification of the different steps involved in the selected construction technique as well as its corresponding date of execution and cumulated cost. Over the last few years the authors have been experimenting with these capabilities and through the use of student projects have developed 4D virtual construction models capable of simulating the gradual construction process of buildings. Some of these 4D models include the Recreation and Sports Center and the [Parking Garage with Rooftop Athletic fields](#) recently constructed at the WPI campus. (Salazar/Alvarez/Gomez, 2014)

BIM Software tools that support the development of 4D and 5D models continue to improve in functionality and operability making it possible to produce more informative simulations linking the visual progression of construction with time and cost impacts. With the continuous advancement of technology a constant challenge for construction methods instructors is to design course content in such a way that essential technical and managerial aspects from the construction point of view maintain a proper balance with the rapid and continuous change of the BIM-based tools. One must also recognize the essential differences that exist between modeling construction through BIM software tools and the actual construction that takes place in the field. Therefore, course instructors must design course content and delivery formats that can be executed within the stringent time constraints imposed upon faculty and academic programs without losing perspective of the original course intent. Even with the availability of

helpful educational and training resources provided by software vendors the course instructor is still responsible, and will and continue to be responsible, for the academic value of the content of the course.

2. THE BIM-BASED PLATFORM

In order to meet these challenges on a continuous basis and with minimum efforts the authors have joined their efforts to create a BIM-based platform that supports the delivery construction planning and scheduling courses through the use of Virtual Construction techniques at the two universities in which they teach. At the core of these courses it is the design, selection and evaluation of construction methods. This platform relies on the implementation of a term project that uses a 3D digital model of a hypothetical but realistic construction project that defines the context of a typical scenario where a contractor is preparing the response to a request for proposal. Using Virtual Construction tools, students simulate the project execution and assess the impact on time and cost for the project. Figure 1 below illustrates this concept.



Figure 1 Course – BIM Platform Conceptual Interaction

To be as efficient as possible, the BIM-based platform should serve the needs of courses in the settings of both institutions at the undergraduate and graduate levels can. At WPI, undergraduate courses run on an 7-week term basis whereas at the graduate level the courses are imparted on a 14-week semester basis. Therefore the common length of execution of a term project for both types of academic programs and institutions was set to 6 weeks.

The BIM-based platform is comprised essentially by an object-oriented digital model that is manipulated through parametric rules and supports the execution of the term project. Most commercial BIM software tools usually provide the user with standard libraries of basic elements to represent a finished building. However, these libraries typically do not provide elements which are only temporary during construction but are necessary to build the facility such as formwork, staging, cranes, etc. In many instances, the building objects as directly provided by the software can be manipulated directly by the student. However, this is not always the case and a set of virtual prototypes than can be manipulated in the context of a construction project decision-making were specially created by the authors. A key role for the success of virtual prototyping is to have the proper construction components involved in the selected construction method.

3. TERM PROJECT

An important determination in selecting the appropriate size and complexity of the term project is crucial for allowing the students to finish the model within the time restriction of a six-week duration. The project has to be small but yet offer the challenge of have multiple choices for construction methods. The selection of the project should engage the student in applying the theory and fundamentals of a construction method and provide the feeling of the implication of the method in the performance of the construction process. The project allows the students to make choices of construction method and resources and to determine time and cost impacts.

The term project integrates the students' knowledge acquired through the lectures during the course. Therefore a scheduling strategy for the development of the term project should be defined along with the theoretical content of the course. Milestones along the term project are also defined to provide feedback and complete the learning process. Figure 2 below illustrates the components of the BIM-based platform that support student decision making and evaluation with regards to construction planning and scheduling.

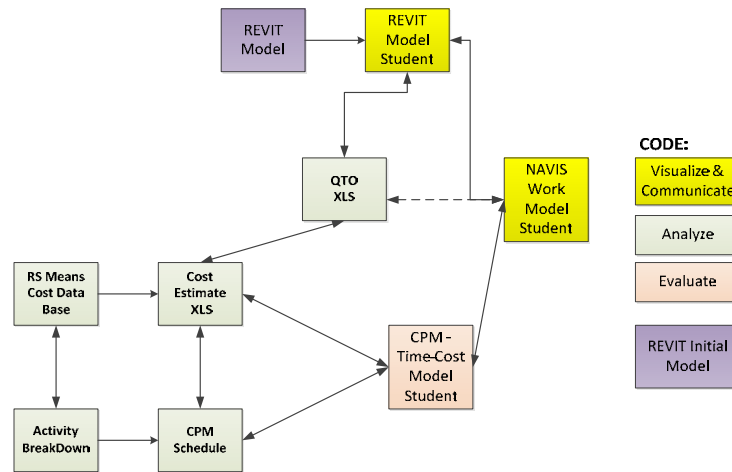


Figure 2 BIM-Based Platform Architecture

4. INITIAL MODEL & VIRTUAL PROTOTYPING

An initial REVIT model from which the students could proceed with the development of term project is provided by the course instructor. A digital model of a gymnasium was created from actual drawings of an actual facility built in Massachusetts, see Figure 3 below. The building has two stories and its footprint is 138' x 89'. The model contains architectural and structural elements with Level Of Development (LOD) 300 and 350 (BIMForum, 2013) to facilitate decision-making during the construction planning process. These include:

- Reinforced Concrete Foundation: Strip and isolated footings, foundation walls, slab on grade. Reinforcing steel and formwork elements are also included and explicitly modeled.
- Steel Frame: columns, beams, joists, cross bracing, elevated slabs on deck
- Exterior and interior walls including doors and windows.
- Roof, floors and stairs.

The model included the site topography and its corresponding elements to include modeling of the excavation and backfill for the foundation during construction planning. The model as provided to the students represents the typical model created to communicate design intent but not means and methods. In this way the student concentrates on the construction planning process as opposed to spending time in assembling the complete 3D model. It also comes with all the elements described above.

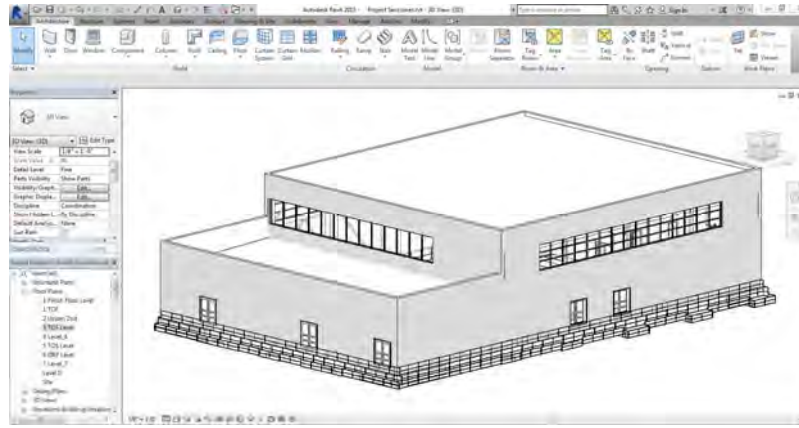


Figure 3 Initial Model given to the students

Creating these elements is not an easy task, in fact, it is an advanced skill, because it not only requires the creation of the 3D element but also understanding of the parametric and intelligent aspects of these elements to make them capable to interact with other components within the 3D model. The authors have extensive knowledge and experience in this regard through the development of their BIM models (Salazar, Alvarez & Gomez, 2011, 2013, and 2014).

A major consideration during the design of the model was given to the time the student need to dedicate to adapt an existing model to match the needs of the selected construction strategy, for example foundation walls and footings are usually modeled as large single items, however the construction strategy may consider the building of this elements in stages or sections, therefore the model elements need to be split in order to be able to simulate the construction sequence reflecting the construction strategy. The same happens with elements that are usually modeled in the BIM as a single item, such as walls, floors, slabs.

Split an element by itself is an easy task, each software has the tools to split some elements with a single mouse click, however, splitting an element of a BIM may have unwanted consequences, elements attached to the split element may not behave in the same way as before the split happened and this is particularly true with elements that hosts rebar. The rebar is positioned in the element using a border of the element as a reference, from which the location and distribution of the rebar is set. When an element containing rebar is split, the rebar will remain only in the element which contains the border referenced by the rebar the other element will not contain rebar at all. To address this issue, the elements with rebar were modeled in a small sections for each grid or level. Figure 4 shows elements for footings and slab on grade.

Depending on how the element is modeled. Such elements have the rebar defined in a way that is parametric in relation with the size of the element, that is, the element can be stretched as long as needed to match the construction stages of the element and preserve the rebar layout as was in the design intent.

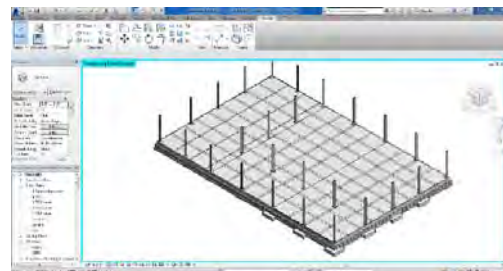
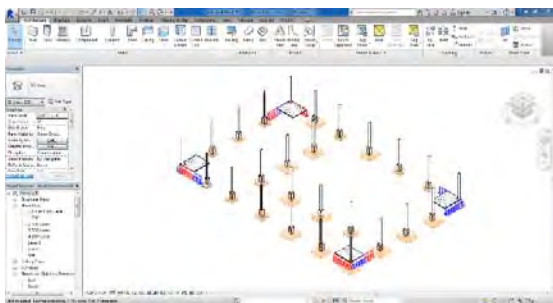


Figure 4 Modeling footing and slab on grade elements for construction purposes

Therefore the student instead of splitting the element he or she will stretch and copy the element as many times he or she needs, and always preserve the design intent of the rebar contained in the element. Formwork is another element that was carefully modeled to allow the student experiment with different approaches of construction stages for the elements using formwork. The formwork object library was created from scratch and placed in small modules no longer than 8 ft. allowing sectioning the concrete elements and analyze how the formwork can be reused. The walls, floors and roofs, were modeled using the standard object libraries of the software, however all the layers of a composite wall, floor or roof, were modeled as this will be needed to analyze the construction sequence. These elements were modeled as a hole, but the sectioning of them, using the standard tools in the BIM software, were successfully tested.

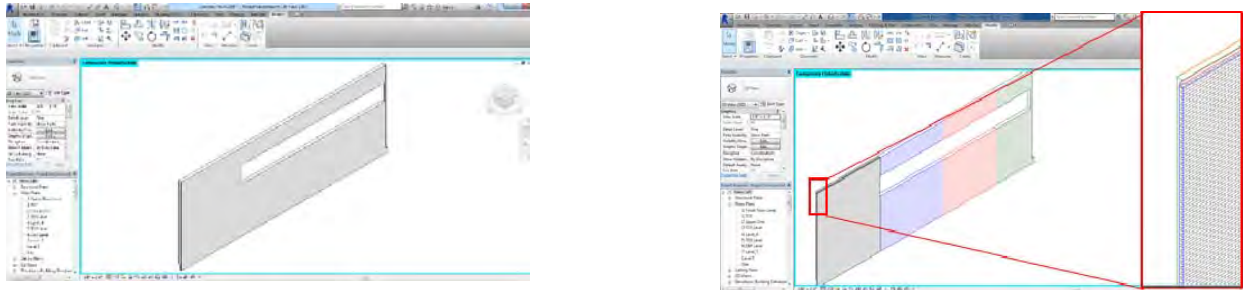


Figure 5 Wall element modeled for construction purposes

Figure 5 on the left shows a “whole” wall as given to the students in the original model; Figure 5 on the right shows the same wall sectioned by the students according to the sequence of execution and different finishes. Finally, Structural steel elements were modeled as they are usually delivered by the fabricators, that is, for example a truss is a single element, with the cords and webs contained as a group. Steel connectors were not modeled as the trade of having the a light and relatively easy to handle model against the academic value of having the connectors modeled was not justified.

5. UADY FIRST EXPERIENCE

The first offering of a course supported by the BIM-based platform was imparted in the fall 2014 to students of the graduate master program at UADY who worked in groups of three students each and developed their term project in six weeks to produce the planning of the construction including site logistics and resource utilization. The students had architectural or civil engineering background and determined the team members’ responsibilities among themselves, as well as their workflow, team dynamics and software resources. They developed a work plan which included the training sessions.. The professor played the role of a consultant with weekly meetings. The role of the consultant was to guide them in the use of BIM for their purposes according to the BIM Project Execution planning guidelines which requires to perform a self-evaluation of each team member’s knowledge and skills in the use of BIM. This evaluation helped the consultant to determine the specific type of training.

The students began the work with model by sectioning building elements and to include temporary elements to match their construction strategy. They used Autodesk Navisworks ® to create the work packages in a one to one relation between a work package and a schedule task. Some of the teams used Navisworks for determine quantities of work for each work package and used a construction cost database to determine the productivity and duration of each work package/task. All the teams used Navisworks to link the schedule and the model and to create a 4D model.

Animation was used to simulate the equipment operation such as Crane operation to determine and validate its proper size. Movement of the crane and concrete-mixer/pump trucks were also animated to determine the free space needed for their operation. Animations were also used to determine interferences in time and space between the equipment, and the construction crews, as well as between the building

construction and temporary spaces such as the site office, bathrooms, and temporary storage. They were able to detect and fix such interferences.

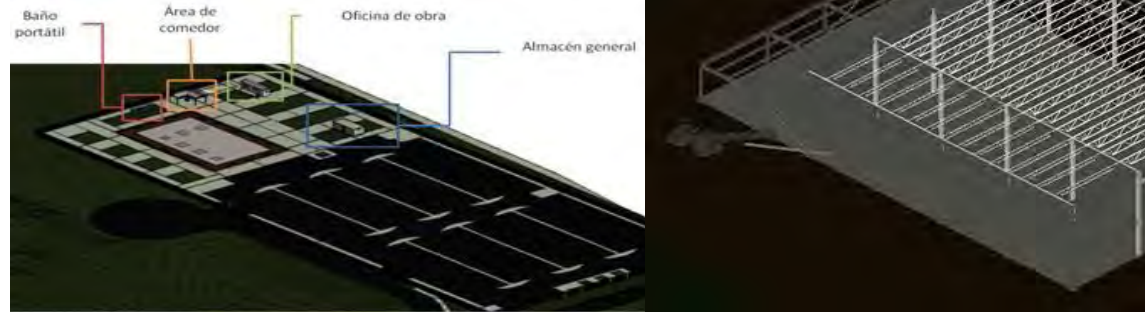


Figure 6 Screenshots of simulated parts of the construction planning

There were two deliverables in the project, the proposed plan for the construction, which included the schedule, the 4D simulation, site utilization drawings. The second deliverable was a report of the BIM implementation process including the team members' responsibilities, workflow and team dynamics.

The motivation and involvement of the students was remarkable and exceeded expectations for self-discovery with regards to software learning and understanding of the subject.

WPI Experience: At this point, an experimental course, CE302X Construction Methods and Virtual Construction, is being developed by the authors. The lessons learned from the UADY experience have been incorporated in the preparation of the first course offering at the undergraduate level at WPI. The proposed course is intended to build upon two already existing courses: CE3020 Project Management and CE3031 "BIM Software Tools and Principles. Although the WPI Academic Plan does not have strict prerequisites, students who have taken these courses will have enough proficiency in construction planning and on the use of BIM tools that will facilitate modeling of the construction process. However, for those students who have not taken CE3031 the use of the BIM-based platform should facilitate their work in the course. There is also abundant online material that students can consult to help them increase their level of proficiency required to complete assignments.

6. CONCLUSIONS AND FUTURE WORK

The original purpose of this work was to develop an approach to allow instructors in construction planning and scheduling related courses at the two universities in which they teach in order to incorporate the use of technology efficiently on a regular basis. For this reason they joined their efforts to create a BIM-based platform based on the development of a term project and virtual prototypes that supports the delivery construction planning and scheduling courses through the use of Virtual Construction techniques. The work accomplished so far indicates that the approach herein taken satisfies their educational needs within the constraints imposed by time and continuous technological change. However, the implementation of this work at WPI is still to be tested. A formal validation strategy for this work is being gradually developed to be completed in the summer of 2015 with the assistance of a professional consultant in the field as it has been stated in the terms of the grant received to initially support the development of this work. This validation addresses the objectives of this work as well as the ABET learning outcomes that the WPI accreditation program at WPI demands. During the winter of 2015, a group of four students from UADY who participated in the first offering of the course has visited WPI to further discuss the results obtained so far and to formulate modifications and adjustments for future offerings of the course at both universities. Nonetheless, the lessons learned in the development of the virtual prototypes can be extended to other type of permanent or temporary construction work in the development of future prototypes for the modeling of elements in site work, structural, mechanical and electrical type of work. In this way students able to split these elements according to their own

construction strategy, as opposed to the imposed software constrains for object manipulation, and match them with elements of their own schedule Work Breakdown Structure (WBS) and local professional practices

ACKNOWLEDGMENTS

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AN INTERDISCIPLINARY APPROACH TO INTEGRATE BIM IN THE CONSTRUCTION MANAGEMENT AND ENGINEERING CURRICULUM

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ABSTRACT

It is clear that Building Information Modeling (BIM) is the trend of the future, with increased use documented in the construction industry in the last few years. To sustain the momentum of BIM, effective workforce development that aims to balance the supply-demand equation in the labor market is essential. For many, experience with BIM begins in academia. The challenges reside in the classic gap between academic focus on disciplinary principles and the industry needs for specific application proficiency. As a result, architecture and civil engineering education needs to embrace the opportunities provided by BIM and overcome the challenges presented by BIM to remain current and relevant. Although a growing number of architecture, engineering, and construction programs have begun to offer courses that include BIM-related content, few programs have strategies in place to fully integrate BIM across the curriculum. This paper presents an interdisciplinary approach adopted by the Department of Civil, Architectural, and Environmental Engineering at Illinois Institute of Technology (IIT) to promote BIM-enabled learning. Experiences in integrating BIM into the Construction Management and Engineering Graphics programs at IIT are presented and discussed through sample courses and specific course sessions including student projects. The curriculum changes that are implemented to facilitate the learning and understanding of BIM are evaluated. The objective is to educate the engineers/architects of the future who will be actively using BIM routinely. Curriculum modifications and student reactions are continuously monitored and assessed. The results are presented in this paper. The IIT strategy relative to BIM is expected to help architecture, engineering, and construction professionals be prepared for the needs of the industry in the future.

Keywords: BIM, Curriculum Assessment, Construction Management, Engineering Graphics, Sample Courses

1. INTRODUCTION

The proposed definition of Building Information Modeling (BIM) by the US National BIM Standards Committee (NBIMS) is “The digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it and forming a reliable basis for decisions during its life cycle, from earliest conception to demolition.”

BIM is not simply a software package, but a human activity that ultimately involves broad process changes in the construction industry. Procurement of building projects has become more complex and technically demanding. We need to recognize that all sorts of people populate the territory of BIM: (1) design professionals such as architects, architectural engineers, structural, civil and MEP services engineers, specialist subcontractor designers (cladding, building envelope design, MEP building services, and environmental technologies), specialist consultants (acoustics, environmental applications) and technologists; and (2) construction professionals such as the quantity surveyor, project manager,

construction manager, planning consultant, regulation specialist and others all have to be integrated into the project delivery process.

Working with BIM increases the need for co-ordination, and management of design and construction processes and collaboration. Although a growing number of architecture, engineering, and construction programs have begun to offer courses that include BIM-related content, few programs have strategies in place to fully integrate BIM across the curriculum. This paper presents an interdisciplinary approach adopted by the Department of Civil, Architectural, and Environmental Engineering at Illinois Institute of Technology (IIT) to promote BIM-enabled learning. This paper focuses on the instructional strategies used to teach integrated processes through the activities of design and construction processes.

2. LITERATURE

The SmartMarket Report published by McGraw-Hill Construction (2012) shows a rapid increase of BIM usage in North America. The percentage of companies using BIM is 71%, increased from 49% (2009) and 17% (2007). However, the role of BIM is not fully understood neither in the construction industry nor by a large segment of educational institutions that specialize in architecture and engineering. According to the National BIM Report (2012) there is still further work to be done in regards to preparing the industry for full adoption of BIM.

Educational institutions are either already providing, or preparing to provide, BIM education at both undergraduate and graduate levels. The industry's reluctance to change, and a shortage of experienced/educated BIM practitioners/ technicians/ educators is slowing the inevitable uptake of BIM in the AEC industry (NATSPEC 2013, 2014).

The technology is advancing in a rapid fashion. We have experienced more change in the past couple of years than in the previous couple of decades. The next decade the acceleration of change will be much more. Knowledge and skills can always be acquired and learned. The real skill is to adapt the change and see possibilities in new situations by following the agenda (BIM Handbook, 2010).

According to Turk and Gerber (2011), the rapid movement from CAD to BIM by professional architects, engineers and construction managers has created several challenges and opportunities for educational programs. Most of the programs started offering BIM courses during the 2006 to 2009 timeframe. Architecture programs started offering BIM courses earlier than the engineering and construction management programs. The survey indicates that BIM is comparatively new in construction management programs. The majority of the programs (67%) are expecting to have at least one course on BIM, 29% of them 2-4 courses and 4% 4-6 courses in their curricula in the future.

Professional bodies, industry and academia are the key stakeholders of BIM education. It is the role of the professional bodies to represent the BIM professionals and create attractive job positions in the construction industry for those who are skilled and talented. They need to ensure that BIM is a career choice. The professional bodies accredit degree courses provided by universities, and then inspect them to ensure that they come up to their required published standards. There should be a dynamic interaction between the professional bodies and academia, which should be informed by the requirements of industry as the end user (Demirdoven and Arditi, 2014).

To equip current and future industry professionals with the necessary knowledge and skills to engage in collaborative BIM workflows and integrated project delivery, it is first important to identify the competencies that need to be taught at educational institutions or trained on the job. Succar et al. (2013) describe the individual BIM competencies as the personal traits, professional knowledge and technical abilities required by an individual to perform a BIM activity or deliver a BIM-related outcome.

The value that degree education adds to the professional and to the industry needs to be determined. Industry always wants to employ individuals with experience; as a result, it is rare for companies to offer placement to students with no experience who want to work on site. For professionals, it is important to acquire managerial skills and to understand the process. Soft skills and team-working skills are needed. Graduates can leave university with a broad picture of the industry if they are exposed to a realistic simulation of construction projects in their studies.

3. BIM IN THE CURRICULUM AT IIT

The increased use of BIM has brought about new roles such as the BIM manager, coordinator, leader, champion, consultant, expert, technologist, etc. The BIM professional's competency could cover technology, process, commercial, and personal skills. Those skills define the professional's role depending on the entry conditions into the construction industry and the qualifications and background of the professional. It is realistic to recognize different BIM professional roles in various stages: (1) project initiation (defining the scope/customer needs), (2) preconstruction (design information for project procurement), (3) construction (construction and installation information for project delivery), and (4) facilities management (in-use building information for project operation).

Project initiation and preconstruction roles cover the design process which is essentially iterative and creative. In contrast, construction management roles cover the construction process, which are essentially orderly and linear. According to Demirdoven and Arditi (2014) the role of the BIM profession is to form an interface between the design and construction processes by minimizing information overload and producing only what is needed. The BIM curriculum at IIT targets improving BIM software skills (ability to create, understand and interpret building information models), covering design and construction processes in an integrated environment, and stimulating BIM professionals' collaboration with other construction professionals. This curriculum helps students to understand the plurality in the construction professions.

A study conducted by Yalcinkaya and Arditi (2010) investigated the extent to which BIM was being taught in civil engineering programs in the US and came to the conclusion that a set of courses need to be offered that cover not only the basic aspects of BIM but also the management of a project designed using BIM. The potential for a joint undertaking was then explored between the Engineering Graphics Program and the Construction Engineering and Management Program at IIT. Finally, the Department of Civil, Architectural and Environmental Engineering incorporated BIM into its curriculum in 2011 through the introduction of two course offerings: (1) EG 430 -Introduction to BIM, the senior level elective in the Engineering Graphics Program; and (2) CAE 573 - Construction Management with BIM, a graduate level elective in the Construction Engineering and Management Program.

3.1 BIM Education for Engineering Design

Undergraduate BIM education in the Engineering Graphics Program covers the integrated design process by focusing on the BIM terminology and workflow. The undergraduate curriculum provides students with the cognitive tools they will need to work with BIM. Students are presented with complex, novel and authentic tasks. Instruction occurs in technology specific issues as well as in the more discipline specific technical issues. The software platform provides support for interoperability, integration, and information exchange. In addition to instruction about the desktop solutions, instruction is also focused on a web-based solution.

EG 430 - Introduction to BIM is an ongoing experimentation with mostly undergraduate and some graduate students from different majors including civil/structural engineering, MEP engineering, architectural engineering, architecture, and construction management. This course aims to demonstrate how architectural and engineering design functions are impacted by Building Information Modeling (BIM). It helps students to understand the fundamentals and practical uses of information technologies in design and construction. The course objectives are (1) to understand the concepts of Building Information Modeling (BIM), (2) to review software and technology available for BIM, (3) to learn how to use a model created by a BIM software, (4) to use Revit as a design software to create and present a 3D design project.

3.1.1 Course Content: 3D Modeling for Integrated Design Purposes

The course content covers all design aspects and tools of BIM. In addition, the BIM workflow, parametric modeling, interoperability, sustainability, and collaboration issues are discussed using hands-on software training. The instructor focuses on providing instruction for students on the processes and tools that would

enable the students to perform the responsibilities for their specific disciplines. Two different types of projects (one residential and one commercial) are utilized for the design and preconstruction activities by using Autodesk Revit 2014. The instructor also ensures the participation of industry professionals from Bentley Solutions who present best practices for working in an interdisciplinary team using BIM and who provide feedback about student project development. This feedback provides the students with a support system for advancing their knowledge and skills in the areas of decision-making. This feedback also facilitates the selection of alternative project solutions based on valid information from credible sources.

The topics covered include introduction to BIM, BIM tools and parametric modeling, interoperability and BIM workflow, integrated design and BIM for designers, BIM for green buildings, introduction to Autodesk Revit, preliminary design, building an architectural model, building a structural model, building an MEP model, creating component families (architectural, structural components, and MEP components), collaborating with others, documenting and presenting the project, and working with analysis tools (structural analysis, and conceptual energy analysis). The students learn to coordinate, update and share design data through all phases of a building's life cycle by using real world drawing projects and working with a software program to expand their knowledge.



Figure 1: In class-sessions held by the Invited Guest Speakers and Industry Experts (Sharma, M., ESD Global, BIM Manager; and Lazear, T., Consultant to Bentley Systems Academic Group)

3.1.2 Collaboration Workshop: A Real Life Experience with Industry Partnership

Students participate in a Collaboration Workshop for experiencing worksharing and an integrated design environment. The workshop involves solving a real life problem and is facilitated by the instructor and an industry partner. In this workshop, students experience being in a worksharing environment, being a part of an integrated design team, understanding the use of information in different formats such as design files (DWG, DXF, RVT, RFA, DGN, DB1, etc.), spreadsheets, word documents (DOC), adobe systems (PDF), and all kinds of files containing multi-media information such as rendered images (JPEG, BMP), animations (AVI), and 3D webpages in Virtual Reality Modeling Language (VRML). After the workshop, students are expected to understand that (1) implementing BIM is much more than learning how to use a software suite, (2) effective BIM requires integrated teamwork and collaboration, and (3) interoperability between platforms is a key issue.

3.2 BIM Education for Construction Management

The objective of graduate level BIM education is to provide graduates that have the applicable managerial skills that are required by the construction industry. CAE 573 - Construction Management with BIM is

relevant to the realities of an ever evolving industry. The students who are enrolled in this course gain strong collaboration and teamwork skills for developing and executing a BIM strategy, a broader perspective of social, environmental and economic issues, and finally construction management knowhow that goes along with BIM practice.

In a BIM design process happening, a management process needs to be happening in parallel to enable the design to coordinate with construction by all means of design activities, people, processes and resources. Construction management knowledge and skills with BIM enables the effective flow and production of design information, contributes to achieving the successful delivery of the project on time, on budget and on quality. True use of BIM helps delivering the value through integration, planning, co-ordination, reduction of risk and innovation. The objectives are achieved through collaborative and integrated working and value management process.

3.2.1 Course Content: Management and Control with 4D and 5D Models

CAE 573 - Construction Management with BIM is an ongoing experimentation with graduate students from different majors including civil/structural engineering, MEP engineering, architectural engineering, architecture and construction management. This course aims to demonstrate how construction management functions are impacted by BIM and helps students to understand the fundamentals and practical uses of information technologies in the construction industry. The course objectives are (1) to understand the concepts of BIM, (2) to review software and technology available for BIM, (3) to understand how to use a model created by a BIM software in construction management, (4) to use BIM to check for interferences and conflicts on a building construction project, (5) to explore construction scheduling using BIM, (6) to explore cost estimating using BIM, (6) to explore how BIM can assist in facility management, and (7) to use Vico Software as a construction management package to create and present construction analysis and reports.

The topics covered include introduction to BIM, BIM uses and implementation of BIM, BIM tools and parametric modeling, interoperability, BIM for owners and facility managers, BIM for architects and engineers; BIM for contractors, subcontractors and fabricators; constructability, clash detection and 3D coordination, model-based quantity take-off, cost estimating, planning and scheduling, reporting and change management, BIM for green buildings, and enabling technologies and future of BIM. Each student is assigned a real life project for the accomplishment of construction management functions using Vico Software. The instructor also ensures the participation of industry professionals from other software vendors such as Synchro Professional who provides a comparison of the critical path method (CPM) and location based system (LBS).

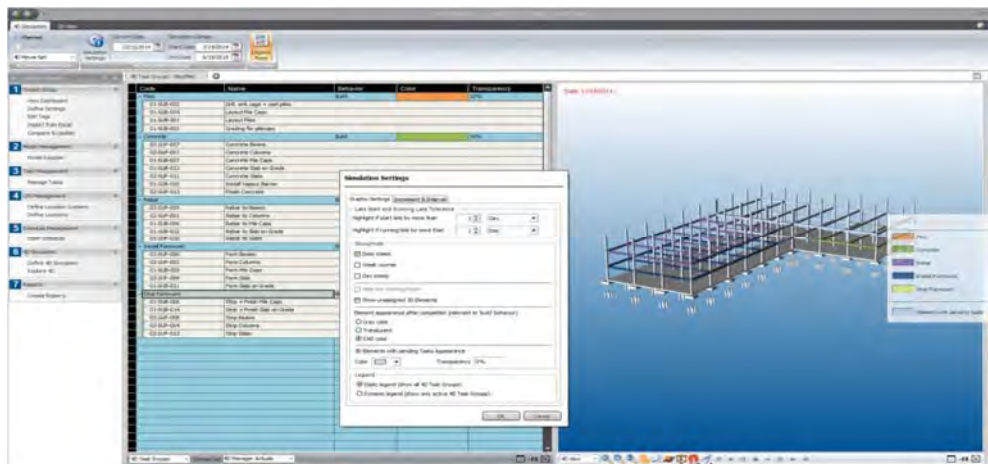


Figure 2: During 4D simulations, 3D model elements are connected to Tasks. (Vicoosftware screenshot from the student project by the courtesy of Yang, J.)

3.2.2 BIM Project Execution Plan: Experiencing Teamwork and Strategic Planning

Teamwork begins with identifying the BIM goals for the project. Traditionally, the goals are based on project performance, and advancing the capabilities and experience of the project team members. The BIM Project Execution Plan provides a framework for the fundamental coordination strategy that the student teams can use for their projects and a template for the teams to define the BIM goals and uses, the execution process, the deliverables and also the infrastructure for the implementation of the projects (CIC, 2011). The teams form at the beginning of the semester with each team member defining their primary role in the group. The students are aware of the general project background. This information allows them to develop and complete the BIM Project Execution Plan and practice it. Integrated practice requires collaboration among team members, and BIM depends upon unrestricted information exchange between all team members involved in the building process. In order for this collaboration and information exchange to work successfully in building information modeling, a project team must create and implement a detailed comprehensive plan for the project (AIA, 2007).

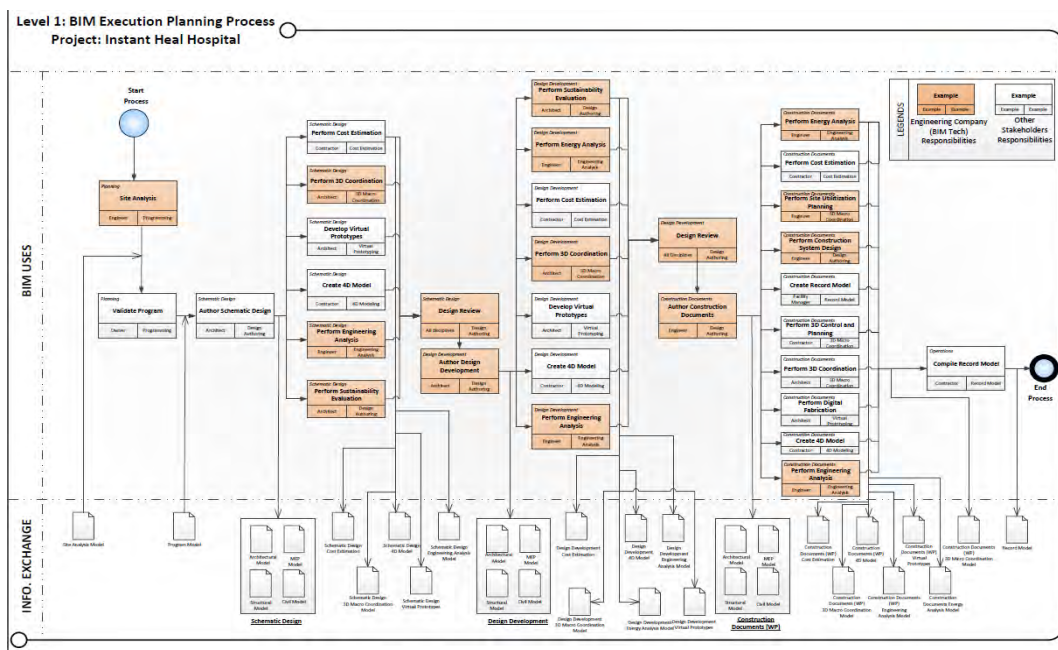


Figure 3: Information Flow Process Diagram (from the students’ group project by the courtesy of Kayo, L., Tetik, A., Alothaimeen, I., Kilincarslan, Y., Gureeva, O and Alaskar, s.)

3.3 An Ongoing Survey of The BIM Curriculum

Designing a curriculum of courses that can provide an interdisciplinary BIM experience is a serious challenge. A feedback study was conducted to address the urgent needs for instructional strategies that consider multiple aspects of BIM, including the desired qualifications of a BIM instructor, and feedback from students who have gone through the BIM curriculum. The lack of adequately trained BIM personnel is a significant constraint hindering the use and adoption of the technology in the industry. Thus the research is also devoted to improving college BIM education and talent cultivation via enhanced academia-industry partnership.

3.3.1 Methodology

The questions address (1) demographic information in terms of (a) educational background and (b) majors, (2) BIM competencies in terms of (a) professional practice and user experience, (b) skills and knowledge,

(3) curriculum evaluation in terms of (a) course content, (b) course setting, (c) instructor and course method, (d) overall course evaluation, and (e) participant benefits . A list of factors that affect these issues was collected by means of a literature review. This list was refined by making use of the contents of the curriculum that was designed to equip IIT students with BIM competencies. The student surveyed had different majors such as architecture, architectural engineering, civil engineering, structural engineering, construction management and information technology management (facility management). The survey was first conducted in May 2014 and the results were published by Demirdoven and Arditi (2014). Then it is updated recently, in January 2015. The survey covered the academic years of 2012, 2013 and 2014. Out of the 106 distributed surveys, 77 valid responses (73%) were returned.

Demographic information: 66% of the respondents were graduate students, while 34% were undergraduates. 90% of the students who have taken CAE 573 were graduate students while 10% were undergraduates. 51% of the students who have taken EG 430 were graduate students while 49% were undergraduates. 34% of the respondents had no industry experience, 31% had less than one year, 22% between one to five years, and 13% more than five years of experience in industry.

3.3.2 Results

BIM competencies: (1) Concerning professional practice and user experience, 29% of the respondents became aware of BIM and its benefits via course announcements that they received from a friend or colleague (20%), from a job posting (14%), from an instructor (13%), in a course description (13%), via vendor promotion (5%), during a conference (4%), and during a research (2%). 91% of the students stated that demand in the construction industry influenced their decision to learn BIM, while 9% of the students were interested in learning BIM for some other reason. (2) Concerning skills and knowledge, students were asked whether they placed a greater importance on people and processes or equipment and software when using BIM. 78% of the responses emphasized people and processes, while 22% were focused on equipment and software. The most positive aspect of using BIM was teamwork and collaboration for 67% of the respondents, decision making for 15%, sustainability for 11%, working internationally for 2%, promoting the business for 1%, post-completion ease for 1%, and other for 3%.

The respondents were also asked to rate the importance of selected factors using a five-point Likert scale, with 1 being strongly disagree and 5 strongly agree. 86% of the respondents believed that BIM is/will be very important in the industry. 87% thought that BIM will impact their job in the future, and 82% believed that having BIM skills presents a significant opportunity for getting new jobs or promoting to higher positions. 55% thought that they will be left behind and/or struggle to survive if they do not adopt BIM. 90% believed that using BIM improves their productivity. 82% stated that BIM is relevant to their business. 76% thought that BIM is a new technology that requires substantial investment in training. After taking EG 430 and CAE 573, 51% of the respondents were confident in their BIM knowledge and skills. Only 34% thought it is hard to keep up with new technology every year. 70% felt comfortable sharing data with other parties involved in a project. 53% thought that making the shift from a traditional 2D workflow to a 3D BIM workflow is not very hard. Only 11% of the respondents wished they hadn't adopted BIM.

Curriculum evaluation: Based on a scale of 1 to 5 where 1 is strongly disagree and 5 strongly agree, the factors received average scores that were higher than 4 in general. It can safely be stated that both courses achieved their goals. The course contents match the stated objectives, are relevant to present or future works, are arranged to be conducive to learning, and are easy to understand and practice. Course settings were satisfactory. The instructor stated the objectives clearly, was knowledgeable about the topics covered, and taught the material in a practical way that was easily understood. The presentations, software practices, invited guest lecturers, assigned projects, and workshops held enhanced learning. 97% of the respondents were satisfied with these courses and 86% said they will recommend the courses to others in the future. The evaluation of the participant benefits are given as an example in Table 1.

Table 1: Evaluation of participant benefits.

Evaluation of participant benefits	average (mean)	strongly disagree (1)	disagree (2)	neutral (3)	agree (4)	strongly agree (5)
The course addressed my expectations	4.03	1.3%	10.4%	11.7%	37.7%	39.0%
I learned better skills than the ones I previously knew	4.36	0.0%	1.3%	6.5%	46.8%	45.5%
I likely will change my thinking and/or actions as a result of my participation	4.19	0.0%	2.6%	13.0%	46.8%	37.7%
The course materials will be useful in the future	4.47	0.0%	3.9 %	1.3%	39.0%	55.8%
The software skills I learned will be useful in the future	4.45	0.0%	2.6%	5.2%	36.4%	55.8%

4. CONCLUSIONS

To sustain the momentum of BIM, effective workforce development that aims to balance the supply-demand equation in the labor market is essential. For many, experience with BIM begins in academia. The challenges reside in the classic gap between academic focus on disciplinary principles and the industry needs for specific application proficiency. There is a need to establish and improve BIM knowledge, skills and experience of current engineering professionals. There are many BIM competencies that need to be learned by engineers involved in the design, construction and operation of facilities. An academic framework informed by BIM research, BIM professionals and other industry stakeholders is a prerequisite for delivering collaborative BIM education in universities. The IIT strategy relative to BIM is successful and expected to help architecture, engineering, and construction professionals to be prepared for the needs of the industry in the future.

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BUILDING INFORMATION MODELLING (BIM) EDUCATIONAL FRAMEWORK FOR QUANTITY SURVEYING STUDENTS: THE MALAYSIAN PERSPECTIVE

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ABSTRACT

For the past few years, the wave of Building information Modelling (BIM) has been hitting the shores of Malaysian construction industry. The unprecedented changes it brings to the design responsibilities of construction professionals in Malaysia has led to a pre-emptive strategic focus for Quantity Surveying (QS) profession. The QS profession adheres to the 5th dimension of BIM, which invariably translates to the context of costing, offering the capability to generate quantity take-off, counts and measurement directly from a model. BIM digitalized data lead to accurate automated estimation which reduces variability in cost estimation. From the academic point of view, requirements to meet this paradigm shift to BIM requires an enhancement to the existing set of skills and knowledge available in Malaysian institutions of higher learning. The promotion of BIM educational framework for the QS graduates have been professional body led. This is carried out by the Royal Institution of Surveyors Malaysia (RISM) which has been actively involved in establishing the educational framework which in turn has been referred to by the higher institutions that offers quantity surveying program. This paper describes the educational framework for the QS in the context of BIM implementation that charts a route on how knowledge on BIM principles and its application can be imparted to the whole-life inter-disciplinary design and construction with prime focus on the QS scope of work. The primary aim of the framework lies in equipping QS graduates with the necessary skills in project delivery through the use of BIM by focusing on four spheres of attainment level and two different level of knowledge acquisition.

Keywords: Building Information Modelling, Education, Framework, Quantity Surveying, Malaysia.

1. INTRODUCTION

The construction industry development board (CIDB) BIM roadmap (2014-2020) projects the actualization of about 300 to 600 skilled BIM graduate users per year from the schools of engineering and environment in various institutes of higher learning in Malaysia (CIDB, 2014). The McGraw Hill report (2009) opined that BIM inclusion into education pedagogy is crucial in preparing skilled graduates for employment in the industry. Meanwhile, the previous McGraw Hill report (2008) posits the inadequacy

of strategy and capabilities of institutions of higher learning to introduce BIM which provides a wide hurdle to the BIM adoption. The overwhelming state of development of collaboration in construction utilizing BIM tools and processes raises concern on the readiness of institutions of higher learning (Becerik-Gerber et al., 2011; Allen Consulting Group, 2010; Forgues et al. 2011; Macdonald, 2012). Over time, research in BIM education began overcoming such laxities. Table 1.1 highlights the areas of QS involvement during the construction lifecycle of a project both pre-and-post construction. BIM presents the potential to automate processes which are time consuming in cost quantifications (Hannon, 2007; Mitchell, 2012; Nagalingam et al., 2013; Thurairajah and Goucher, 2013; Fung et al., 2014). BIM provides students with greater insights to construction divisions, clash and visual details, increased level of communication, increased speed and accuracy in quantity take off (Azhar et al., 2010; Taylor et al., 2008; Gier, 2008). The Royal Institute of Chartered Surveyors (RICS) report found that BIM significantly improves efficiency and accuracy which therefore improves relevance of the profession (Withers, 2014).

Table 1.1: Stages of QS involvement in construction (Olatunji et al., 2010; Fung et al., 2014)

Pre-Construction Stage	Post-Construction Stage
Preliminary estimates and feasibility studies	General contractual advice
Cost plans and schedules	Assessing interim payments
Bills of quantities preparation	Evaluating variation
Procurement and tendering procedures	Preparing finance statements
Evaluation of tenders	Settling final account
	Alternative dispute resolution

This advantages of BIM in education however faces challenges in implementation which among others include factors such as lack of space to accommodate BIM in curriculum, inadequate time and resource deployment to develop curriculum, lack of available BIM referencing materials, inadequate lab skills on software, general dissatisfaction by students and faculty on the need to transform in line with advancement in technology-based curriculum (Sabongi and Arch, 2009; Clevenger et al. 2010; Enegbuma et al., 2010; Sylvester and Dietrich, 2010) and limited occurrence of research into BIM potentials in the QS profession (Mitchell, 2012; Perera et al., 2011; Fung et al., 2014). QS BIM research in Malaysia found through an interview survey that 11 capabilities of BIM were in consonance with the professionals' perception. This is shown in Table 1.2 below.

Table 1.2: QS BIM Capabilities in Malaysia (Fung et al., 2014)

1	Cost appraisal can be prepared quickly at feasibility stage
2	Preliminary cost plan can be prepared by extracting quantities from model
3	Easily update cost plan more details as design developed
4	Easily generate accurate cost estimates for various design alternatives
5	Design changes reflected consistently in all drawing views
6	Cost implication of design changes can be generated easily
7	Clash detection reduces design errors and cost estimates revisions
8	Cost checking performs quickly to ensure all items are captured
9	Improve visualization for better understanding of design
10	Automatically quantification for BQ preparation
11	Intelligent information management data can be stored in centrally

BIM was first mentioned in Malaysia during a two-day infrastructure and construction Asia building information modelling and sustainable architecture conference in 2009 (Ismail, 2014). This conference spun the tide towards the paradigm shift to BIM industry wide. Awareness through conference and seminars began increasing the pace of BIM adoption in the industry (Ismail, 2014). Previous research highlighted the inadequacy in awareness in aspects of interoperability, standard forms of contract relating to BIM, education pedagogy of BIM in institutions of higher learning combined with the high cost of training and software purchase (Enegbuma and Ali, 2011). The BIM adoption model for Malaysia

proposed by Enegbuma and Ali (2012) buttressed the interrelations between soft issues (People, Process and Technology) with strategic IT implementation mediated by collaborative processes in improving BIM adoption. Business process re-engineering had the highest effect on BIM adoption (Enegbuma et al., 2014a,b). The process change in Malaysian construction industry led to the 2010 National Cancer Institute (NCI) pilot project utilizing BIM (Ismail, 2014). The Construction Industry Development Board (CIDB) in 2011 initiated the National BIM steering committee. Part of the committee's task was to monitor education and awareness in academia (Ismail, 2014). Subsequently, the Malaysian Chapter of the BuildingSMART international has been launched. The Malaysian BIM roadmap workshop involving representatives from Persatuan Arkitek Malaysia (PAM), Board of Engineers Malaysia (BEM), Royal Institution of Surveyors Malaysia (RISM), Perumahan Rakyat 1 Malaysia (PR1MA), Sime Darby Properties, Economic Planning Unit (EPU), University Malaysia Pahang (UMP) and private developers listed Academia as the number two motivators to BIM implementation. The third thrust of the Malaysian BIM roadmap 2014-2020 also hinged on education and awareness. This section has introduced recent efforts in BIM in Malaysia, subsequent sections will elucidate on the methodological approach, examine global BIM in education and present the proposed Malaysian BIM education framework.

2. METHODOLOGY

Malaysian educational system consist of 20 public universities, 33 private universities and university colleges, 22 polytechnics, 37 community colleges and 500 private colleges (MOHE, 2014). To gather more insight into educational research and framework across the globe (Creswell, 2012), an extensive literature review was carried out to derive the objectives, medium and learning outcome to be accommodated in the BIM education framework for quantity surveying students. Subsequently, an extension through an open-ended interview of 15 construction professionals adept with knowledge on BIM was carried out. The initial framework was later refined to include validation feedback from a focus group session at the international workshop on BIM education and training content development organised by the Royal Institution of Surveyors Malaysia (RISM). The focus group was divided into five groups to discuss BIM education and training namely; (1) general knowledge on BIM in Malaysia, the region and the world; (2) measurement rules for building and MEP; (3) what can RISM do to facilitate changes; (4) BIM management and contract and; (5) modalities to steer and request information from designers to effectively extract quantities. The framework was assessed by QS Accreditation Council, Board of Quantity Surveyors Malaysia (BQSM) and discussed in a dialogue sessions between BQSM and representatives of the private and public Institutions of Higher Learning that offers quantity surveying programs both at Diploma and Degree level.

3. BUILDING INFORMATION MODELLING FRAMEWORKS IN EDUCATION

Macdonald and Mills (2011) posit the need for establishing BIM education frameworks to support adoption of collaborative design and BIM education by Architecture, Engineering and Construction (AEC) schools. Macdonald (2012) developed the Illustration, Manipulation, Application and Collaboration (IMAC) framework to help teachers benchmark their curricular to improve collaborative design education among students of the architecture, engineering and construction (AEC) disciplines. The framework synthesized learning taxonomy of Bloom et al. (1956) divided into cognitive, affective and psychomotor and Krathwohl et al. (1964) which extended to include changes to interest, attitude and values. The framework aims at redeveloping current course to accommodate BIM competences for different disciplines. The framework under Illustration, Manipulation, Application and Collaboration targets disciplines structured into management, specialism, IT, building technology and environment respectively. The disciplines are encourage through partnership from University of Technology Sydney, University of South Australia and University of Newcastle. The full IMAC education model is illustrated in Figure 1.1.

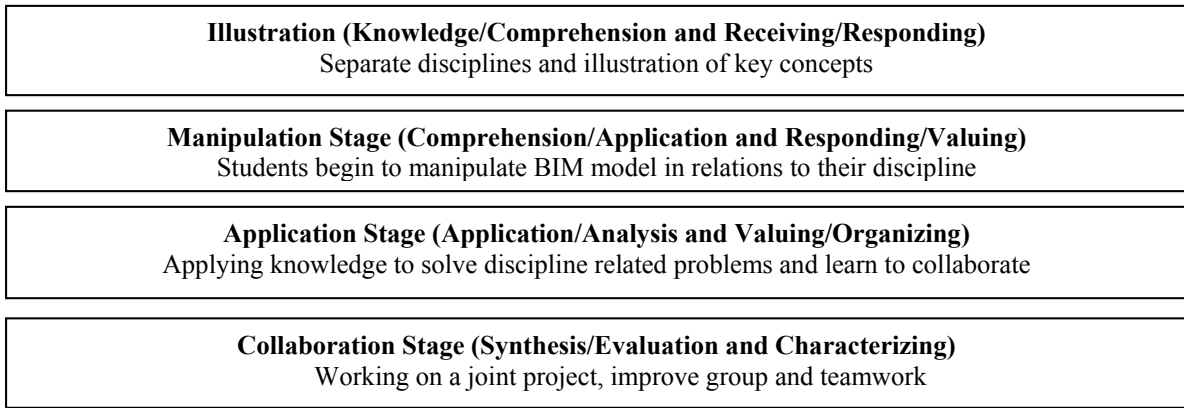


Figure 1.1: IMAC BIM Education Framework Australia (Macdonald, 2012)

The process change to BIM by the UK government published in the UK BIM Report and Government Construction Strategy (GCS) lead the UK BIM Academic Forum (BAF) to discuss strategic improvements for academia. BAF highlighted the need to improve the skills of staffs to support the delivery of the desired learning outcomes on BIM; industry push for student employability with BIM competence; framework for learning and; keeping pace with the development of BIM. The learning outcomes shown in Figure 1.2 are divided accordingly, at level 4 (year one of undergraduate study) students will be introduced to context and background of the industry professions and how collaboration within the BIM technology works. Level 5 (year 2) entails developing knowledge and understanding of BIM as a business driver for collaborative working which affects the whole life cycle cost of projects. Level 6 (year 3 and potentially after year out in industry) focuses on building competence and knowledge around people, systems and process (HEA, 2013).

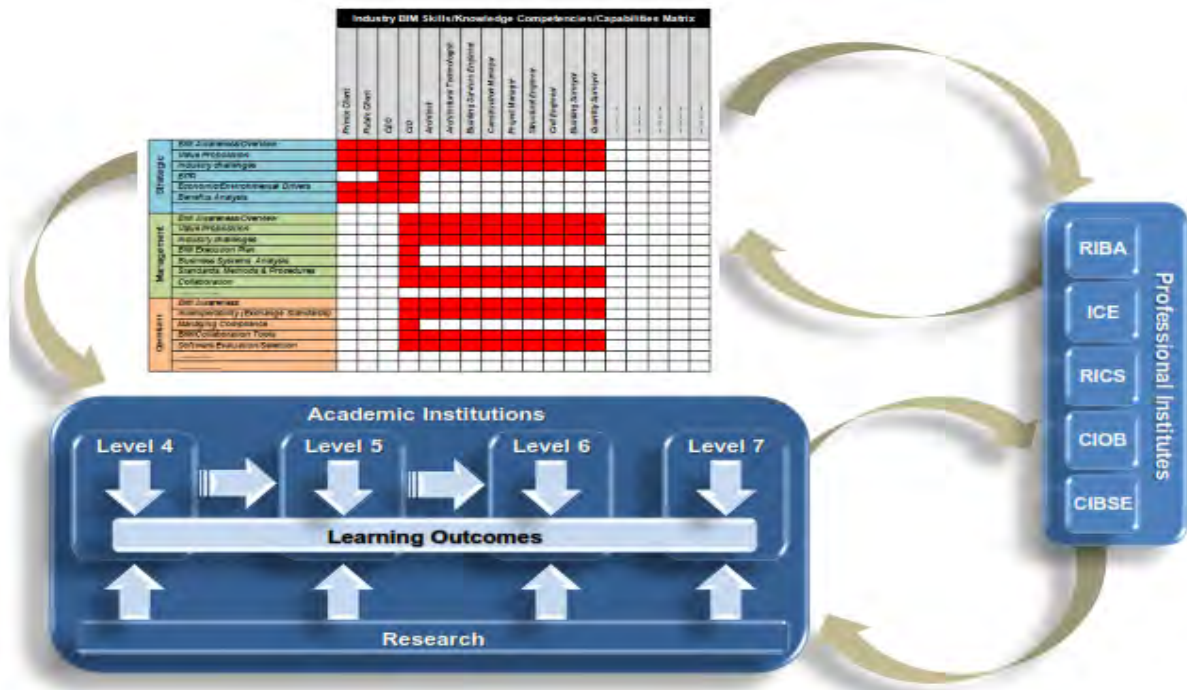


Figure 1.2: Initial UK BIM Learning Outcome Framework (HEA, 2013)

Clevenger et al. (2010) reported a positive feedback from students of construction management education in a pilot implementation of BIM in education by Colorado State University (CSU). CSU deployed BIM framework in two stage strategy to integrate BIM into construction management curriculum. The first was the establishment of an introductory BIM software course and develop stand-alone teaching modules for integration into a variety of core courses including, but not limited to structures, mechanical, electrical and plumbing (MEP) coordination, sustainable design and construction, pre-construction, cost estimating, scheduling, contracts, and material and methods. The framework expressed the need to inculcate core construction concepts into the teaching of BIM to showcase leading industry best-practices forming a different variant from popular software tutorials. Barison and Santos (2010a) found that BIM implementation follow 3 processes namely; single course module (Hu, 2007; Nielsen et al., 2009), interdisciplinary (Hedges et al., 2008; Plume and Mitchell, 2007) and distance collaboration (Hedges et al., 2008; Dilg, 2008). The predominant approach of introduction of BIM is in design studio out of eight different course in the curriculum namely; visualization, quantification, planning and scheduling and management (Barison and Santos, 2010a). Lack of integration among different course curriculum presents a great challenge to implementing BIM pedagogy. Kymmell (2008) and Barison and Santos (2010a) recommend focus on individual skills on BIM model in first year, expansion to teamwork and complex collaboration in second year and further expansion to real life projects in collaboration with construction companies.

4. FRAMEWORK AND DISCUSSION

The analysis of BIM education frameworks lead to the division of QS BIM framework into four (4) objectives namely; visualization, quantification, planning and scheduling and management. The subsequent learning outcome are currently limited to two concurrent phases of Diploma and Degree levels. To achieve in-depth knowledge on visualization in BIM models, three courses Draughtmanship, Construction Technology and Construction Services were identified as means to enhance visualization studies in BIM. Draughtmanship courses will be enhanced to include the use of BIM software as a basic tool for design. Construction technology is envisioned to improve the students' knowledge and skills of construction building codes, construction documents, mechanical systems and construction safety to include BIM. In Quantification, Measurement and Cost Estimating were identified to improve the level of quantity surveying students understanding of BIM for effective measurement. This skill set will improve the employability and demand within the growing BIM industry. In Planning and Scheduling, Cost Planning and Cost Analysis courses were identified to improve QS students' skills in line with BIM compliant software while for Management, Project Management, Professional Practice and Contract courses were identified to be improved to accommodate legal dimension, BIM competence expectancy in the job market and lifecycle BIM management of a project.

The desired learning outcomes for the quantity surveying education framework is targeted to ensure that at diploma level quantity surveying student are able to skillfully master the visualization and quantification utilizing BIM as a foundation to future degree studies. At degree level, the foundations are extended to include evaluating and integration of BIM in cost planning and scheduling task. Similarly, the ideals of legal liabilities and effective integrated project delivery are taught to differentiate the two classes of learning outcomes. To achieve the aforementioned learning outcome, the framework took into account the need to upgrade quantity surveying students skills in Microsoft Excel from the basic knowledge to more advanced QS task. The task of quantification and automatic take-off from BIM models is improved through upgrading the skills in various BIM interoperable software. The learning approach encompasses hands-on lectures and embedding of BIM related courses. The developed framework is outlined in Figure 1.3.

AIM	OBJECTIVES	MEDIUM	Diploma	Degree
			OUTCOME	OUTCOME
To equip QS graduates with appropriate skills in project delivery through the use of Building Information Modelling	Visualisation	Draughtmanship	To be able to appreciate 2D design and basic 3D models	To be able to appreciate 2D design and basic 3D models
		Construction Technology		
		Construction Services		
	Quantification	Measurement	To be able to apply the quantity take-off software and spreadsheets software	To be able to apply the quantity take-off software and spreadsheets software
		Cost Estimating		
	Planning and Scheduling	Cost Planning & Scheduling	To be able to appreciate the fundamental principle of cost planning and cost analysis through the application of appropriate software	To be able to understand the fundamental principle of cost planning, scheduling and cost analysis through the application of appropriate software
		Cost Analysis		
	Management	Contract	To be able to appreciate the legal implications of the integrated project delivery system	To be able to assess the legal implications of the integrated project delivery system
		Professional Practice	To be able to appreciate the procedural aspects of the integrated project delivery system	To be able to assess the procedural aspects of the integrated project delivery system
		Project Management	Project Management	To be able to appreciate the complexity of working in interdisciplinary teams and managing collaborative design and production
To be able to appreciate a construction project through visualisation of construction process	To be able to manage a construction project through visualisation of construction process			

Figure 1.3: BIM Education Framework for Quantity Surveying Students in Malaysia

The framework for QS students in Figure 1.3 was validated through the focus group discussion which derived feedbacks that are subsequently considered in the overall framework. The feedback emphasized the need for changes to physical conditions of institutions of higher learning covering reference materials, training of staffs, hardware and software including establishing a planning, review and monitoring panel consisting of three (3) members adept in BIM/IT knowledge. On visualization, the emphasis were placed of students understanding of 2D/3D visual design tools and improving understanding of Level of Details (LOD) in BIM models from 100-500LOD. In Quantification, emphasis were on software choice for quantity take-off, effective use of standard method of measurement (SMM), comprehension of quantity cost within a model and updates to design changes. On planning and scheduling, focus was similar to those mentioned in the previous quantification objective with variations in information use which is

directed to sustainable construction, cost effectiveness, life cycle costing and scheduling. In the final objective of Management, emphasis were focused on students' comprehension of 7th dimension of BIM models, the legal implication surrounding model ownership, liability of various professionals in BIM modelling and regular updates of BIM roles and best practices.

5. CONCLUSION

This paper set out to derive a framework for equipping QS students with the necessary knowledge and practical skills to meet the industry demand for BIM competent graduates. The framework involved four dimensions of visualization, quantification, planning and scheduling and management. This dimension were further broken down into 10 mediums targeting various learning outcome for both diploma and degree QS courses in Malaysian institutes of higher learning. The framework was presented, assessed and accepted by the QS Accreditation Council. The framework was also presented at a dialogue session involving the Board of Quantity Surveying Malaysia (BQSM) and members from the public and private sectors. The framework underscores the importance of improving the skill set of QS graduate through the adoption of outlined mediums to produce effective learning outcomes for both diploma and degree graduates. However, the success of the QS BIM framework is very much dependent on the commitment and willingness to overcome the resistance for change by educators of higher institutions of learning. This efforts are geared towards supporting the industry-led and government support initiatives to BIM implementation in Malaysia. This change is optimistic to set Malaysian institutions of higher learning amongst a competitive sphere with QS graduates across the globe. The framework also recommends an increase in the awareness of BIM in institutions of higher learning, organization of BIM design competitions and initiating BIM software proficiency training. Future research could be directed towards curriculum development, accessing perception of students and lecturers and extension of framework for higher graduate courses.

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FRAMEWORK FOR EXPANDING BIM ADOPTION WITHIN THE TAUGHT CURRICULUM

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ABSTRACT

Construction and civil engineering industry is gaining momentum in the BIM (Building Information Modeling) implementation and development. For academics, the actual expansion of an informed and equipped workforce with valuable information modeling skills is a growing priority. Besides this fact, it may be that the requirements of all higher education institutions respond to changing needs across industry, and although many programs have begun to recognize this trend, the need for a guided and consistent framework should also come into focus. This paper considers the impact that BIM may have on the learning needs of undergraduates' coursework and it is framing the topic needs of a construction management (CM) program in the southeast US. The CM program in particular is housed with a civil engineering (CE) program under same department authority. Some of the CE courses are also considered in the proposed framework as a need to follow up the upward trend of Civil Information Modeling (CIM) applicable to civil engineering related topics. Specific CM and CE courses are cross-listed with potential modeling topics of interest within the taught curriculum in an attempt to expand the overall BIM and CIM adoption in the department curriculum framework. This framework is based on the existing course offerings and is delineating specific learning outcomes within the academic context of accreditation bodies for each program. Expanding BIM adoption in the proposed framework is planned through various software packages and information technology platforms that are capable of supporting instructors' up-skilling to sustain the delivery of the desired learning outcomes and to create better student employability skills. These software packages exposed the need to keep the pace with the development and understanding of various BIM and CIM applications meant to improve the construction industry productivity.

Keywords: framework, information modeling, coursework, academic context

1. INTRODUCTION TO CONSTRUCTION MANAGEMENT AND CIVIL ENGINEERING CURRICULUM

Teaching possibilities in the BIM arena are growing over the entire Civil Engineering and Construction Management curriculum within nation's Universities. The way in which BIM can be taught and the impact BIM could have on teaching is always an important consideration with great implications on the instructors' courses. Clearly there is a broad spectrum of possibilities encasing the following aspects:

- the technology used in the course offering and the approach adopted
- the application(s) to enhance understanding of the process in which BIM is embedded
- the all-embracing pedagogy

In addition, specific CM and CE courses may be cross-listed in the curriculum and they may have the potential of introducing students to modeling topics of interest within the taught curriculum in an attempt to expand the overall BIM and CIM adoption in the authors' department curriculum framework. These topics are of particular interest for academic instructors working closely with industry because they are challenged to certain recommendations the industry would like to get across the curriculum before hiring graduates:

- updating skills of the respective faculty to support the delivery of the desired learning outcomes
- efficient framework for learning to variety of students
- keeping the pace with the development of BIM in construction and software industry
- increasing student employability
- moving the classroom topics closely related to industry field-specific problems

The specific objectives envisioned by authors for a potential standard framework to expand BIM and CIM adoption within taught curriculum are revolving around growth of BIM and CIM implementation and understanding of this trend in industry setting:

- focus on training and elevate the learning; also research aspects of BIM and CIM and their implementation in industry
- mutual promotion of BIM and CIM (expand the trend to more trade-specific markets)
- establish open medium for communication, consequently sharing knowledge, experience, case studies, opinions, etc.
- collaboration for joint activities and research projects with industry
- research matters for teaching and learning in the BIM and CIM arena
- challenge to create standard practices for BIM and CIM incorporation across curriculum

1.1 Construction Management Courses

From instructor's experience with previous semesters, surveys, assessments and conversations with the industry, it is apparent that integrating virtual design and construction (VDC) activities as a central idea in construction education requires some necessary changes in existing teaching methods and philosophies. Table 1 below reflects the initial implementation of the BIM curriculum in the CM program within the Engineering College.

These illustrations in Table 1 are course offerings (i.e. Project Planning and Scheduling) that are proposing the inclusion of BIM and/or BIM applications and practices in the specific topics. As an example, the construction schedule developed in P6 can be integrated into a 3D building model with Synchro software. Students are exposed in this course to be capable of linking P6 schedules with Synchro 3D models to visualize a project schedules. This way a 4D planning and scheduling is generated by adding schedule and resource data to a 3D building models. In this process, students also learn the use of BIM for scheduling and work sequencing in a more visual and compelling format and understanding.

1.2 Civil Information Modeling and Civil Engineering Courses

By observing the industry trends and requests, in the Civil engineering curriculum within the same department of the Engineering College (Civil Engineering and Construction Management, CECM) there is usage of Bentley products, specifically for a CENG (4th year) course, Water Supply & Wastewater Collection Systems. FlowMaster is used for calculating water head loss of different pipes, and the instructor teaching this course is planning to use WaterCAD, SewerCAD, and StormCAD in the upcoming semesters. Also, there is an identified possibility to insert other Bentley products in another 4th year CENG course, Open Channel and Pumps. FlowMaster and CulvertMaster are also convenient programs for solving open channel flow problems. They can be used in either the 4th year CENG course Open Channels and Pumps or 2nd year CENG course, Civil Engineering Fluids. However, there is a similar feature within AutoCAD Civil 3D, which is installed on all of the laboratory computers where

these classes are taught. WaterCAD is used mostly for water pipe distribution problems introduced in this course.

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

Course name offered in the CM program		Topics covered/Software used	Future applications of the topics for understanding BIM
<i>Year I</i>	Engineering/Construction Graphics	- Geometric modeling to represent operations of construction equipment (i.e. a crane, bulldozer, etc.) - Some form of 3D building visualizations	- Requirements for productivity, efficiency and safety
<i>Year II</i>	BIM for Construction Management	- Learning BIM as a collaboration and coordination tool; - Software applications with: Revit Architecture/Structure/MEP, BIM 360 Glue, Navisworks Manage, Tekla Structures, Tekla BIMsight	- Mobile technologies for field use; productivity enhancements, visual estimating, accuracies and scheduling realization
<i>Year III-IV</i>	Project Planning & Scheduling	- Project Scheduling methods such as Bar Charts, CPM and PERT, AOA, AON and CPM techniques; resource allocation and time/cost trade-off analysis, EVM - Software applications with: Microsoft Project 2013, Primavera P6 R8.2, Synchro for linking schedule to a building model and running simulations	- Creating schedules, simulating activities in project examples, comparison of CPM and location-based scheduling, industry lean construction practices
<i>Year IV</i>	Senior Project - Capstone course	- Laser scanning, Photogrammetry & 3D applications, Scan-to-BIM integration; Software used: Cyclone, Agisoft Photoscan, Photomodeler, Autodesk Recap Pro, Revit Cloudworx	- Creation of 3D models of existing structures, terrain and topographic modeling; accuracy comparisons by different measurement techniques

Looking into the future opportunities, BIM for transportation infrastructure asset management practices can benefit from integrating scope, schedule, and budget along with 2D CAD plans, maintenance records, project specifications, warranty information, procurement requests and HVAC plans into a 3D model. By incorporating all project information into one or multiple 3D models, with multiple data sets, benefits may result for several stakeholders. For example, owners can use the model for operation and maintenance and engineers and contractors can use the information in design and building deliberations. Various alternatives can be easily compared in order to achieve optimum life cycle cost. A key benefit is the accurate geometrical representation of the parts of building infrastructure in an integrated data environment (Marzouk & Abdel Aty, 2012). These skills can be taught in certain civil engineering classes with visual equipment and support (hardware and software) or in classes cross listed for CE and CM students in our program.

Furthermore, project stakeholders can acquire a greater level of detail at early stages of the project to better inform decisions before they are implemented in the field. In addition, operation and maintenance histories can be well documented. Transportation infrastructure typically has a life cycle of decades and, in general, the project maintenance is driven by financial considerations. It is typical to have multiple construction crews and engineers producing documents regarding the same infrastructure asset over extended periods of time. BIM provides value in managing relevant data about current conditions and facilitates the analysis of alternatives by being able to embed data on life expectancy and replacement

costs in BIM models. Such documentation can help the owner understand the benefits of investing in materials and systems that may cost more initially but have better payback over the life of the assets. The basic premise of proactive asset management is that during the normal life cycle of an asset or system of assets, there is the need to intervene at strategic points to extend the expected service life (Cagle, 2003). BIM enables this to be done more cost effectively by providing the potential for up-to-date, accurate, and geometric representations of the assets and their sub assets. Highway design courses in CE curriculum covers different approaches to roadway design based on considerations of geometric controls, structural requirements, drainage needs and costs. Also, the CIM concept would be of applicable value and in concordance with industry trends because it covers different approaches to highway pavement design, including asphalt pavement and Portland cement pavements.

Implementation of BIM technology necessitates in some cases re-engineering the design, construction, and maintenance processes (Mihindu & Arayici, 2009). The change process is a journey through adapting principles of integrated processes, interoperability for BIM information management, collaborative working practices, and finally development of BIM-based services organizations operating in the field of the built environment (Makelainen et.al, 2012). This is also relevant to Civil Information Models (bridge design, roadways, rail infrastructure, etc.). One of the biggest challenges associated with BIM and CIM is effectively using and fully leveraging the process during construction phases. This process understanding is difficult to convey in classroom setting because there is not much related student experience that they may have during their college years. Furthermore, it can take multiple implementations and countless hours for BIM usage to become a normal integral part of project construction culture, which is difficult to understand with less modeling knowledge upfront. Using BIM or CIM includes a process of unlearning the previous systems that were once in place to help in the decision making process (Makelainen et.al, 2012).

Initially companies need to invest time and money into training individuals on chosen software. Training individuals to operate BIM software can require a sizable investment in money, time, and hardware. These trained individuals can come as graduates of CE and/or CM program within the CECM Department with certain Information Modeling skills gained during their curriculum coursework. Software is usually RAM intensive and requires hardware that is capable of processing the data retrieval needed to be accessed in order to perform the modeling functions. In general, there are many options in the development of constructing a BIM model, and when implementing software into a company's culture, some of these options are chosen by chance due to inexperience (Makelainen et.al, 2012). These are all challenges that can take place when incorporating new technology into an otherwise tried and trusted system. As individuals learn new, effective processes, there is the potential to increase productivity and significantly reduce project cost by using the BIM or CIM software, especially with intermediate-level skills that may be acquired during junior and senior years as college students.

As an organizational example from industry, New York City Transit Authority (MTA) adopted BIM across the board with use of Bentley products. They are currently using BIM for preconstruction through construction phases. It is their goal to use their BIM information for Operations & Maintenance (O&M) once the projects are completed. Projectwise software product (Bentley, 2015) has been implemented as the main source of BIM and CIM information. By request of the senior vice president, NYMTA has purchased and is testing Autodesk Suite for a comparative analysis as to which design platform is better suited to meet their needs. Another example for a potential class project but in the Structures I and II courses (combined CE and CM students) and Structural Analysis course (CE students) would be relative to scrutiny of a contractor who documents the usage of Bridge Information Modeling (BrIM) in the processes of project delivery and potential future asset management. In this collaborative project, software programs may be used in various stages like Autodesk Infrastructure Design Suite, version 2014. On these particular projects, digital exchanges in support of the following aspects would be of main interests: visualization and 3D modeling, bridge roadway geometry, initial bridge design, bridge structural analysis, fabrication details, Quantity Takeoffs, and asset management concerns such as load rating/permitting and drawings generation for a particular contract.

2. LEARNING OUTCOMES

Table 2 below is an adaptation from BIM Academic Forum presentation of learning outcomes from workshop group sessions (found at www.bimtaskgroup.org) and the corresponding Student Learning Outcomes (SLOs) as approved by the new ACCE requirements. These SLOs are described further in the next sub-section of this paper.

Table 2. BIM Undergraduate Levels in the Construction Management curriculum and the SLOs

Levels/Skills	Knowledge and Understanding	Practical Skills	Transferable Skills
<i>Undergraduate Level I</i>	- Importance of collaboration - The BIM business	- Introduction to technology used across disciplines	- BIM as a process/technology/people/policy
<i>Undergraduate Level II</i>	- BIM construction processes - Stakeholders' business drivers - Supply chain integration with BIM	- Use of visual methods representation - BIM tools and their applications - Characteristics of a BIM "system"	- Value, lifecycle and sustainability - SaaS platforms for projects - Collaborative working - Inter-disciplinary teams communication
<i>Undergraduate Level III</i>	- BIM across the disciplines - Contractual and legal frameworks/regulation - People/change management	Technical know-how: - Structures, materials - Sustainability matters - Green materials and their integration in buildings	Process/Management: - How to deliver projects using BIM - Information and data flows - BIM protocols
Student Learning Outcomes →	<i>SLOs: 1, 2, 7, 8, 12, 17</i>	<i>SLOs: 1, 2, 4, 5, 7, 18, 19, 20</i>	<i>SLOs: 1, 2, 4, 5, 9, 10, 15, 16</i>

2.1 Learning Outcomes by ACCE accreditation body

According to the new requirements (outcome-based) of all ACCE Accreditation of Postsecondary Construction Education Degree Programs, Document 103 is defining Standards and Criteria for accreditation. In this document (found at <http://www.acce-hq.org>) it is stating that (the authors selected only the relevant ones to the BIM topics described above) "Upon graduation from an accredited ACCE 4-year degree program, a graduate shall be able to:

1. Create written communications appropriate to the construction discipline.
2. Create oral presentations appropriate to the construction discipline.
4. Create construction project cost estimates.
5. Create construction project schedules.
7. Analyze construction documents for planning and management of construction processes.
8. Analyze methods, materials, and equipment used to construct projects.
9. Apply construction management skills as a member of a multi-disciplinary team.
10. Apply electronic-based technology to manage the construction process.
12. Understand different methods of project delivery and the roles and responsibilities of all constituencies involved in the design and construction process.
15. Understand construction quality assurance and control.
16. Understand construction project control processes.
17. Understand the legal implications of contract, common, and regulatory law to manage a construction project.

18. *Understand the basic principles of sustainable construction.*
19. *Understand the basic principles of structural behavior.*
20. *Understand the basic principles of mechanical, electrical and piping systems.”*

2.2 Learning Outcomes by ABET accreditation body

The SLOs for the Civil Engineering program in the Department of CECM are the (a) through (k) outcomes specified in the 2013-2014 ABET Criteria for Accrediting Engineering Programs. The only relevant one is SLO (k): “*an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*”. The Bentley products including FlowMaster, CulvertMaster, WaterCAD, SewerCAD, and StormCAD are considered modern engineering tools necessary for engineering practice mentioned by ABET criteria. The authors are planning for a continued investigation regarding the table above as a way to compel all SLOs in the curriculum to the respective undergraduate levels, positioning students at different learning stages of their coursework.

3. VALUE OF BIM AND CIM FOR CM AND CE GRADUATES

Cost is a driving factor in all aspects of construction. Any owner would want the highest quality product for the least amount of money. BIM and CIM potentially allow the needs of multiple project stakeholders to be realized more effectively and efficiently, thereby adding value. For example, life-cycle project costs can be impacted by factors such as the state of disrepair of the asset, what has previously been repaired, and how the repairs were performed or how the asset was originally constructed (Stratford et.al, 2009).

BIM potentially allows for such considerations to be assessed and addressed through collaboration using a 3D model. Stakeholders can provide design alternatives in a digital format to address problem areas and apply degradation models to determine the most cost effective and appropriate means of addressing design and construction issues. Over various CE courses the design and construction issues can be analyzed in small projects and with group work participation. The use of 3D modeling can help stakeholders move important decisions from the field to some computational reasoning where changes are easier and more cost effective. This advantage must be taught and applied in CE and CM courses in bridges, roads, buildings or even large plant construction. The possible software products well suited for this purpose may come from Autodesk Infrastructure Design Suite or Autodesk Plant Design Suite, versions 2014.

Additionally, another fact that can be learned in combined CM and CE classes from the industry side is that stakeholders may develop a shared understanding of the project through cross disciplinary collaboration that helps reduce design errors and miscommunication, which in turn reduces risk and liability (Bennett, 2012). Role-play on the collaboration process can be undertaken in these classes for a better understanding of interaction and participatory role of all stakeholders in design and construction processes. Finally, additional value may result through the use of BIM by avoiding data diffusions, and duplication of efforts, increasing efficiency and safety, and reducing time for routine data collection and recording, all of which could translate into cost savings to the owner and increased structural safety of the assets (Lwin, 2006). As an example, the role-playing on the collaboration process can be implemented in classroom through Autodesk BIM 360 Glue; also, concepts of cloud-sharing may be introduced in the same time.

Many times research suggests BIM implementation can have noticeable cost savings; overall cost diminishes as unplanned maintenance is replaced by planned maintenance. Excessive levels of planned maintenance can also drive the overall cost back up (Cagle, 2003). Infrastructure owners and engineering firms seek integrated and cost-effective solutions that span the entire project life cycle (Jones, 2012). In a recent study by McGraw Hill, it was determined that 67% of the users of BIM associated with infrastructure were seeing a positive return on investment (ROI), and those users that identified themselves as experts with BIM were seeing as much as a 50% ROI. Information management is a key

feature when implementing BIM for infrastructure asset management. Keeping the data current throughout the life cycle of the infrastructure, however, requires proper information flow. Incorporating and integrating large amounts of data using BIM can potentially save significant time and cost for facility managers. For example, facility managers might spend some time searching for manufacturer's contacts in order to replace or maintain a part. However, with BIM, a single click on any part could show all information (Marzouk & Abdel Aty, 2012). With BIM software, it is possible to define different attributes and components of a building and categorize them into major categories: structural, architectural, mechanical, and electrical (Marzouk & Abdel Aty, 2012).

Cost can also be incorporated in the model to allow for model-based estimating. Various aspects of the 3D model can produce cost information and data regarding repair, replacement, manufacturer, fabricator, location on where a certain part/assembly was built, and if it has recently been serviced. Having such information in one place potentially reduces time and costs associated with typical repairs. With BIM, it is possible to leverage knowledge of location, characteristics, maintenance history, and condition of the asset, combined with a systematic approach to inspections and maintenance to allow responsible authorities to effectively manage the condition and capacity of the asset and therefore, indirectly, the capacity/capability of the assets network (Hosseen & Stanilewicz, 1990). Cost Estimating and Quantity Estimating courses within CM curriculum may integrate assignments of these natures to help students (CE or CM) to better understand where the actual savings are generated.

At organizational level, companies and organizations are also beginning to realize the benefits of incorporating CIM into their transportation infrastructure asset management. In addition, CIM may be used to view and organize monitored data across a collection of assets. For example, air quality sensors, temperature and moisture sensors can be placed within infrastructures and input data into the CIM to provide the ability to monitor and analyze specific conditions. As another example, the managers of a subway system may be able to control the Heating, Venting and Air Conditioning system through BIM-integrated software if the indoor air quality is poor or moisture levels too high. Also, off-site access to such information can help management teams monitor safety issues before they happen. Such new technologies and opportunities provide the prospect for radical improvement from preconstruction through operation and maintenance in the management of transportation infrastructure assets. The benefits can be evidently disseminated in any of CM and/or CE courses dealing with HVAC systems and their interaction with the surrounding built structures.

4. CONCLUSIONS AND FUTURE VISION

This paper addressed the potential impact that BIM and CIM may have on the learning needs of undergraduates' coursework and it is framing new topic needs of a construction management and civil engineering program in a southeast US University. The expansion of BIM and CIM adoption in the department curricula can be seen as a technological upgrade required today concurrent with a greater infusion of more high-tech integration at face of design, construction and operation of buildings and infrastructure.

As the industry continues to implement BIM or CIM and gear itself to improve productivity and safety of all operations, the demand for CE and CM graduates will not only be disciplinary competences but also some level of BIM knowledge and capability that will continue to increase. Also, students are becoming increasingly aware of the importance of BIM as further enhancing their employability skills in an emerging construction and civil engineering market and, along with accreditation, this is important in their choice of an appropriate curriculum. ABET and ACCE accreditation bodies and other professional bodies, such as the BIM Forum, AGC of America, BAF, etc., need to come together in order to begin addressing the implications for a transforming industry and the accreditation of curricula that incorporates BIM and CIM. They are presently into a transformational period as they work to standardize student learning outcomes capable of meeting the current and future needs of a transformational industry.

Inspiring young people through BIM and CIM education will enable the creation of a construction industry image that corresponds to the new century requirements, which is no longer considered "dirty",

“difficult” or maybe “dangerous”, but high-tech, highly professional, and a key contributor to the delivery and management of a built environment that positively affects the everyday lives of people and produce noteworthy economic growth for all communities.

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INTEGRATION OF BUILDING INFORMATION MODELING (BIM) COURSE INTO DESIGN CURRICULUM CASE STUDY: STUDY PROGRAM OF ARCHITECTURE, INSTITUT TEKNOLOGI BANDUNG

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ABSTRACT

The relevance of Building Information Modeling (BIM) is apparent in today's construction industry. Benefits of implementing BIM has been identified as real-time integration of changes throughout the model which appears both graphically in the views and numerical data in the schedule, which in turn leads to more accurate budget and cost predictions, as well as the minimizations of fragmentations between myriads of different file formats among collaborating consultants.

Given these benefits, it is imperative that educational institutions start integrating BIM into their curriculum to prepare future practitioners who will perform better and more efficiently in construction teams. It can be concluded then that BIM's promise to improve construction practices lies on its capability to facilitate direct inter-disciplinary collaboration throughout the design process. But while it can be argued that the main potential of BIM is its application across teams of various disciplines, a fully functioning BIM model relies heavily on the appropriateness of the model to the actual construction for the data it generates to be accurate. Furthermore, it also demands project team members to have a better understanding of a building's components, as unlike conventional 3D models, the components pertains actual as built construction information.

It is crucial then that introductory courses on BIM in school stresses the importance of students having good fundamentals of designing and modeling in BIM, before proceeding to the collaborative aspect of BIM. This paper seeks to evaluate and share ITB's experience in conducting the first BIM course in architectural school, as well as exploring ways in which BIM can be further extended and integrated into inter-departmental courses.

Keywords: BIM, curriculum design and integration, individual learning, collaboration, curriculum

1. CONTEXT OF BIM EDUCATION IN HIGHER EDUCATION ENVIRONMENT IN INDONESIA

Being one of the fastest growing cities in Southeast Asia, practitioners of the AEC (Architecture, Engineering, and Construction) industry in Indonesia is currently facing a heightened boom of demand for construction projects, going strong despite having lost much of its traction over the past year as compared to its 2010 period¹, and taking into account the coming exaction of ASEAN Economic Community in the end of 2015, as well as the recently elected president of Indonesia's invitation for foreign investments in the country², it can be expected that AEC practitioners in Indonesia will face an even greater challenge in keeping up with the demand of construction projects, amongst the myriads of challenges in many other sectors of its economy³.

Unfortunately, no revolution comes easy, and the implementation of BIM itself to the largely CAD based Indonesian AEC industry is by no means excluded from this fact. Clients have regularly cited the steep learning curve of BIM to be one of the main reasons for refraining from converting to BIM⁴, often preferring to do projects the conventional way, while outsourcing a BIM consultant to deal with the actual construction and integration of BIM model in projects. While it is possible to execute a BIM project in this manner, it may not be entirely feasible for an AEC consultant to sustain this method in the long run, as the method will require additional consultants in the process of delivering a project, and in doing the project in the conventional manner in the first place, the consultant would lose much of the benefit of BIM's capacity for Integrated Project Delivery (IPD).

Having realized this, and given the difficulty of training their currently already experienced staffs in BIM, the demand for BIM-enabled fresh graduates (particularly those whose BIM operating platform is Revit) have been steadily increasing over the past year, from both local and international design and construction firms. It can be expected then that in the near future, as the competitive pressures from the enactment of ASEAN Economic Community makes its way into the Indonesian AEC market, the demand for these graduates will also increase in Indonesia. Hence it is essential that educational institutions in Indonesia also contributes in the education of future graduates who understands, and is able to operate within a BIM defined framework, if the AEC consultants in Indonesia are to remain competitive in the Southeast Asian AEC market.

It is in consideration of this increasingly global context of the AEC sector in Southeast Asia that, Institute of Technology, Bandung (ITB) had recently held its first fully devoted course on the education of BIM. The recent ITB's Department of Architecture accreditation from the Korean Architecture Accreditation Board (KAAB) had also required the department to have a course in BIM, further amplifying ITB's Department of Architecture's needs to integrate BIM in its education process. The department's commitment to integrate BIM into its curriculum was represented in its establishment of AR 4122 – Introduction to BIM, as well as the integration of BIM in AR 2250 – Computational Studio.

2. CLASS OVERVIEW AND COURSE DESCRIPTION

The course of AR 4122 – Introduction to BIM was delivered in the span of fourteen weeks, in Institute of Technology, Bandung's Department of Architecture computer lab, with the educational version of Autodesk Revit 2014 serving as the platform of BIM operations for the forty four students who took up the course. This course offers an introduction to operating in BIM both individually, and collaboratively, as well as clarification to the common misconception among architectural practitioners that BIM is just a 3D modeling software by introducing students to the proper use of tools in Autodesk Revit, and explaining how this information will be interpreted in the course of real construction projects.

The course was broken down into 8 bi-weekly handout modules with each module explaining specific parts of the tools in Revit, and a short introductory lecture, followed by a hands-on workshop session discussing the implementation of the specific tools being the main delivery method of the course. A rundown of the materials covered in the class can be observed from the course syllabus (Table 1).

There were no previous class requirements for students who wish to attend the course. In the future however, participants are expected to have completed the AR 2250 – Computational Studio course in their second year to be admitted in this elective course.

Table 1. AR 4122 - Introduction to BIM course syllabus

Week #	Topic	Sub Topic
1	<i>Introduction to BIM in the construction industry</i>	<ul style="list-style-type: none"> • Evolution of information technology in architectural design • Design method using BIM technology • Autodesk Revit's principles and workflow • Autodesk Revit's user interface and key features
2	<i>Architectural BIM: Setting up project</i>	<ul style="list-style-type: none"> • Topographic modeling • Image references • Datum: project location, grid, elevation
3	<i>Architectural BIM: Component modelling</i>	<ul style="list-style-type: none"> • Basic component modeling • Column, Walls • Openings: window, doors
4	<i>Architectural BIM: circulation and roof</i>	<ul style="list-style-type: none"> • Circulation: Stairs, ramp • Roof types
5	<i>Architectural BIM: Family Creation and Editing</i>	<ul style="list-style-type: none"> • Family creation and editing • System families • Loadable families • In- place families
6	<i>Architectural BIM: Curtain Wall</i>	<ul style="list-style-type: none"> • Curtain wall system
7	<i>Architectural BIM: Mass modelling and editing</i>	<ul style="list-style-type: none"> • Mass modeling and editing
8	<i>Exercise (mid-term project submission)</i>	<ul style="list-style-type: none"> • Project exercise
9	<i>Introduction to Collaborative BIM</i>	<ul style="list-style-type: none"> • Introduction to Collaborative Revit • Setting and the principle of worksheet • Project workshop in collaboration with PT. Intiland Development, Tbk.
10	<i>Project Workshop</i>	<ul style="list-style-type: none"> • Project workshop
11	<i>Project Workshop</i>	<ul style="list-style-type: none"> • Project workshop
12	<i>Collaborative Management</i>	<ul style="list-style-type: none"> • Introduction to Naviswork for clash detection • Exercise on project and rectification
13	<i>Collaborative Management</i>	<ul style="list-style-type: none"> • Project modification and elaboration
14	<i>Project Finalization (final-term project submission)</i>	<ul style="list-style-type: none"> • Project finalization • Course feedback

4. COURSE OBJECTIVE

The course aims to introduce students to the basics of operating in BIM, as well as its main benefits in comparison to the conventional method. These benefits were identified as: 1). Provision of accurate and integrated documentation of drawings and other information within a project, and 2). Facilitation of cooperation across teams of different disciplines by use of its work sharing feature⁵. Having these two objectives in mind, we divided the workshops into two major sessions during the course of the lecture, with the first focusing on the students' individual learning of basic element modeling, and the second session, which focuses on the application of BIM's collaborative aspects. The method we hypothesize, would allow students to produce a fully functional BIM model that contains accurate data, and thus able to contribute in a team of inter-disciplinary consultants working in BIM, be it for future projects, or research purposes, thus achieving the two main objectives of using BIM.

5. COURSE IMPLEMENTATION

Having identified the two main objectives to be achieved in the course, we accordingly divided the course materials to be covered in two distinct sections during the lecture. The first part of the course discusses about the principles of BIM, as well as the proper application of its tools, including each of its relation to its respective real construction project counterparts in the first eight week of the course, and the last six weeks were allotted to the discussion and practice of BIM's collaboration capacity. Students were handed full copies of the handout for each of the two sections at the start of these two major sections to allow for self-paced learning, aside from the regular pace of the course.

It is to be noted though that during the second part of the course, we had invited Indonesia's PT. Intiland Development Tbk to lecture on the collaborative aspects of BIM. Being traditionally oriented towards the teaching of the architectural design aspects of a construction only, like most other architectural schools, we had initially found that our current pool of case studies insufficient to demonstrate the inter-disciplinary capacity of BIM. Thus, we hope to make up for this by inviting an industry partner who has had experiences on the subject.

5.1.1. Understanding BIM, and Individual Projects

We started off the course by giving students an understanding of the term "Information Modeling" in BIM, as well as its relevance to construction projects. The following demonstration was done to achieve this.

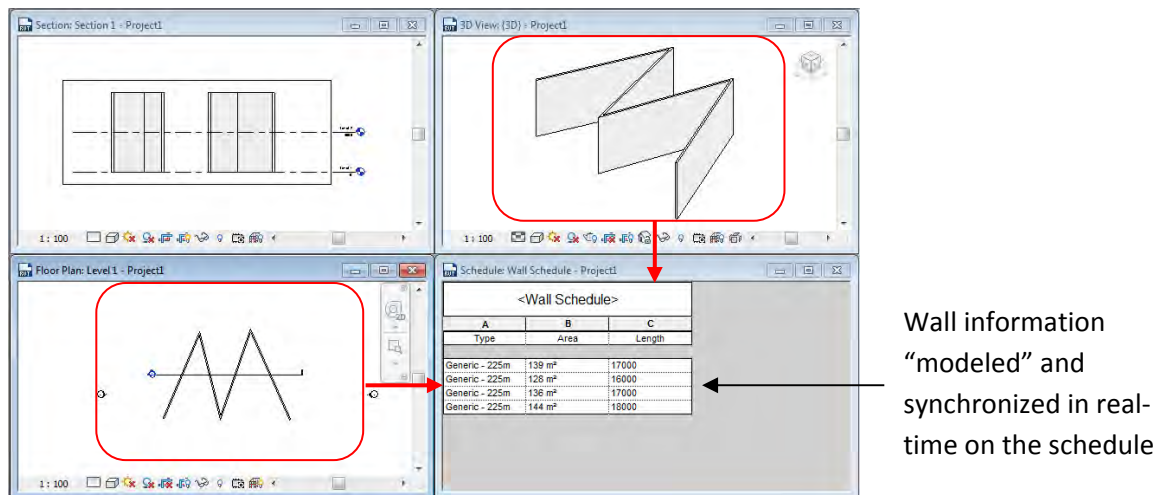


Figure 1. "Information Modeling" Definition Demonstration

Further addition of walls in any of the three opened views (floor plans, sections, axonometric 3D) would automatically result in the addition of information in the schedule views, which is set to show the walls' area and lengths. Hence the demonstration makes its point that the term "Information Modeling" in BIM refers to the automated generation of a building's information (in this case wall area and length) in sync with the creation of its related building element (wall) in the model, as opposed to the conventional methods, where architects and engineers have to finish designing a building first, and have a quantity surveyor manually extracts these information from the finished drawings later.

The following example was also presented to explain to students the efficiency of file, and by extension, project management in BIM:

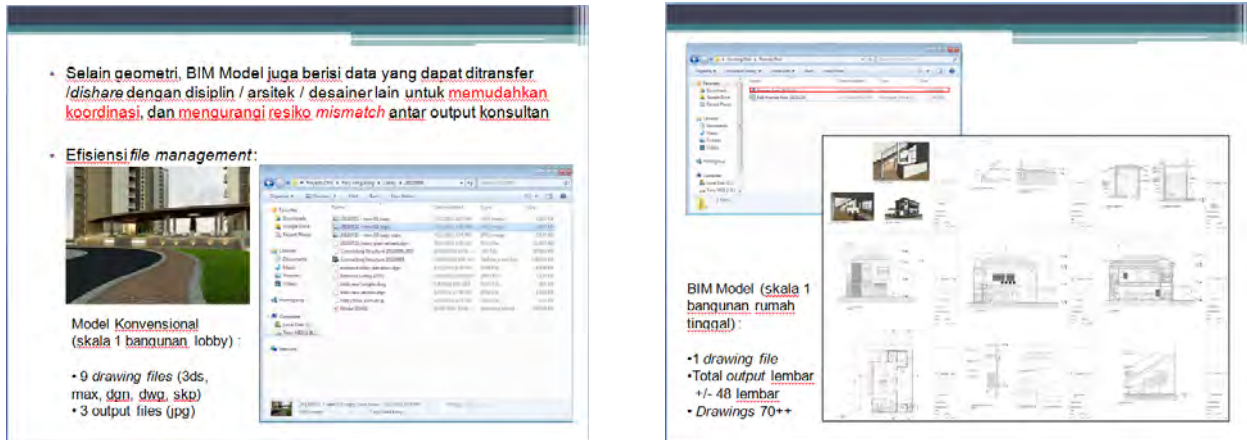


Figure 2. (left) various files used to manage projects in the conventional methods (right) one BIM file containing all of the project's drawings

Having explained the basics of BIM and its benefits, we proceeded to the introduction of building elements in Autodesk Revit, and its real world equivalence in relation with each respective building element's parameters.

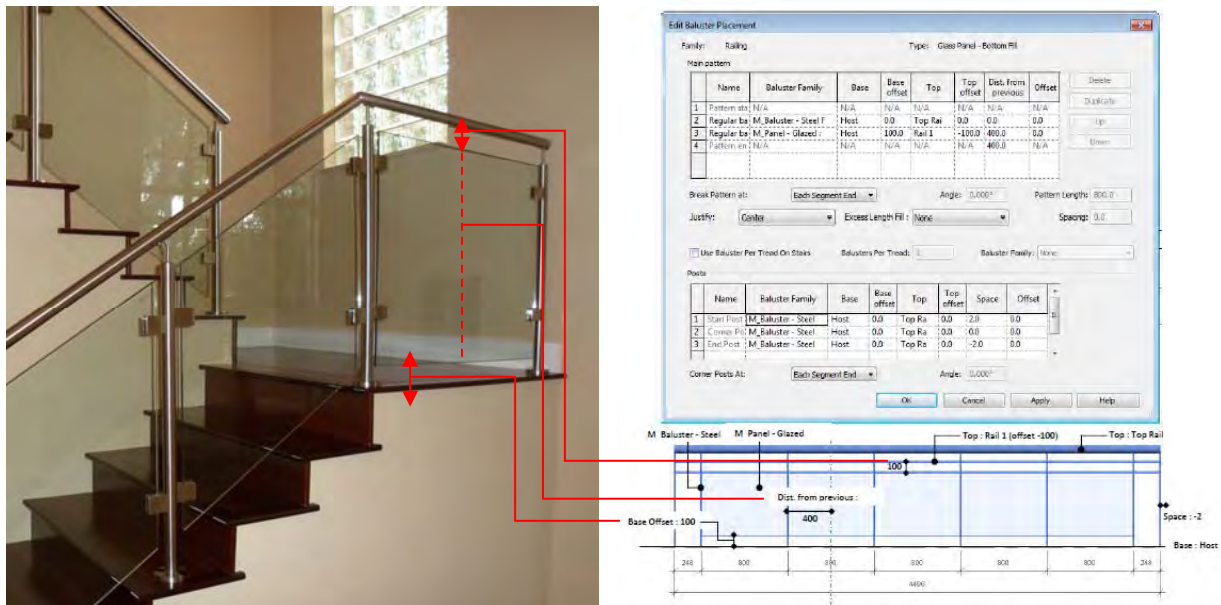


Figure 3. Example of explanation on railing baluster parameters and samples of real-world application

Detailed explanations of each building element's parameters and its real world sample applications were given, up until the eight week of the lecture, where the students are then asked to submit their personally modeled version of the case study given after receiving the CAD version of the model, with grading assigned based on the accuracy of their building information as compared to the information of the original BIM model.

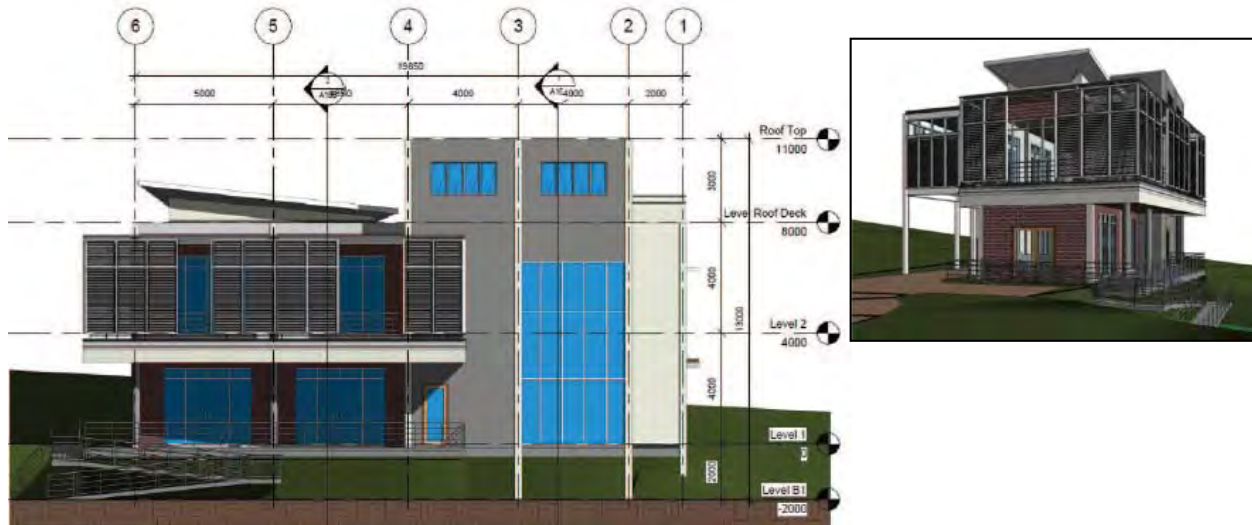


Figure 4. Sample case study of individual project assignment (inset shows the 3D Perspective Approach View)

5.1.2. Collaborative Projects

By the start of the second part of the lecture, which focuses on the teaching of the collaborative aspects of BIM, students are expected to have a solid understanding of basic element modeling in BIM, so as to function in a team of BIM enabled consultants. The lecture started off with representatives from PT. Intiland Development Tbk explaining the current application of BIM in their organization.

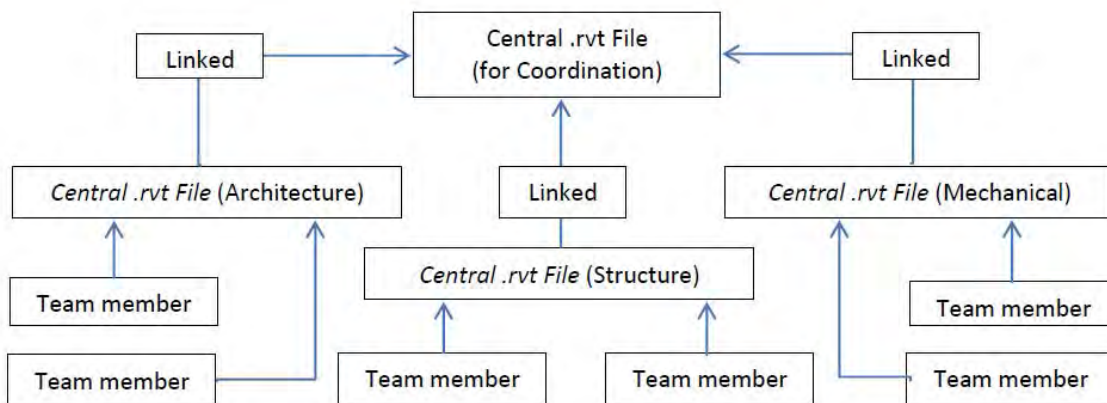


Figure 5. PT Intiland Development Tbk's BIM Collaboration Scheme

The scheme provides students the opportunity to explore both methods in which collaboration is facilitated in Revit, which are: 1) Worksets, and 2) Linked Files, each with its own constraints and benefits. Explanation of matrices consisting of building elements categorization were then introduced, and utilized as the basis of performing clash detections and interferences of building elements

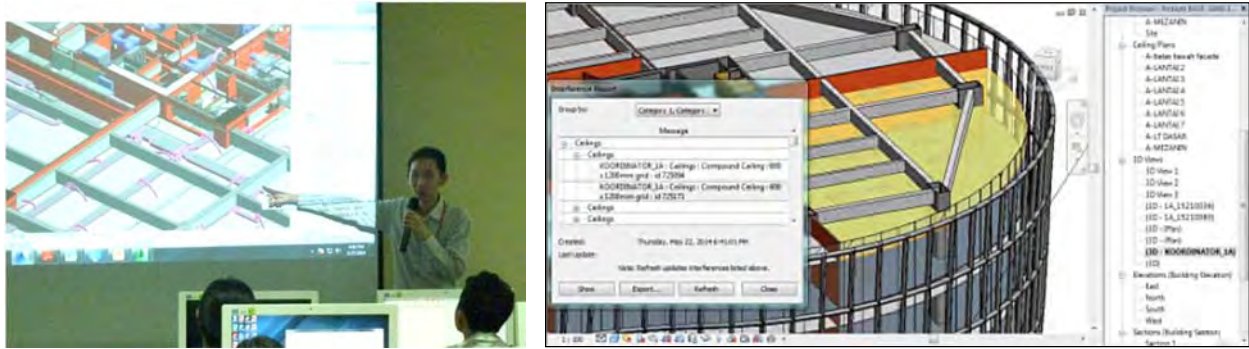


Figure 6. Lecture by Gerry's PT Intiland Development Tbk on Collaboration in BIM & sample student work

Students were divided into groups of four to five persons per team. Each assigned a group identity to allow for cooperation as follows: alphabet (A-C) to represent the individual apartment tower, number (1-9) to represent individual teams, and was asked to do a remodeling of PT Intiland Development's "South Quarter". Grading was given based on each teams' appropriate alignment to the central file of the apartment, which contains the basic level and grids, as well as the podium model of the apartment, and the accuracy of information compared to the original exercise file.

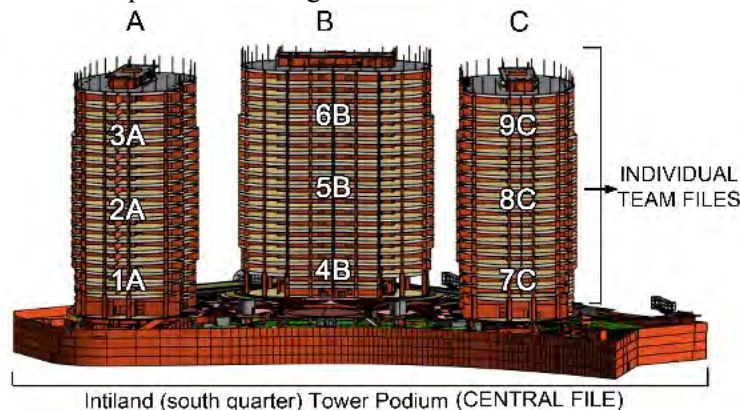


Figure 7. Diagram showing each team's responsibilities, and relation to the central file

The collaborative aspect we introduced in our class puts great emphasis in the process of clash detection studies, which were achieved by using Autodesk Naviswork©. Operations of the software were explained in the early second part of the AR 4122 course.

3. CONCLUSION/FUTURE INTEGRATION DEVELOPMENT-COLLABORATION/RESEARCH OPPORTUNITIES

We realized that there are many aspects of BIM we have yet to cover in our course. Further iteration of the course syllabi will need to be made for the future, especially considering that we have previously integrated the basics of element modeling in BIM into the second year course of AR 2250 – Computational Studio. By doing this, we are hoping that we can allocate more time to teach additional features of BIM such as energy, and lighting analysis in our future BIM course.

Our future plans for the course includes having a joint class between ITB's department of architecture, and ITB's department of applied physics and civil engineering to enhance our intention of pursuing interdisciplinary studies on BIM. We have found that not only collaboration process gives our student a better understanding of construction process and BIM, it also provides a scaffolding opportunity in our class, allowing students who are behind in the course to catch up to their peers when collaborating for a project. There is definitely still room for improvements in the design of our BIM Education course, and we would

welcome any additional inputs and discussions to better ours, as well as other's future efforts to integrate BIM into their curriculum.

ACKNOWLEDGEMENTS

“South Quarter” residential apartment model featured on this lecture provided by PT. Intiland Development Tbk's BIM Division. This course is featured in <http://www.autodesk.com/education/prepare-and-inspire/education-showcase> Autodesk Education Showcase website, under the name of “Taking Collaborative BIM to the Next Level”

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INTRODUCTORY COURSE TO CONSTRUCTION AND FACILITIES MANAGEMENT AT BRIGHAM YOUNG UNIVERSITY

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ABSTRACT

The introductory course in the Construction and Facilities Management program at Brigham Young University introduces students to career options within the construction and facilities management industry. The course also provides the students with a sampling of the coursework topics included within the program. The topical areas of the course include plan reading, using a scale and basic construction math, building information modeling, estimating, scheduling, site selection and project feasibility, project management, and facilities management. Utilizing BIM in multiple applications within the introductory course provides a good foundation for the students to utilize BIM later in the curriculum.

Keywords: BIM, construction management, facilities management, curriculum.

1. INTRODUCTION

The introductory course in the Construction and Facilities Management (CFM) program at Brigham Young University (CFM 105 – Introduction to Construction and Facilities Management) is designed to provide students with an overview of various career options available within the construction and facilities management industry. This course is typically taken by students who are interested in either construction or facilities management and introduces them to the type of coursework that is offered by the program. Students are introduced to plan reading, using a scale and basic construction math, building information modeling, estimating, scheduling, site selection and project feasibility, project management, and facilities management.

The majority of students that currently enroll in the introductory course do not have a background in construction or facilities. Even those students with some background in either industry have typically received that exposure in a laborer type role and generally only received instruction from a supervisor about how to perform basic tasks. Therefore, these few student with some experience have typically not been involved in reading and interpreting construction documents to identify and understand what tasks need to be performed.

2. COURSE TOPICS

2.1 Plan Reading

One of the fundamental skills of either a construction or a facilities manager is the ability to read and understand construction documents. This skill is required because so much information about the facility, from the plan for construction to how it was designed to function upon completion, are contained within

these documents. The documents that the students utilize in the CFM 105 course, including the lecture and homework assignment, are based on a 19,000 sf church building.

The reason that this set of plans was selected is because it was readily accessible, the students are familiar with the layout, and it blends basic aspects of commercial and residential construction. The documents for this project include the plans, specifications, and soils report. The in-class lecture is used to provide an overview and explain the reasoning of how and why each of these documents are structured using MasterFormat. Following the lecture portion of the class, the students are then assigned questions to answer regarding the church project. For example students are asked to identify the square footage of the roof, where the depressed slabs are located, the depth of the geotechnical bore logs, and the lineal footage of a certain size of duct. The questions are designed to help students explore different aspects of the project documents. To help the students understand how the lecture applies to the questions, the instructor then goes through about half of the answers with the class. The questions that are selected help demonstrate to the students the thought process necessary to efficiently find the answers as well as targeting some of the more challenging items to locate. This assignment seems to be effective in providing a good introduction to plan reading.

2.2 Scale and Basic Math

Along with plan reading skills, students also need to understand how to obtain measurements from the plans to help calculate quantities of materials. The students have had previous math classes, but these typically have focused solely on solving problems from a textbook. Although the concept of cubic feet or cubic yards is something they may have learned to calculate many years ago, for some reason students often struggle with interpreting what the concept actually means. When students are introduced to the idea of obtaining material quantities from a set of plans, this is a new approach to applying math. For example, students do basic volume calculations in junior high, but maybe never actually applied it to a real world application. Reviewing this basic skill provides a good refresher for the students and prepares them to begin to perform quantity takeoffs later in the semester. Lecture materials regarding this skillset include information about the units of measurement used in construction. While linear feet and acres are often familiar to the students, Square Feet of Contact Area (SFCA) and Board Feet (BF) typically need some explanation.

2.3 Building Information Modeling

Building Information Modeling (BIM) is the next section covered within the course. BIM is introduced in this introductory course so that the students can continue to be exposed to it in a number of other follow on courses within the curriculum. During this section of the course, the book “*Design Integration Using Autodesk Revit 2015*” (Stine, 2014) is used to introduce the students to developing a BIM model with Revit. Using this book, students go through the basic modeling of a simple building in a single chapter. This is followed by additional chapters that go into more depth on creating floor plans, adding furniture, importing additional components into the model, adding structural elements like footings, beams, and columns, and modeling mechanical systems. The textbook contains step-by-step instructions on how to perform these tasks using the software, and students are able to work at their own pace through these tutorial exercises. During the studio, students work on these assignments with the aid of the instructor and teaching assistants. Literature suggests that BIM aids students in their understanding of construction systems and visualizing the various components (Richards and Clevenger, 2011; Barham et al., 2011; Kim, 2012; and Clevenger et al., 2010). The authors do not dispute that BIM can improve student understanding of construction systems. Although this course has been taught several times using this format, it never ceases to amaze the instructors that many of the students still do not actually comprehend what they are modeling. Unfortunately, the students are just doing what the book tells them to do for the assignment, and not necessarily linking what is being modeled to the various construction systems. Although this simple observation is anecdotal, it continues to be a reoccurring experience with many of the students.

2.4 Estimating

Once the students have modeled the architectural and structural elements of the project, they are ready to receive an introduction to estimating. Students download a completed model and print out the plans for the project. The students then use a scale to measure the quantities for the takeoff. Rather than have the students flounder with determining what to takeoff, a spreadsheet template is given to them to use. The takeoffs that are performed are at a system level, taking off items such as CY of footing concrete and SF of slab. The pricing for these takeoffs is also included in the spreadsheet template. An example of the spreadsheet structure is shown in Figure 1. A link to this estimating template can be found at the following URL:

<http://cmfac.groups.et.byu.net/miller/cm105/assign/Law%20Office/Law%20Office%20EstimateSchedule2013.xlsx>.

Description of Work	Qty	UOM	Prod Rate	UOM	Price	AMT
1 General Requirements						
General Conditions	8.5	mn			\$ 18,000.00	\$ 153,000
3 Concrete						
Footings		cy	1.507	cy /ch	\$ 420.00	\$ -
Foundation		cy	1.750	cy /ch	\$ 560.00	\$ -
Slab on Grade		sf	145.350	sf /ch	\$ 4.00	\$ -
Slab on Metal Deck (SOMD) & Struct Steel Support		sf	41.858	sf /ch	\$ 13.25	\$ -
4 Masonry						
Split Faced CMU		sf	71.792	sf /ch	\$ 12.00	\$ -
5 Metals						
Roof Structure		sf	149.500	sf /ch	\$ 5.25	\$ -
Metal Stairs Architectural		ea	0.025	ea /ch	\$ 15,000.00	\$ -
Metal Stairs		ea	0.025	ea /ch	\$ 10,000.00	\$ -
6 Woods, Plastics Composites						
Cabinets		ls	0.125	ls /ch	\$ 3,000.00	\$ -
7 Thermal and Moisture Protection						
Insulation		sf	215.375	sf /ch	\$ 2.00	\$ -
Roofing		sf	149.500	sf /ch	\$ 3.25	\$ -

Figure 1: Estimate Spreadsheet Template

It is at this point in the semester that the instructors are able to observe that many of the students don't often understand what they have actually modeled. For example, one of the interesting things that typically occurs each semester is that the students ask questions such as, "What are the footings?" Only two weeks prior to performing the estimate, the students were modeling the footings. This leads the authors to believe that just because the students have modeled the footings, they haven't necessarily internalized what they are, why they are there, and where to actually find them. Although current literature has demonstrated that BIM increases the student's understanding of construction systems (Glick et al., 2012; Sah and Cory, 2009), it appears that many students still may need several touch points to internalize their understanding of these construction systems.

2.5 Scheduling

The scheduling portion of the class is very basic. The purpose behind the schedule is to have the students think about the sequencing of construction activities. A template is given to the students for the schedule, and the activities included within the schedule are the same items that were included in the estimate. The scheduling durations come from the estimate that the students had just performed. The productivity rates are provided in the spreadsheet template and generate the durations of the activities.

The students are instructed that the project should take 38 weeks and the schedule should not be any shorter or longer than that. The reason for not allowing a different length is that the students haven't been exposed to or have the background to know how many activities can occur concurrently. Without providing the minimum length, it was found that the students generate a schedule that can be completed in about half the time it takes with typical construction practices. Students receive furthering scheduling and appropriate sequencing in later coursework within the curriculum. A link to the scheduling template used within this course can be found at the following URL:

<http://cmfac.groups.et.byu.net/miller/cm105/assign/Law%20Office/Law%20Office%20Schedule%20Template.xlsx>

2.6 Site Selection & Project Feasibility

Many of the students within the BYU CFM program have an interest in commercial or residential property development or property management. The program offers courses in these areas. Therefore, the students are given a quick introduction to these areas as well in the introductory course.

To introduce the concept of site selection and project feasibility, students first go online to see a detailed property map of Utah County. (See <http://maps2.utahcountyonline.org/ParcelMap/ParcelMap.html>) Using this website, the students are given three different properties to consider for constructing the project that they have modeled, estimated and scheduled. The first parcel is located in a grocery store parking lot, the second is near a river in a developing area, and the third is located in a professional business park.

As with other assignments within this course, the students are given a spreadsheet template and also some financial consideration to apply to each property. The students are taught how, and then asked to perform an analysis of each property given the financial constraints as well as the size and location of each property. The students also perform a Strength, Weakness, Opportunities, and Threats (SWOT) analysis of the different properties to help them decide the most appropriate property for locating the building.

After the students have selected a site, they then download the property lines from the county website and incorporate this information back into their model. The students then propose an appropriate location for the building on the site, and arrange the parking configuration given the constraints of the assignment. The students are also encouraged to add landscaping and other components to the site to make it realistic as possible. An example of this is shown in Figure 2.

2.7 Project Management

In the project management portion of the class, students export the property boundaries and the location of the building on the site to a PDF document to create a site management plan. Students then open the document in BlueBeam and annotate on the site the location of the following: fence, site trailer, laydown/staging area, employee parking, traffic patterns, and gates. While this isn't an in-depth experience, it starts the students thinking about consideration that must be made concerning how to build the project on the site.



Figure 2: Final project image

2.8 Facilities Management

A brief introduction to facilities management is also included within this introductory class. Our program consists of both a construction management and a facilities management emphasis, and both require enrollment in this course. Although this topic may seem more relevant to the facility management students, the construction students also benefit from understanding the post-construction needs of the building. Further, facilities managers have also begun to explore how BIM can be utilized to benefit their industry (Wang et al., 2013). Since the introduction to BIM is a large component of this course, students begin to appreciate the true life cycle process of a building. The facilities management topics are currently covered primarily by guest speakers. However, the instructors for this class are exploring other course assignments that could be included within the course to help the students understand BIM use with facilities management.

3. CONCLUSIONS

This paper provides a detailed example of an introductory course using BIM for construction and facilities management students. This course continues to evolve each semester, and as new technology or processes are being adopted by industry these are being incorporated into the course. The instructors are currently in the process of evaluating how to add the following two items to the course:

- Strengthen the plan reading skills by spending additional time on this subject
- Incorporate a BIM space planning exercise

In general, in its current format this course has been a great introduction to construction and facilities management. Students are able to participate in hands-on experiences in several different areas of both industries. The format of the class is highly interactive between the instructors and students, which students appreciate. It also provides the students with good foundational knowledge that they are able to later utilize in future coursework. For example, students rely heavily on the introduction to BIM received in this course when they later take Construction Modeling, Scheduling, and Estimating. Since the students receive this introduction to BIM early within the curriculum, the faculty continue to look for other ways of incorporating the use of BIM within other coursework.

As indicated in this paper, the authors acknowledge that although BIM enhances students understanding of construction systems, many different touch points are still necessary to solidify these concepts. We have found that using the plan reading, building information modeling, estimating, and schedules sections of the course provide multiple opportunities for students to conceptualize various construction systems. The authors have found that simply performing the modeling alone is not as effective without incorporating the other tasks within the course. The later sections of estimating and scheduling help to further solidify the students understanding of the various construction systems.

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TWO YEAR GRADUATE TRANSDISCIPLINARY BUILDING LIFECYCLE CORE CURRICULUM

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...liberal education provides students with the intellectual capacity to make sense of their environment and reflect on their place in the world. Professional education, by contrast, must provide the knowledge essential to a particular field of endeavor but also ways in which students can engage this knowledge for the common good." Sullivan and Rosin, A New Agenda for Higher Education: Shaping a Life of the Mind for Practice (Sullivan, 2008)

Conservatism in human beings may be characterized as behavior by individuals who possess a reluctance to update their beliefs in the face of new information. Chen, The physical foundation of economics: an analytical thermodynamic theory (Chen, 2005)

ABSTRACT

The authors propose a theoretical framework and rationale for the design of a two year graduate building core program as well as its collaborative project based pedagogy. This paper is a proposal for the curriculum design.

This curriculum is designed for the education of **all** professionals participating in the life cycle of a building project. Its framework is based on the evolution of building information models as they have incorporated into the life-cycle of the building process. Standards have been developed and approved describing the need, design, construction, management and end of use for the project. The detailed activities described in the standards are adapted for a transdisciplinary building life-cycle curriculum for a two year graduate academic program. The core program consists of four phases: Demand, Acquisition, Use and Demo/Recycling. The intent of the curriculum is to break down the barriers between academia and practice through the use of feedback loops. The pedagogy is based on collaborative project based workshops (which mimic practice) that will educate all professionals who are active in the building process. Through these workshops, these professionals will hopefully learn to respect the work of others across the building process. Underlying the pedagogy and curriculum will be a digital tool system (evolved BIM) which permits realtime updates of design decisions for all design and performance criteria for the project. The core program will be the basis for additional courses required for accreditation and licensure in the building arts or a terminal master's degree.

Keywords: Core Curriculum, Transdisciplinary, Collaboration, Project Based Workshops, Graduate Program

INTRODUCTION

In two articles published in JBIM: "A MODEST PROPOSAL FOR A TRANSDISCIPLINARY CURRICULUM..." (Henderson RA, 2009) and "TEACHING FOR COLLABORATION: ..."

(Jordan, 2010), the authors proposed the intellectual framework and rationale for a graduate two year transdisciplinary building life cycle core program with projects based on a collaborative pedagogy. This paper describes in detail the design for that curriculum.

DESIGNING A BUILDING LIFE CYCLE CURRICULUM SYSTEM

The “modest proposal” is the design for a curriculum that attempts to resolve the problems and conflicts within an industry due to the separation of professional education across the building industry fields. This curriculum also has the potential to enhance the effectiveness of the building services to the community it serves. As stated, the curriculum is designed for the education of **all** professionals participating in the life-cycle of the project: owners, designers, contractors, facility managers and users.

The intellectual origins of the curriculum are found in proposals made by the IFC developer, International Alliance for Interoperability (IAI), starting in the early 1990’s. One of the important concerns of the developers was how IFC’s were to be applied to the design process, construction and management software. The notion and vision of the building lifecycle as a design process was discussed and diagramed in many forms and forums.

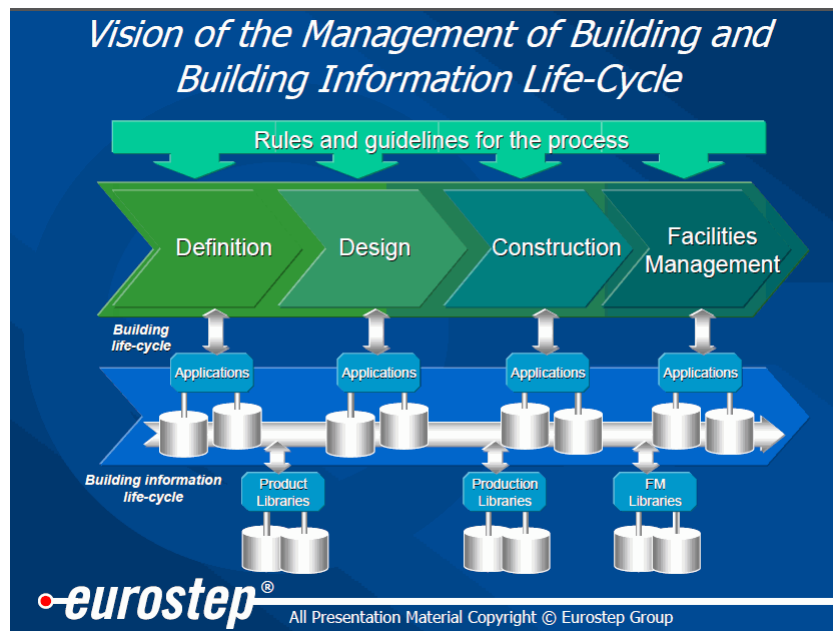


Figure 1 IFC Life-Cycle Vision (Houbaux, 2003)

The eurostep visionary diagram (Figure 1) developed by Houbaux establishes the relationship between various digital components and elements in the lifecycle design process. A second diagram (Figure 2) describes various software applications, users and their roles during the life-cycle of a project.

In addition to the program structure based on the life-cycle building process there are additional pedagogic elements, attributes and properties necessary to make the program successful, dynamic and feasible. The following are the elements that are essential to the core of the curriculum and are in no particular order:

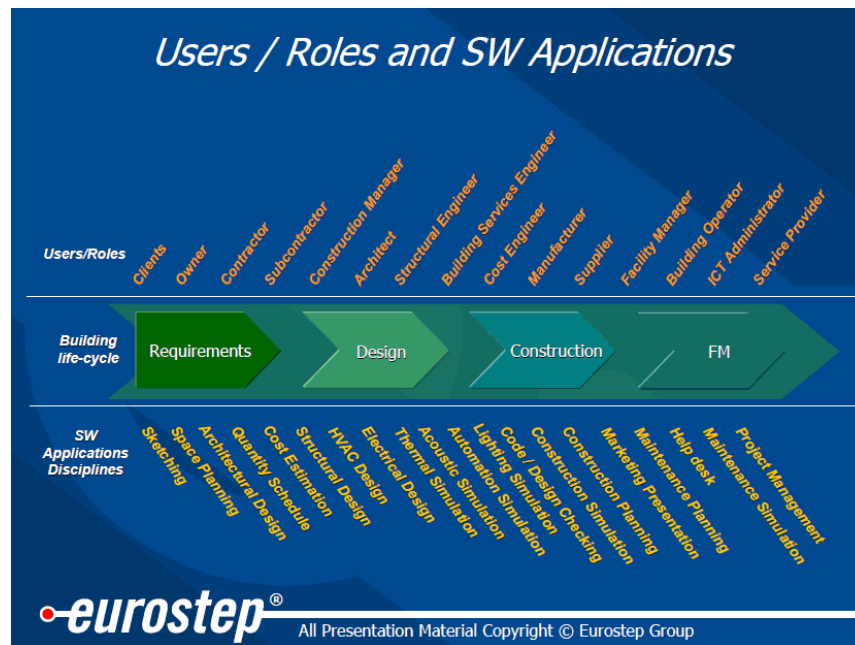


Figure 2 Users/Roles and Software Applications (Houbaux, 2003)

1. The “epistemology” (framework and the internal structure of the process of reasoning) (Maruyama, 1976) shall be general systems theory and thinking(von Bertalanffy, 1968) (Churchman, The Systems Approach, 1968) (Emery, 1972)(Meadows, 2008). A systems approach will provide a common cognitive model for all professionals as well as giving cognitive structure for a complex system.
2. The program will be a graduate program. Research in learning theory suggests an adult learner has the maturity, cognitive skills and sense of self which is an appropriate time for professional education. (Knowles, 1998)
3. An undergraduate pre-building set of academic courses are required. This is similar to law and medicine.
4. Project based collaborative workshops are to be the center of the professional curriculum with consultants drawn from relevant knowledge communities (transdisciplinary) within the university. This pedagogy mimics practice. (Jordan PhD, 2010)
5. All building professionals need to be educated with the similar values resulting in mutual respect for all members of the building team.
6. The paradigm shift of tool systems from a stable transparent linear analog toolset to an evolving interactive real time digital tool system is an evolutionary challenge for students, faculty and practitioners. The underlying building information model (BIM) is the data format for the life-cycle of the project. This tool system with further development needs to become more transparent and stable.
7. As part of the life-cycle education and practice system there will be an extensive set of feedbacks loops between students, faculty, and practicing professionals as means of informing both elements of teaching, learning, research and practice.

Thus, by establishing the criteria for such a program, we need to look for a model for the building life-cycle that can be used as the basis for designing the graduate curriculum.

LIFE- CYCLE

Within the literature there are numerous versions of the building lifecycle diagrams. Some are generic and others more specific. After reviewing the various diagrams, the authors have selected a vetted ISO building lifecycle standard which was designed and developed for the building industry and which would be the most appropriate model.

The curriculum is based on “ISO 15686-10 Buildings and constructed assets-Service life planning-Part 10 When to assess functional performance” (Figure 3). In adapting the life cycle process documented in the standard, the proposed curriculum framework incorporates additional pedagogic layers for workshop design, scholarship, research and professional skills as well as feedback systems from practice.

The standard and its diagram have described discreet activities throughout the life cycle process. The “Overall Enterprise” is divided into four major stages governing the life cycle of a project: Portfolio Management, Project Delivery, Property management, and Disposal. Each phase has been divided into stages with a specific set of tasks necessary for completion of each phase. Within the standard itself the tasks have been further broken down into sets of requirements to accomplish and complete various tasks in the lifecycle process.

Thus, the standard provides a curriculum framework for the collaborative project based workshop pedagogy.

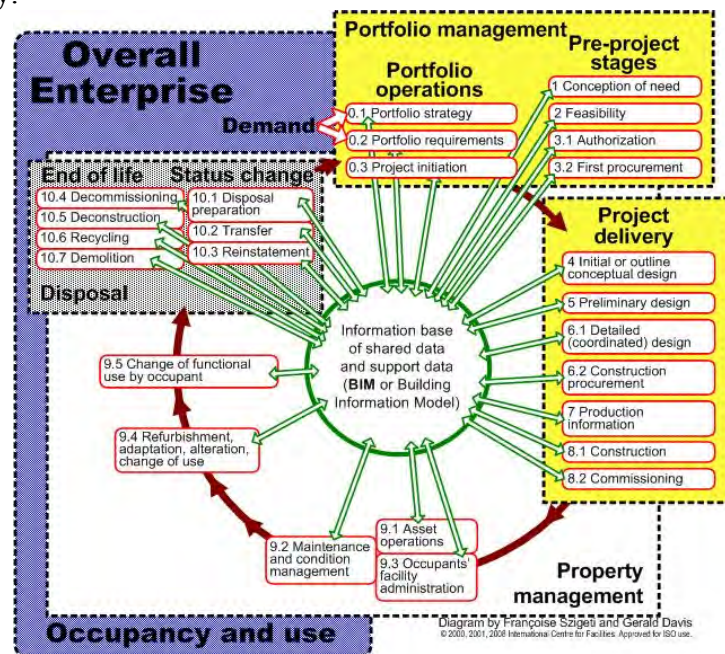


Figure 3: ISO 15686-10 Life-Cycle Diagram (Szigeti, 2008)

EXISTING ACADEMIC MODELS

Prior to the actual design of the curriculum, we reviewed various professional school curricula to determine if there was a curriculum format that was appropriate for the building lifecycle core curriculum. The learned professions (licensed by states and necessary for title or practice): law, medicine, architecture, engineering, and accounting have adopted various educational curricula models for the education of their respective disciplines. Accounting, engineering and a majority of architectural programs are undergraduate curriculum. Law, medicine as well as some architectural programs are at the graduate level.

In evaluating the various professional programs, the four year medical curriculum with a two-year preclerkship core program seemed closest to our proposal (Cooke, 2010). Medical schools have developed three formats for their preclerkship curricula: discipline-based, organ-system or integrated medical studies and case-based. Of the three formats the problem-based and case-based learning model is the latest in the pedagogic evolution in medical education. They find that problem-based learning (PBL) “is the essence of discovery learning (Sweeney, 1999) and is aligned with the premises that learning is participatory and distributed” (Cooke, 2010, p. 80). It is important to note that during the preclerkship years, all medical students are socialized as future physicians thereby developing a consistent value system and knowledge about the domain of human health and the practice of medicine. As students explore various clerkships in the third and fourth years, the problem based learning process is reinforced.

Below are two examples of the two-year core curriculum for medical school. The examples have the same intellectual content, but the curriculum is designed to educate the students using different pedagogies. The Georgetown University program (Figure 4) uses a problem and case based approach covering a diversity of medical and practice based topics. The UCLA program (Figure 5) approaches education on the organ based model with doctoring and clinical based skills.

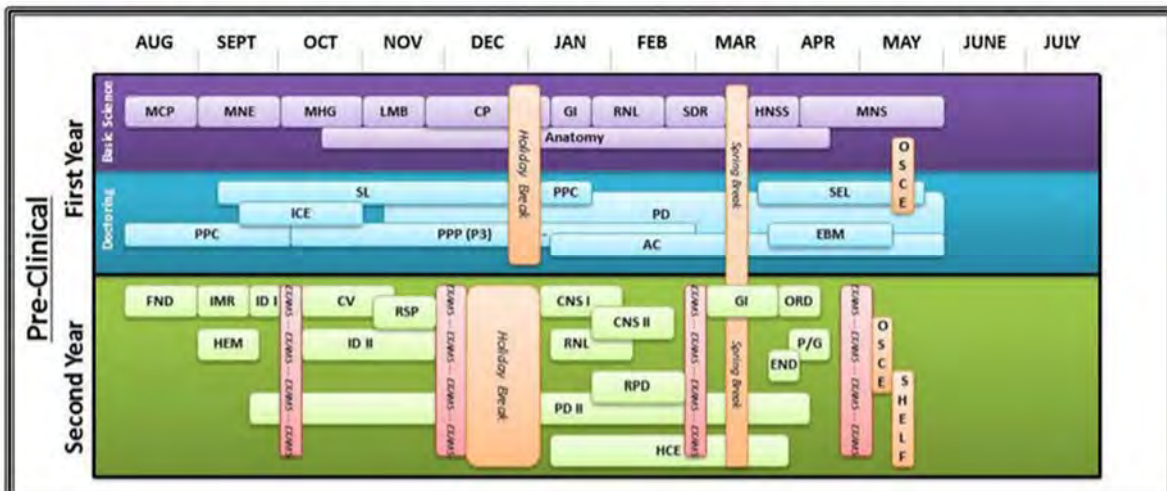


Figure 4: Georgetown University School of Medicine Pre-Clinical Curriculum (Georgetown University School of Medicine, 2013)

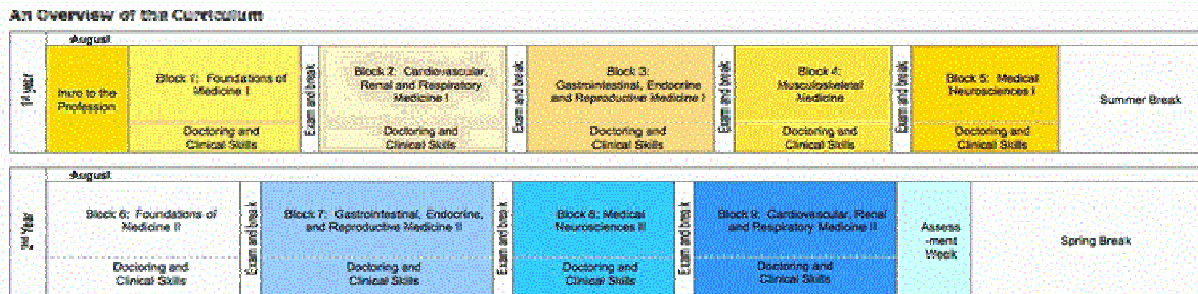


Figure 5: UCLA School of Medicine Pre-Clinical Curriculum (David Geffen School of Medicine at UCLA)

Thus, we have pedagogic models in graduate level programs as examples of teaching a complex and comprehensive knowledge system--the human body. However, unlike medical education, the building core program requires a curriculum that focuses on the lifecycle of non-existing human artifact-architecture.

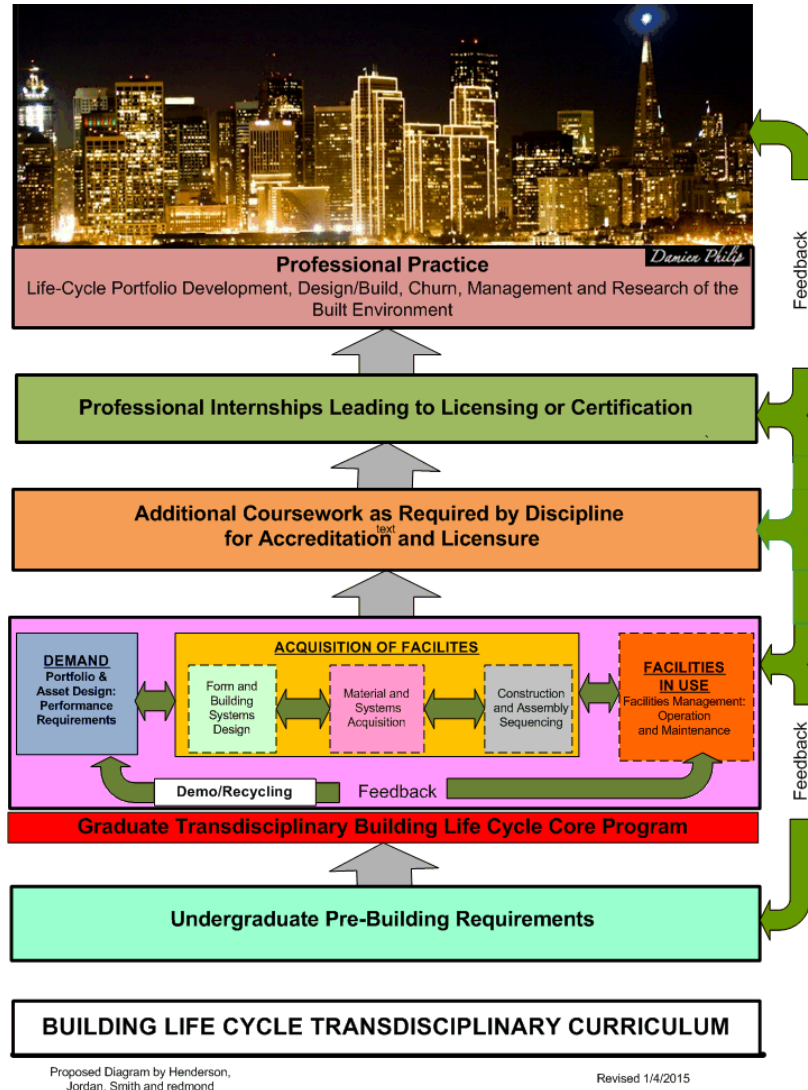


Figure 6: Building Life-Cycle Graduate Transdisciplinary Curriculum (diagram by authors)

PROPOSED TRANSDISCIPLINARY BUILDING LIFE CYCLE CURRICULUM

With established criteria--a life-cycle standard for the building industry, as well as evaluating comparative curricula and pedagogic strategies, we propose a transdisciplinary building life cycle core program that is divided into major syllabus components: Demand, Acquisition of Facilities, Facilities in Use and Demolition/Reuse. The pedagogy will be collaborative project based workshops/learning (Jordan 2010). The workshops will be supported by appropriate knowledge systems within the University and practitioners from the industry. The diagram below describes the content and relationship within academia and the building industry system.

As noted in Figure 6 the proposed curriculum system is structured as five interrelated elements:

1. An undergraduate “pre-building” set of required courses. Due to the social and cultural impacts of the built environment, the prerequisites will be diverse not only in the general requirements but in the selection of a major and a related and unrelated minor.
2. The core graduate program is, as noted, divided into four general components. The core program can be incorporated into an existing building related discipline or established as a separate program. For those who are interested or have degrees in related disciplines, the core program can be a terminal Masters degree. For example, an individual with a degree in civil engineering can take the program if they are interested in pursuing a career in the building industry.
3. The third element describes additional coursework as required for professional certification in accredited programs as well as for personal academic pursuits.
4. Many professions in the building industry require that the individual pass through a professional internship and take licensing or certification exams.
5. As one has finished their education, passed through the internship and licensing process, they become practicing professionals. As part of the health, safety and welfare mandate, professionals should actively contribute to the educational feedback loop.
6. Project based learning will consist of topics found in ISO 15686. Each topic will have a defined topic and be supported and facilitated by appropriate faculty from within the schools of the university as well as practitioners who specialize in the project topic. The bathroom design problem described in the 2010 JBIM article has numerous areas of specialization necessary for the design of a bathroom.
7. University faculty and practitioners will be educated in the PBL process and the art of teaching collaborative skills.

As with all the proposed elements in the professional education process, the most important element is the feedback loops that exist between the various components. The feedback loops are essential in taking the real world practice and knowledge and testing it and incorporating it into an evolving curriculum. This educational process is essential and critical in a rapidly evolving and developing building environment.

DISCUSSION

Undoubtedly, this proposed curriculum may generate interest with substantial comments. Below is selection of possible topics for discussion.

1. Concerns:
 - a. Issues of program complexity
 - b. Holes in life cycle knowledge and needed research
 - c. Digital tool development
 - d. Industry interest and acceptance
 - e. Willingness of faculty and university to start such a program.
 - f. Can the program only exist within a university that has the knowledge communities to support the curriculum?
 - g. The establishment of appropriate accrediting, faculty, student and professional associations
 - h. Educate faculty as well as professional adjuncts for project based collaborative teaching.
2. The Positives:

- a. Improved decision making, design, construction and maintenance within building industry
- b. Real time sustainable/resilient design, simulation and analysis.
- c. Collaborative problem solving skills
- d. Developing mutual respect among all building professionals
- e. Redefining and providing a life cycle design and decision criteria
- f. Permits a professional within the industry design to knowledgably and efficiently incorporate additional disciplines in to their practice.
- g. Respond to changes in internship and licensing requirements.

CONCLUSION

The proposed “Transdisciplinary Graduate Building life-Cycle Curriculum” is an attempt to design an academic program that resolves many of the conflicts and problems within the education of professionals within the building industry. With the changes in tool systems, the change in professional relationships, new business delivery systems, as well as ecological constraints and the emerging issue of resource limits, it behooves us to explore educational option that meet the needs of the future.

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ENHANCED COLLABORATION BETWEEN CONSTRUCTION MANAGEMENT AND ARCHITECTURE STUDENTS UTILIZING A BUILDING INFORMATION MODELING (BIM) ENVIRONMENT

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ABSTRACT

To enhance the educational value of the existing-graduate-level Building Information Modeling (BIM) course at Arizona State University (ASU), the authors have developed a curriculum that will bring students together from the Construction Management (CM) and Design School (Architecture) programs. The students will collaborate on a real-world design-build (DB), BIM integrated solution model, to serve as a semester course project. By implementing dual-function teams and a course project, the instructors will initiate communication and coordination between the interdisciplinary students. The goal will be to task the student Design teams with the creation of information rich, evaluative BIM iterations within their studio environment, coordinate with the CM students at defined intervals (i.e. 30%, 60%, 90%) to make informed project decisions, and enlist the CM students to provide real-time feedback and CM-specific deliverables such as schedules, estimates, and constructability reviews. Generating a dialog between students and faculty across these disciplines, and introducing a high level of collaboration between the Schools will provide additional value to each of the programs. This type of curriculum will ultimately provide the students with an applied project experience that can be easily transferred to industry. It is expected that this program will be expanded into a broader alternative project delivery method (APDM), DB, integrated project delivery (IPD) education model that will utilize the full resources of all related disciplines within ASU (CM, Architecture, Facility Management, and Engineering Disciplines).

Keywords: Pedagogical Models, Interdisciplinary Approaches, Curriculum Integration, Sample Courses & Sample Lessons, Building Information Modeling (BIM)

1. INTRODUCTION

As building information modeling (BIM) becomes more prevalent in the AEC industries, it is important for educational models to respond and prepare incoming professionals for the multitude of opportunities presented by the changing landscape. Educational responses have come in the form of differing pedagogical models including but not limited to remote course learning, interdisciplinary collaboration approaches and distance learning collaboration (Barison et al.). It is the emerging belief that students must be properly equipped with both technical skills and management skills in order to successfully navigate the industry as related to effective BIM implementation (Pikas et al. 2013). In response to the need for collaboration skills in industry, instructors at Arizona State University (ASU) intend to link

ADE-522: Advanced Architectural Studio II and CON-575: Information Technology for Construction (both Master's level courses in the Design School and the Del W. Webb School of Construction (DEWSC), respectively) in order to help students validate design decisions through continuous question answer process via the vehicle of iterative model transfer between architecture and construction management students (Denzer et al. 2008). Therefore the definition of BIM that will be introduced to the students involved with this course will be: a modeling technology and associated set of processes to produce, communicate, and analyze building models (Eastman et al. 2008).

The goals of merging these courses are to begin the creation of an enhanced collaborative educational model between architecture and construction management students through the utilization of a Building Information Modeling (BIM) integrated solution model as a means for a semester project deliverable and to begin researching student responses to collaborative BIM environments within the Arizona State University educational model. The purpose of this approach is to provide students with the necessary technology skills to execute BIM as well as introduce collaboration and BIM process management through a multi-disciplinary project-delivery framework.

This paper attempts to create and organize the initial framework from which the instructors will navigate the first course offering during the spring semester of 2015 by analyzing current trends in BIM education and alternative project delivery methods. The multi-faceted approach to technology and collaboration integration is an attempt to highlight the needs of the industry landscape as illustrated by the Macleamy Curve (CURT 2004). This framework will also present an updated methodology of education in response to the changing requirements of the National Architectural Accrediting Board (NAAB) and the American Council for Construction Education (ACCE). The linked-course aims to address the following mandates of each of the accreditation boards:

- 1) NAAB Condition for Accreditation (NAAB 2014)
 - a. Integrated Architectural Solutions
 - i. Research
 - ii. Integrated Evaluations and Decision-Making Design Process
 - iii. Integrative Design
 1. "Ability to make design decisions within a complex architectural project while demonstrating broad integration and consideration of environmental stewardship, technical documentation, accessibility, site conditions, life safety, environmental systems, structural systems, and building envelope systems and assemblies
- 2) Section 3.3.2. of ACCE (ACCE 2011)
 - a. Critical Thinking and creativity
 - b. Use of Information and Communication Technology
 - c. Current Issues in Construction
 - d. Complex Project Decision Making and Associated Risk Management
 - e. Advanced Construction Management Practices

In a statement by Denzer et al., moving from traditional Computer-Aided Drafting models of education to BIM education requires more than the basic introduction of a new tool or technology (Denzer et al. 2008). Through utilizing BIM in a dual-discipline environment the instructors will introduce a larger problem set for the course project including topics such as programming analysis, code compliance, structural analysis, MEP analysis including energy simulation and life-cycle decision making, construction economic factors, advanced construction techniques such as prefabrication, modularization and digital fabrication, and integrated construction scheduling.

2. BACKGROUND

The utilization of BIM in the AEC industry is trending upwards as is shown in FIGURE 1 (RIBA, 2013). One of the major reasons why this growth has been building momentum is widely attributed to the need

for increased collaboration amongst the many stakeholders involved in a construction project. As the AEC industry is challenged with providing higher productivity rates, lower construction costs and increased overall project quality while also facing an increase in project complexity, the use of BIM as a cross-disciplinary tool that can aid in accomplishing these goals will gain more momentum. As such, it is paramount that educators at the university level tailor the curriculum to ensure that students have been introduced to BIM, understand the proper usages for BIM and create an environment where collaboration is not just encouraged but engrained in the learning culture.



FIGURE 1 - Awareness and use of BIM: comparison (RIBA, 2013)

One of the key components of instituting a collaborative culture at the university level is placing the students in an environment that fosters such a workplace. Having the students work in silos or placing them in teams within a standard computer lab does not suffice, nor does it emulate the AEC industry in terms of how a project is created, designed and constructed. Co-location becomes key to project success along with specialized group environments. Each element of the process of project creation and execution requires an immense amount of coordination. At ASU, this topic was studied extensively, attempting to create the optimum environment that would not only mimic the AEC work place, but also give the students the tools and resources to encourage collaboration. The result of this research led to the creation of the Virtual Construction and Collaboration Lab (VC²L) (Chasey et al. 2012).



FIGURE 2 – Perspective view of VC²L (Chasey et al. 2012)

As can be seen in FIGURE 2, the layout of the space is such that students are continually interacting with each other in the classroom setting while the instructor is able to communicate to the students through a variety of presentation tools. This classroom setting has been replicated and is being used for a variety of courses at the DEWSC, including CON 575, providing the students the workplace in which to utilize the BIM tools being discussed during the semester. It will be simulated as such to represent a co-location as is employed in the (AEC) industry on similar projects which utilize the same or like processes, systems and BIM authoring tools.

By using this collaborative space, the CON 575 students will be able to effectively communicate with ADE 522, utilizing the same BIM authoring tools. In addition, this cross-disciplinary approach is an extension of the evolving curriculum in the DEWSC and Design School at ASU, again in direct response the NAAB and ACCE accreditation requirements. This evolving curriculum is noted in Figure 3, and the resultant CON 575/ADE 522 efforts will be a continuum of providing students at ASU an education that fully prepares them for entrance into industry. As noted by Becerik-Gerber et al. the academic community has been trailing industry in the implementation of BIM, while traditionally university research is at the forefront of emerging technologies (Becerik-Gerber, et al. 2011). While this can be partly attributed to resources available at the

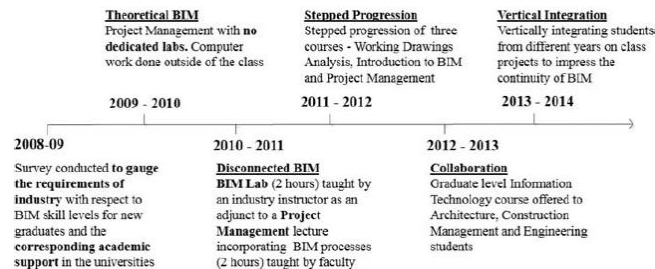


FIGURE 3 – Chronology of BIM Education at ASU (Ghosh et al. 2014)

university level, it is clear that industry has adopted BIM and both undergraduate and graduate level programs must embrace this evolution in order to stay abreast with the AEC industry, utilizing the same multi-disciplinary approaches (Becerik-Gerber et al. 2011).

The ongoing evolution of this curriculum will also follow a natural progression that mirrors the growth of the AEC industry towards alternative project delivery methods (APDM). From simple design-bid-build (DBB) projects to more advanced APDM systems such as design-build (DB) and integrated project delivery (IPD) one can see in Figure 4 and Figure 5 how these iterative processes are linked between academia and industry. As projects become more complex and owners demand more of the design and construction teams, the need to begin collaborative efforts prior to completion of design is required (FIGURE 4) and as the complexity of the

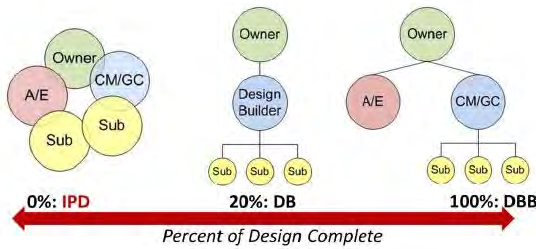


FIGURE 4 - Differences between DB, DBB and IPD. (E) Asmar et al. 2013)

academic curriculum increases so does the need for enhanced collaborative efforts (FIGURE 5).

Through the maturation of AEC-focused academic programs, the curriculum can begin to match more closely the evolution of industry, specifically in regards APDMs. It would be beneficial then for academic programs such as CM, architecture and related engineering disciplines, to model courses and therefore entire programs accordingly. Enhanced collaboration across academic programs is certainly a step in the right direction, as well as ensuring that the curriculum is reinforced throughout the student's coursework. Future course offerings or specific programs focused directly on APDM methodologies may create the response required to carry knowledge gained in an academic setting seamlessly into industry.



FIGURE 5 – Enhanced Collaboration through course evolution

3. BASIS FOR ENHANCED COURSE INTEGRATION

While BIM has become a focal point of curriculum development within the Del E. Webb School of Construction at Arizona State University, the authors believe that an enhanced collaboration environment utilizing a cross-disciplinary pedagogical model will enhance student learning and provide greater value to BIM education as a whole. In order to begin validating this theory, the authors administered a short survey to previous students involved with education at both the Del E. Webb School of Construction and the Design School at Arizona State University. This survey was tailored to highlight ways in which previous students learned BIM tools and the BIM process as well as their expectations for material application within the industry environment. The survey responses can be seen in Figure 6. While the authors acknowledge the limitations in regards to responses collected, the information provided, and initial review of provided responses, did highlight the disparity in BIM education as compared to the cross-disciplinary collaboration expected in industry. Review of the short answers from question number six begins a conversation in regards to past approaches to BIM education and current trends in perceived BIM needs for successful integration into the architecture/engineering/construction (AEC) industry.

Student Respondent	1	2	3	4	5	6	7	8	9	10
1) How did you learn Building Information Modeling (BIM)										
1. Through a specialized course in school				X	X	X	X	X	X	
2. Through an integrated curriculum in school	X									
3. Taught yourself		X	X							X
4. Don't know BIM										
2) Have you collaborated with other disciplines through the use of BIM?										
1. Yes	X		X	X			X	X	X	X
2. No		X			X	X				
3) If yes, what disciplines have you collaborated with(circle all that apply)?										
1. Architecture	X		X	X					X	X
2. Structural Engineering	X		X	X			X			X
3. Mechanical/Electrical Engineering	X		X							X
4. Civil Engineering	X			X			X			X
5. Construction Mngmnt.	X						X	X		X
6. Facilities Management	X						X		X	X
4) Do you use BIM as a model authoring tool?										
1. Yes			X	X			X			X
2. No	X	X			X	X		X	X	
5) Do you anticipate using BIM in your career? Or do you currently use BIM in your position?										
1. Yes	X	X	X	X		X	X	X	X	X
2. No					X					

Question 6) Short answer responses as additional description and follow-up to question 5 from above (anticipated uses for BIM in industry as perceived by each respondent):

Student 1	Design-Build Environment
Student 2	To design, collaborate with other professionals, and to manifest architectural construction documents.

Student 3	I currently use BIM in my office to create construction documents, coordinate placement of structure, mechanical ducts, electrical outlets and lines, plumbing fixtures, and A/V equipment. It helps, but sometimes Revit gets in the way of just drawing what is needed.
Student 4	I use BIM in my research study for understanding Construction Quality control by investigating the differences between as-designed model (BIM) and as-built data (Laser scanning).
Student 5	Yes. I am tracking to become a professor in a construction management program teaching mainly project controls. I plan to show the value that BIM can bring to the management of construction projects, specifically estimating, scheduling, planning, and clash detection.
Student 6	In facilities management to manage the buildings.
Student 7	As project engineer or while in working in pre-construction I need to have basic knowledge of BIM so I can find estimates, review go through drawings, track changes, perform clash detection , etc.
Student 8	I anticipate using BIM by doing clash detection, answering subs questions regarding placement, efficiency modeling and probably multiple other way
Student 9	In academia, I plan to continue educating others in the use of basic uses of BIM, the collaboration potential and partnering with industry to demonstrate how BIM is being utilized across multi-disciplinary teams.
Student 10	I plan to engage in management of the BIM process on advanced technology facilities in order to streamline the design, construction, and operations process in order to help shift the curve in capital costs and operational expenditures

FIGURE 6 – Survey Responses

4. PROPOSED METHODOLOGY

The authors think of “integrative,” not only as integration of disparate components into a unified design, but also integration of related Academic Disciplines as well as industry professionals into a singular experience. By engaging both academia and industry within the course program, the learning outcomes will be enhanced and reinforced through discussions pertaining to cutting-edge industry designs, business models, and delivery-methods. Through the use of a synchronized cross-disciplinary schedule between the architectural course offering ADE 522 and the CM course offering CON 575, the instructors will utilize dual discipline lectures, lab sessions, and enhanced studio collaboration periods. BIM software will be employed throughout the course for enhancement of the traditional design and construction processes in order to replicate advancing industry trends.

The incorporation of BIM into the process allows students to more accurately simulate the “complex whole” of a proposed building. In essence, the use of BIM allows for a complete visualization of the resultant physical systems and management implications on design decisions. The iterative nature of the design process will be simulated and translated into a pre-construction module to engage Construction Management students early in the process. Real-time feedback loops between the two disciplines will be utilized to help inform design decisions through the use of traditional construction management deliverables such as schematic cost estimates, constructability reviews, schedule and logistics tied to the groups BIM.

In order to ensure that the process is documented for consistency across platforms, an overall process mapping exercise will be undertaken by each team in order to properly plan for the utilization of BIM during the semester. This living document will engage students in properly planning for the implementation of BIM during the simulation of the design and preconstruction processes and help gauge the progress of each group over the duration of the course. Incorporating this pre-planning process will aid the students in visualizing the separate components required to execute the project, as well as the interaction between components. Not only will this establish accountability among team members, the

group can recognize the functional steps and modify as necessary to accomplish the team's goals. By internally tracking their progress and adjusting their plan based on successes and failures, the instructors can in turn evaluate the effectiveness of the program.

It is the intention of the instructors to utilize this process in order to collect data at various points over the course of the semester by several means. The design portion of the course offering will utilize traditional studio design reviews at the 30%-60%-90% stages to gauge the level of design solution integration. Pin-ups will be utilized on a regular basis to bring design decisions to the forefront and introduce a conversation piece between the architecture students and the construction students. From a construction vantage point, an initial investigation analysis of course success of the Construction Management students will be through a mid-term paper review in which the topic will be focused on students understanding of BIM in a collaborative project-delivery structure through an industry oriented case-study report. It is expected that the main source of data collection will come in the form of a post-course survey in which the instructors will design a questionnaire for each student to complete. The questions will come in the form of a forced decision, four-point Likert item scale questionnaire offered during exit interviews. The results of the survey can then assist the instructors in making definitive statements in regards to the program's delivery effectiveness and the value-added to the student experience. This, coupled with the intermittent reviews and reports, will enable the instructors to modify course delivery, expectations and overall methodologies based on student input and instructor observation/evaluation. A follow-up paper will introduce the findings from the introductory offering of this course and will provide data and analysis from which future course offerings will be based.

Proposed syllabi and review criteria are uploaded to Arizona State University's Blackboard website and can be made available upon request.

EXPECTED RESULTS

It is expected that the course offering will enhance the current understanding of BIM as it relates to both the design and project management process through a value-driven approach to each discipline. The course is expected to become a signature part of the curriculum for both the Architecture and Construction Management programs. The approach to BIM education deployed by the authors is meant to be a stepping stone towards an integrative design-build program at Arizona State University in which a model-based deliverable becomes commonplace. With industry collaboration the course offering will reflect current issues and engage students at a higher level.

Through a continuous dialogue between Architecture and Construction Management students it is expected that a more developed design scheme will be delivered at the end of the semester. By incorporating cost, logistics, construction means and methods, constructability reviews, and systems analysis throughout the design process, more iteration can be tested and reviewed for performance. Through the expertise of both disciplines a stronger approach to design execution may be realized. Although BIM can be seen as a tool which stifles creativity during the design process due to the elaborate libraries embedded in each program, the intent of weaving this technology and process through the entirety of the coursework is to consistently engage students in real-time, creative design decisions based on the information produced by each discipline. It is the responsibility of each instructor to engage in continuous dialogue with the student groups to ensure that design decisions are being entered into with ample knowledge of the impacts from both the lens of constructability and construction management, as well as form and function.

CONCLUSIONS

As industry begins adopting BIM at an increasing rate, it is important for educational models to respond accordingly. The instructors view a cross-disciplinary approach to BIM education as a value-added approach to enhance both the Construction Management and Architecture programs at Arizona State

University. Through the introduction of a real-world design-build, BIM integrated solution model, as a cross disciplinary, semester project, a collaborative and iterative design, management decision making framework will be offered to the students of both programs. This type of curriculum addition will enhance the current understanding of BIM and provide the students with applied project knowledge that can be transferred to industry. Through the use of process mapping and planning at the onset of the course each student will understand the implications of the BIM process and the decisions that must be made to properly implement BIM on a project. This integrative course offering is seen as the initial steps towards developing a much broader APDM educational model that will utilize the full resources of all related disciplines within Arizona State University not just limited to the Architecture and Construction Management programs.

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BEST PRACTICES AND LESSONS LEARNED IN BIM PROJECT EXECUTION PLANNING IN CONSTRUCTION EDUCATION

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ABSTRACT

The topic of Building Information Modeling (BIM) is being perceived less and less as a ‘novel approach for design, construction, and operation’ and, instead, is becoming standard practice for many applications as building project teams realize the benefits of BIM. To keep students up-to-date with the latest industry trends in BIM, fourth-year construction management students at Arizona State University take a project management course in which they learn about a breadth of BIM topics. In recent years, this course has expanded beyond simply teaching students about the different individual uses of BIM and has begun to teach students how to plan for a variety of uses to realize synergies between selected uses. These planning concepts are taught using a previously developed BIM Project Execution Planning (PxP) guide. Effectively mastering PxP techniques will provide students with the necessary BIM planning and management skills for future career success. This paper explores the pedagogical benefits and challenges associated with teaching BIM execution planning from initial educational efforts at ASU. The observations and perceptions of multiple instructors who taught this BIM PxP course over several semesters are presented. The responses generated from these individuals suggest opportunities to improve BIM PxP education by presenting BIM concepts early in the construction curriculum and also incorporating cross-disciplinary collaboration among students in a variety of building-related majors. Currently, ASU is increasing its focus on teaching basic BIM skills in early construction courses. This will provide an opportunity to spend less time on teaching BIM computer skills in the fourth-year course and allow for more time to be spent on presenting the BIM PxP skills that students will need for future career success.

Keywords: Building Information Modeling (BIM), Construction Education, Project Execution Planning

1. INTRODUCTION

Building information models (BIM) have been defined as digital representations of buildings that include both physical and functional characteristics (buildingSMART alliance 2007). As BIM efforts become increasingly popular in the architecture, engineering, and construction (AEC) fields, the need for effective BIM project planning becomes increasingly important. To assist with BIM project execution planning (PxP) efforts, prior research and development work has created a structured approach to planning for the execution of BIM on a particular building project (Computer Integrated Construction Research Program 2010).

At Arizona State University (ASU), construction management and construction engineering students are introduced to different in-depth applications of BIM in a fourth-year project management course, called “CON 453 – Project Management 1”. This course ties a variety of different project management topics together and emphasizes how BIM can be used as a tool to improve these processes. A semester project tasks students with applying their background construction knowledge to a building project scenario using different BIM applications. In recent years, this course has also sought to enhance the students’ education by adding the learning component of BIM PxP to the course curriculum.

This paper explores the teaching approaches used to present this BIM PxP content to students in the construction management and construction engineering fields at ASU. Prior instructors of CON 453 as well as the teaching assistants (TA’s) involved with the course identified the strategies they used for presenting BIM PxP learning content. Additionally, the observations and perceptions of these prior instructors and TA’s related to the effectiveness of the different teaching strategies were identified and analyzed. The goal of this work is not to suggest a single best way to educate students about BIM PxP, but rather to inform other educators about the aspects of the employed approaches that worked well and also the modifications to the teaching approaches where improvements may be realized in future semesters. Additionally, the prior instructors and TA’s suggested prerequisite courses and skillsets that would be beneficial for students to have prior to learning BIM PxP concepts, based on the observations from their experience. This work will help to provide basic guidance to future educators who intend to begin or expand their teaching of BIM PxP content.

2. BACKGROUND

Many industry leaders within the architecture, engineering, and construction (AEC) fields have been increasing their adoption of BIM in recent years (Bernstein 2014; Young et al. 2008). This trend is in response to many factors including: declining construction productivity in recent years (Teicholz et al. 2001); private and government mandates and contractual obligations, such as those introduced by the United States General Services Administration (GSA); faster and more collaborative project delivery methods coupled with innovative construction techniques; and the positive ROI that has been observed by companies who have already adopted BIM (Bernstein 2014). This adoption of BIM is occurring across the various AEC industries in both vertical and horizontal construction and the different disciplines within these fields are utilizing it in different ways to realize the most benefit for their particular needs.

There are a variety of different BIM uses currently being explored throughout the AEC industries, from simple 3D geometry to 6D lifecycle management opportunities (Eastman et al. 2011). For design teams, BIM is being used in the schematic design phase for orientation studies, shading analysis, design programming, and simple box energy modeling to enhance the lifecycle performance of a building. During construction, BIM is being used for constructability reviews, modularization of building components and prefabrication to reduce schedule duration and rework on-site. Contractors are also pushing the BIM envelope by utilizing multi-trade coordination and bringing the models directly to the field for automatic layout and installation visualization and quality control reviews. From an operator’s perspective, the potential that BIM brings for as-built integration into Building Automation Systems offers an increase in BIM adoption across the full range of building professions.

While the benefits that BIM offers vary among the different disciplines involved in a project, one of the main values that it provides across industry disciplines is in facilitating collaboration and allowing for lean synergies among project teams. The cross-disciplinary nature of BIM allows teams to share, plan, and manage projects in a more seamless fashion in order to make more informed decisions throughout the project. BIM tools aim to facilitate this by leveraging a single model or database with in-depth parametric information that can be accessed by all team members. This compiled approach to information management provides an opportunity for streamlining project information transfer among the project team, but requires proper planning to do so.

To help project teams plan for proper BIM project execution, prior research has developed a structured planning technique (Computer Integrated Construction Research Program 2010). As project

teams use more and more different applications of BIM, it becomes increasingly important for thorough BIM project execution planning (PxP). Furthermore as the industry continues to increase its adoption of BIM, it becomes increasingly important for academic institutions to not only prepare students in AEC educational disciplines with technical BIM computer skills, but also to prepare them with the necessary BIM planning skills for managing BIM on projects in their future careers.

2.1 BIM in education

As with industry, the rate at which BIM is being introduced into various educational models varies across universities and disciplines. At current, architectural programs often see the largest portion of programs with BIM components offered (Becerik-Gerber et al. 2011). This being said, architecture programs have been found to expect their students to teach themselves the basics of BIM in order to deliver basic projects (BIM becomes a more advanced portion of this curriculum via offerings) (Becerik-Gerber et al. 2011). Construction Management (CM) programs have recently become the highlight of the BIM discussion in the realm of education due to their heavy adoption of a BIM component within their curriculum (Becerik-Gerber et al. 2011). While many CM programs are seen as late adopters of BIM in the education realm, they have quickly increased their offerings and are realizing the benefits (Becerik-Gerber et al. 2011). Engineering was the earliest adopter of BIM in education but has not fully embraced the potentials that BIM offers and subsequently has seen a static trend with BIM offerings in overall programs (Becerik-Gerber et al. 2011). A constraint that may play a role in the respective disciplines' offerings of BIM courses may be related to the accreditation requirements of each.

There are many different approaches to BIM in education. At one end of the spectrum, there is a need to teach the individual software application skills to students to prepare them to create BIM content. Conversely, at the other end of the spectrum, there is also a need to teach the cross-disciplinary management skills to lead projects using many different BIM applications. There are teaching opportunities to create hybrid learning scenarios where students can learn both the technical skills as well as the BIM management strategies. Schools such as Stanford are heavily focused on application of BIM in industry and linking with industry professionals to gain insight into the nature of the current BIM process (Lee and Hollar 2013). While this is a more high level approach to the understanding of BIM, schools such as Southern Polytechnic State are focused on the teachings of individual software programs to develop hard-skills involved with BIM information extraction (Lee and Hollar 2013). The main differences between these typologies of BIM education approaches become the interpretation and dissemination of information at a strategic level versus the creation of information in a model format focusing on a tactical level of education. Both styles of education can offer value as the industry requires new hires to have both BIM software capabilities as well as the management skills to enhance the overall process.

In order to address the managerial aspects of BIM while also introducing the technical skills required to create BIM content, instructors at Arizona State University have revamped the course offering CON 453 – Project Management 1. This course is required for fourth year Construction Management students as well as Construction Engineering students. The original intent of the course was to introduce traditional methods of project management, planning, and control. As BIM became more prevalent in industry, the course added an introduction to BIM software tools. In response to the evolution of the industry and the increasing demand for BIM planning skills, the instructors have augmented the course by teaching BIM PxP congruent to software introductions. Over the last few years, the course has seen different approaches to the congruency of teaching BIM software along with PxP learning content. This paper explores the different teaching strategies used thus far in this course to identify the teaching strategies that have been observed to be beneficial and those that have not yet been observed to be beneficial.

3. METHODOLOGY

CON 453 is structured with lecture and lab sessions. Enrolled students attend two 75 minute lectures per week and one two-hour lab per week. Typically, the lecture sessions present more theoretical course

content, such as why BIM use in industry has been increasing in recent years. The lab sessions, on the other hand, are intended to cover more applied, hands-on, content, such as how to manipulate a BIM model using commercial modeling software. While lectures are typically lead by the course instructor, both the course instructor and TA's were involved with presenting the hands-on content in the lab sessions. This provided both instructors and TA's with in-depth experience working with the students in CON 453.

In order to understand the perceptions and observations of the educators involved in teaching CON 453 from prior semesters, instructors and TA's were contacted and asked to provide feedback about their teaching experiences. They were provided with a short questionnaire to allow them to generate responses to targeted questions related to their perceptions and observations about teaching BIM PxP. The questions that were asked included:

- 1) Briefly describe how BIM PxP content was presented when you taught or assisted with the teaching of CON 453?
- 2) How was the BIM PxP learning content assessed when you taught or assisted with the teaching of CON 453?
- 3) From your perspective, what aspects of PxP were well understood by the students?
- 4) From your perspective, what aspects of PxP frequently misunderstood by the students?
- 5) If you were to teach (or assist with teaching) CON 453 again, what aspects of the BIM PxP teaching process would you change?
- 6) If you were to suggest an additional course or specific learning content that would be a beneficial prerequisite for students learning about BIM PxP, what would you recommend?

The questionnaire was sent to the instructors and TA's for this course from prior semesters when BIM PxP was taught. The respondents completed the questionnaire individually. The responses were compiled and analyzed to identify common themes as well as differing perceptions among respondents. Additionally, responses were analyzed to highlight any noteworthy findings that might be relevant to future educators. Lastly, the responses received from the questionnaire that related to prerequisite course knowledge and skillsets suggested by the instructors and TA's for future semesters was organized to help provide opportunities for improving BIM PxP education in the future.

4. RESULTS

The questionnaire developed for this work was given to two different course instructors and two prior course TA's who were involved with teaching BIM PxP content within the project management course at some point over the last two years. Each individual responded to the questions to illustrate their perceptions and observations about how BIM PxP was taught when they were involved with the course. It was of particular interest to identify the perceptions of these prior course instructors and assistants because of their in-depth experience with the course. After compiling the responses to these questions from these individuals, the data was organized and analyzed. Several noteworthy findings were identified.

One of the main distinctions between the different teaching styles between instructors involved in this work was related to the organization of course content. As discussed in the background section of this paper, there is a push to educate students not only about the technical BIM computer skills, but also the high-level BIM management and planning skills. Both instructors who taught this content at ASU included a project-based approach that challenged students to apply both the technical BIM computer skills as well as their BIM planning skills to a sample building project.

For the instructor involved in the Fall 2013/Spring 2014 semesters, this learning content was presented through the two separate projects. In this approach, one project required students to develop a PxP for a building project. A separate project challenged them to apply their BIM computer skills to a different project to create a detailed construction project proposal to demonstrate their technical BIM abilities. This educational approach allowed the instructors to clearly assess each component separately. It also offered some flexibility to the students so that an instance of poor planning judgment during the early

PxP generation would not have a negative downstream impact on the final product created by the students.

The instructor involved with the Fall 2014/Spring 2015 semesters presented this content as an integrated project. In this approach, the learning content was combined so that students would create a PxP for a particular building project and then subsequently develop a project proposal report based on their PxP. These project components were combined to simulate the challenges a real-world project team would face when planning for BIM and subsequently executing a BIM plan. This was intended to situate the learning content related to technical BIM skills within the higher-level context of strategic BIM planning. This situated learning approach has been suggested to be beneficial for students learning content that will eventually be applied to a particular context (Lave and Wenger 1991).

While the organization and structure of the projects differed, the learning content covered by the projects remained similar. Both teaching styles required students to generate a full PxP from the previously created template that was given to them (Computer Integrated Construction Research Program 2010). Both projects also required students to demonstrate their abilities to use BIM tools for several instructor-prescribed construction applications, including 3D coordination, 4D scheduling, BIM-based estimating using automated quantity take-offs, and BIM-based site utilization planning.

Through analyzing the responses from the instructors and TA's involved in this research, it was of interest to identify noteworthy findings from the individuals involved with both types of course formats to determine similar or differing observations. The responses provided were summarized and sorted based on whether the respondent was involved with the course when project content was combined into one integrated PxP and BIM project or separated as two projects. These responses can be seen in Table 1.

Table 1: Summarized responses of instructors and TA's to targeted questions.

	<i>Separated PxP and BIM Report</i>	<i>Integrated PxP and BIM Report</i>
1: How was BIM PxP content presented?	Standardized process using Penn State's BIM PxP Guide	
2: How was learning content assessed?	Through development of BIM Uses within PxP	Incorporation of BIM Uses in BIM Authoring Tools (Revit, Navisworks) to meet specific objectives of their project team's proposal
3: Aspects well understood by students?	Students were able to understand the basic principles for the purpose of a BIM PxP	Attempts to align the project contract documents incorporating a BIM PxP to establish accountability among the project team members
4: Aspects frequently misunderstood by students?	Overall purpose of the BIM PxP and how to actually implement, track and score	The interactions required within the PxP regarding information exchanges, process mapping and accountability/ownership of certain BIM Uses
5: Suggestions to modify teaching strategy?	Introducing the basic purpose for the use of BIM on a project and how the project participants' interactions within that structure will benefit from the development of a project specific BIM PxP	Expanding of the basic purpose and allowing the student teams to develop a unique PxP apart from the template to tailor specifically to that project teams' objectives
6: Suggested prerequisite knowledge or skillsets?	Early introduction into the undergraduate program curriculum and continued reinforcement throughout all courses and potential cross-disciplinary collaboration with design and engineering students	

In examining the responses obtained, it is difficult to conclude that either of the teaching strategies employed is better or worse from this study alone. Instead, it was of interest to explore similarities and differences in responses between the different teaching strategies. For some questions, the responses could be summarized identically, suggesting that the same observations and perceptions could be

identified through either teaching approach. In other instances, responses varied between the different teaching styles. While a number of the questions yielded different responses, there did not appear to be any responses to questions that provided starkly opposing views.

In analyzing the responses that were submitted, there appeared to be a common theme that tied the majority of responses together. Many of the responses advocated incorporating some additional form of cross-disciplinary, collaborative content into the semester project work. The suggestions that lead to this common theme are shown in Figure 1. This common theme was mentioned by each of the respondents, regardless of whether one integrated project was presented or two projects were given.

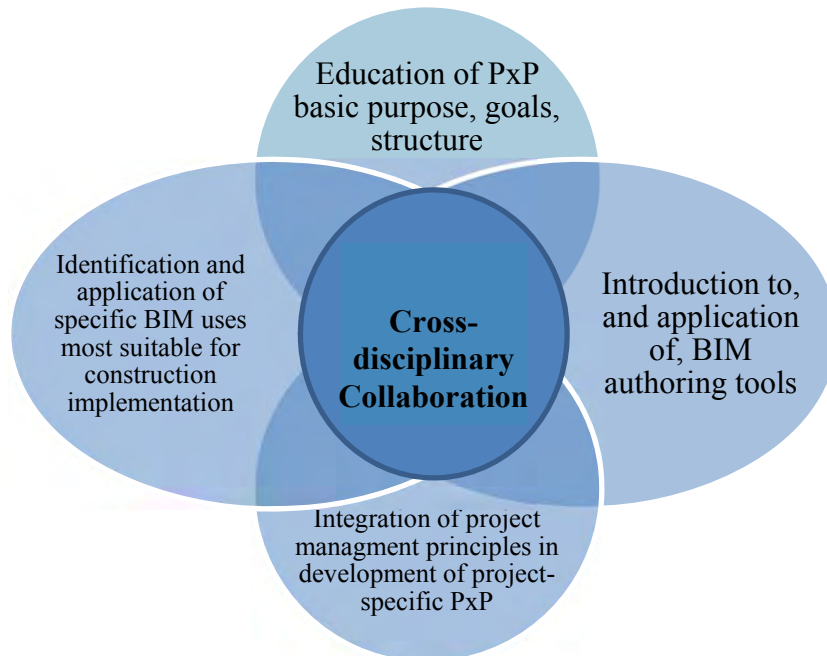


Figure 1: Common response themes were organized to identify overarching trend.

The common theme among the responses suggesting cross-disciplinary, collaborative project components may be due in part to the specific course examined in this work. CON 453 is offered only to students pursuing construction majors. Therefore, there were no students in the course from Architecture, Civil Engineering, Mechanical Engineering, Electrical Engineering, or any other potentially related educational discipline. There may be an opportunity in the future to pair CON 453 with another BIM-based course from a different curriculum, such as Architecture or Civil Engineering to incorporate a common, cross-disciplinary project to encourage the multi-disciplinary interactions on the project that would simulate those that would occur in typical industry settings.

4.1 Prerequisite skillsets

The course examined in this work was the first in-depth BIM course that students took in the construction program at ASU. Students in the construction program were exposed to some BIM overview content in prior courses, but this was not the focus of prior courses. Furthermore, these prior courses did not incorporate a detailed, hands-on, project requiring students to demonstrate their technical BIM skills. The responses to the questionnaire suggest possible improvements to teaching students about BIM PxP by introducing some of the technical BIM skills earlier in the construction curriculum.

Currently, the focus on BIM learning content that is being incorporated into a second-year construction course at ASU is increasing. This increased BIM emphasis may allow subsequent semesters of CON 453 to spend less time presenting technical BIM skills to the fourth-year students and instead, dedicate more time to BIM management and planning strategies. This early introduction to BIM in the

second year may also be an opportunity for future work to create a vertically integrated project where fourth year students team up with second year students to work together on a collaborative BIM project.

5. LIMITATIONS OF FINDINGS

This work offers insight into the way that BIM PxP was presented at ASU, but it does have some limitations. For this work, two instructors and two TA's who had prior experience teaching this content provided responses to the short questionnaire. Ideally, more instructors and TA's would have been questioned to gather observations and perceptions from a broader range of individuals. Unfortunately, it was not possible to survey numerous additional course instructors and TA's because the BIM PxP teaching content was not taught when additional prior instructors and assistants were involved with the course. Therefore, there is a limitation to the findings of this work in that it only explores BIM PxP education at ASU from a relatively small set of instructors and assistants who have had actual experience teaching it. This provides an opportunity to create a modified, more generalized, questionnaire that could be answered by instructors who are teaching BIM PxP content at other academic institutions. This would allow for a broader pool of respondents and potentially help to generate other teaching suggestions that could prove beneficial.

In addition to the limitation related to the small sample size of responders, there is also a limitation to this work in that it explores questions related to BIM PxP only from the instructors' perspectives. The instructors and TA's involved in CON 453 did closely monitor the project documentation that was submitted by the students and also observed how students worked on the project during the lecture and lab sessions. This experience provided them with an in-depth perspective of how the students completed their BIM PxP project, which helped to inform their perceptions and observations related to how the course was taught. However, this prior experience cannot fully represent the students' perspectives and observations about how BIM PxP was presented in the course. This will provide an opportunity for future work to explore BIM PxP education from the students' perspectives in addition to the instructors' perspectives.

Additionally, when students perspectives are sought in future work, it will also open the door to understanding the long-term learning impacts from this course. Over time, it would be valuable to survey graduates of the program to assess the long-term perceptions of BIM PxP. For example, former students could be surveyed to understand the level of value that they place on BIM PxP learning content and the extent to which it continues to be relevant for their current industry careers. This could help to validate or suggest modifications for the methods of presenting BIM PxP content for future students intending to pursue careers in the AEC industries.

6. CONCLUSIONS

This paper explores the observations and perceptions of instructors and teaching assistants who were involved with teaching a fourth-year construction course at ASU. This course taught students about both the technical BIM computer skills as well as high-level BIM PxP skills. The instructors and TA's presented similar learning content, but employed different semester project strategies to assess this content over multiple semesters. In some semesters, the high-level BIM PxP learning content was covered in one project and the technical BIM computer skill learning content was packaged in a separate project. In a subsequent semester, BIM PxP learning content was incorporated in the same project as the technical BIM computer skill learning content to challenge students to plan for BIM and then use their plan.

While the BIM PxP learning content was presented differently between multiple semesters, there were several common themes among the responses from these instructors and TA's. The main overarching theme derived from the questionnaire responses was the suggestion to incorporate more cross-disciplinary collaboration into the BIM PxP teaching and project strategy in future semesters. In the CON 453 course studied in this work, the semester projects incorporated into the course were only completed by students in construction fields. Future educators may find more benefit to students learning

about BIM PxB content by incorporating a project with other students from architecture, civil engineering, or other building-related fields. This may challenge students to consider other viewpoints that they might not have considered alone, which would more closely simulate the cross-disciplinary challenges of a real-world project scenario.

Additionally, the responses to the questionnaire indicated some prerequisite skillsets that would be beneficial for students to have prior to learning BIM PxB content in future semesters. The main prerequisite skillset that was suggested by the questionnaire responders was to incorporate BIM into earlier construction courses. Introducing students to BIM in their early years of study could allow them to understand basic premises of BIM prior to enrolling in the in-depth, fourth-year, course examined. Additionally, students could learn fundamental BIM computer skills in their earlier years of study so that they could enter CON 453 with knowledge of most BIM tools. This would allow the instructors of the course to spend less time teaching fundamental skills and focus more time on high-level BIM planning learning content.

Future teaching efforts will continue to teach BIM PxB content to construction students, but will also monitor how the students respond to different teaching strategies and which strategies they perceive to be of greatest benefit. In addition to future research efforts at ASU, further work related to this topic will also gather feedback from other instructors who are currently teaching students about BIM PxB concepts at other institutions. The observations from both of these future work efforts will help to inform future teaching strategies to provide better preparation for the construction students who will eventually be leading BIM efforts in the construction industry.

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DESIGN DISASSEMBLED: UNDERSTANDING BUILDING SYSTEMS THROUGH BIM

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ABSTRACT

Woodbury University offers a 4-year Bachelor of Fine Arts degree in Interior Architecture accredited by both CIDA and NASAD. Students who graduate from this program are expected to have a global perspective; to address the visual, technical, functional, and aesthetic aspects of inhabited spaces within the parameters of ecological contexts, amongst others. As part of the degree curriculum, students study materials and methods of detailing and documentation for custom work. BIM technologies allow students to meet both curricular and accreditation goals by integrating design, detailing and sustainability via the concept of “design-for-disassembly”.

Woodbury University’s Detail Design course requires students to look at the issues surrounding sustainable design through an investigation into ‘design for disassembly’; approaching a design problem with intent and understanding of the entire lifespan of the structure. Students are asked to design and detail their projects so that the product (the building, component, furniture item, etc.) can be easily disassembled. This allows the parts and materials to be readily reused, re-manufactured or recycled.

The Detail Design course uses BIM technologies to help students explore building and construction methods as they apply to sustainable design, and specifically, “design-for-disassembly”. The presentation will review three learning outcomes and sample student projects to illustrate the use of BIM as a design and research tool helping students understand the “concepts, principles, and theories of sustainability as they pertain to building methods, materials, and systems” as articulated in the CIDA standards.

Keywords: BIM technology, Design for Disassembly, education, technical course, architecture, interior architecture, sustainable design

1. INTRODUCTION

This paper will discuss a specific course, Tectonics 2 (also known as “Detail Design”), offered as part of the second year curriculum within the Interior Architecture Department at Woodbury University. We will review three learning outcomes of the course and sample student projects from the perspective of the faculty member, Tracy Stone (TS), who developed and taught the class, and from the perspective of one of the students, MacKenzie King (MK). In this course, the students were asked to investigate issues of sustainable design through an investigation into ‘design for disassembly’ (DfD). Students were required to design and to detail their projects so

that the product (the building, component, furniture item, etc) could be easily disassembled and the parts and materials could be readily reused, re-manufactured or recycled.

The course expanded on the traditional structure of the class, encouraging but not requiring the students to use a BIM program, Graphisoft's ArchiCAD, as a design and research tool that would allow a deeper investigation into the course material. To understand building systems, students must move beyond a volumetric exploration of form to look at the individual components that together comprise the structural and finish systems. "Like science, architecture involves systematic study" (Architecture: Introduction, 2015). Likewise, we found that the use of BIM in the classroom facilitates the systematic study of geometrical relationships between component elements and their material qualities, and allows for the coding of information associated with these properties.

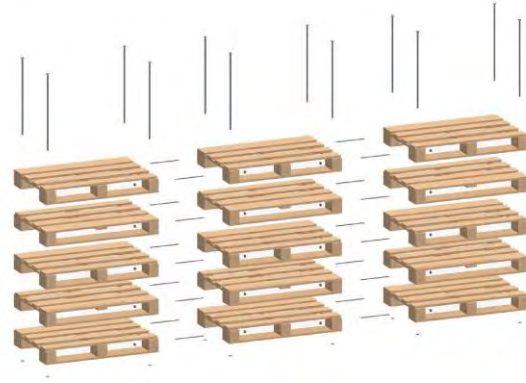


Figure 1: Exploded axonometric to review components. MacKenzie King, Woodbury University (2009)

2. UNIVERSITY CURRICULUM

The Interior Architecture curriculum at Woodbury University provides a good balance between architectural programs that focus on the development of volumetric and conceptual forms and those with a more technical focus. Students are encouraged to explore concept and form generation strategies in the first years of the program. As they progress, courses such as "construction documents" and the tectonics series, including "detail design", layer on the information required to develop into fully functioning professionals. According to Woodbury University's Interior Architecture department head Christoph Korner, "We seek to expose our undergraduates to disciplines outside the strict confines of traditional architectural degree programs, an approach that is simultaneously aspirational and practical" (Woodbury University, 2014).

3. COURSE DESCRIPTION

In the Detail Design course "students are directed through research, conceptual design/diagramming, schematic design, and design development to the final production of a comprehensive project documenting design resolutions of a given project through detailed technical drawings and models" (Woodbury University: 2014-2015 Catalog). For the past 5 years, the class has also included an investigation into DfD; approaching a design problem with intent and the understanding of the entire lifespan of the structure.



Figure 2: Student Design for Exhibit Module. Norella Carboni, Megan Weintraub, Woodbury University (2010)

Prior to the Detail Design class, students have given little thought to the material and structural systems that are required to give form to the architectural shapes they design. This class required that the students learn to think about how architecture works rather than just how it looks. They are asked to create a design solution to a given problem, to select materials that meet the

class criteria for sustainability, and then to figure out how to connect them in such a way that each temporary installation can be easily disassembled and repurposed, recycled, or composted. At the end of the class, the students should have an understanding of basic structural principles and material properties: an essential step in the development of an architect. In 2009, the class evolved to incorporate a BIM software program as a suggested, but not required, tool. Experience with two groups of students within the same class, and with the same assignments, proves that the use of BIM provides an advantage in the Detail Design course at Woodbury University.

The class typically meets for two and a half hours, two times per week. The class presents challenges similar to those identified in a study reported in the Asian Journal of University Education: “[...] limited time to cover the syllabus, and large numbers of students in a classroom.” (Idrus et al, 2009)

4. THE INSTRUCTOR – TRACY STONE (TS)

In the first two years of teaching the course, and prior to the introduction of BIM, it was a challenge to decipher the students’ drawings in the time allotted, leaving little opportunity for constructive input. Often, students have learned to use a 2D drafting software (like AutoCAD), but they haven’t yet learned best practices, so there can be unintended discrepancies between the plans and/or sections. The introduction of a BIM software program had a positive impact on the class in two critical ways: the students built their design models out of real “components” (wood studs, metal studs, palettes, steel tubes, etc) and teacher/student communication time shifted to reviewing the 3D models directly. The 2D documentation was developed after the model with the instructor’s input, and it was no longer a means for communicating intent during the design process.

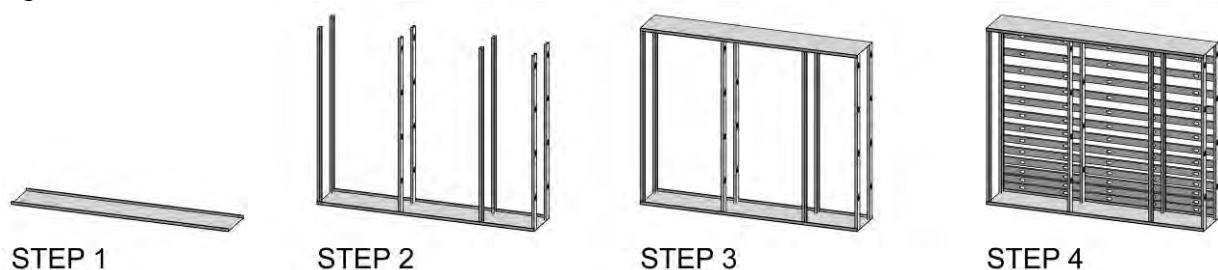


Figure 3: Without having to physically construct a wall, students can now model the wall out of studs with specific lengths and dimensions. Mimi Ho, Woodbury University (2009)

5. THE STUDENT – MACKENZIE KING (MK)

For students, BIM technology offers both challenges and rewards. Woodbury technology courses primarily focus on the use of AutoCAD for drafting and Rhino for all 3D exploration. BIM software forces students to use forward thinking: planning ahead and making correlations between a desired design element and existing BIM modeling tools or components. It can be daunting at first to figure out that a specific tool has many potential uses beyond that suggested by its name. Students soon learn that anything is possible, given the appropriate (and sometimes creative) use of the tools. BIM allows students to spend more time designing, and less time drafting, the associated 2D documentation. Students using BIM can quickly extract as many

views from the model as are required to describe their designs. Students relying on 2D software programs must painfully draft out each section with lines.

6. COURSE LEARNING OUTCOMES

The learning goals for this course fall into three categories: sustainability and life-cycle analysis, material characteristics, and material connections. In order to assess the success of the course and of the use of BIM as a learning/teaching tool, we will review each learning outcome individually.

6.1a. OUTCOME: SUSTAINABILITY + LIFE-CYCLE ANALYSIS

Course Objective: “Students understand how to critically apply concepts, principles and theories of sustainability to the selection of materials and building systems.”

The construction industry consumes “40% of all extracted materials, produces one-third of the total landfill waste stream, and accounts for 30% of national energy consumption” (Kibert, et al, 2002). The Detail Design course required students to look at these issues by approaching a design problem with a plan for the entire lifespan of the design. The design problem, a temporary live/work space for a visiting artist, directed the students to focus on the connection details as a primary means of achieving this goal. Students were challenged to design details that could be easily disassembled at the end of the live-work residency. “DfD is a building design process that allows for the easy recovery of products, parts and materials when a building is disassembled or renovated. The process is intended to maximize economic value and minimize environmental impacts through reuse, repair, remanufacture and recycling.” (King County, 2010). BIM technology allowed students to track the exact components in the design and to estimate the quantity/sizes being used.

Students were also asked to research and select materials based on a life-cycle analysis of their environmental impact, both prior to being installed in the site and after. “The demolition and renovation of buildings in the U.S. produces 124,670,000 tons of debris each year” (Advanced Restoration, 2015). The class objective was to interrupt this waste stream and take advantage of the embodied energy in the selected construction materials by planning for their transition to a future use.

6.1b. ASSESSMENT: SUSTAINABILITY + LIFE CYCLE ANALYSIS

TS: BIM proved very helpful in allowing the students to evaluate the aesthetic impacts of the selected materials, but less successful in contributing to an understanding of the life-cycle impacts of the selection. Students were able to quickly tabulate the amount of materials used and, in the future, additional information could be coded in the “object” properties to track the projected end use of each element of the design.

MK: One of the assignments required students to quantify the materials used by exploding a specific module in the design. Since the modules

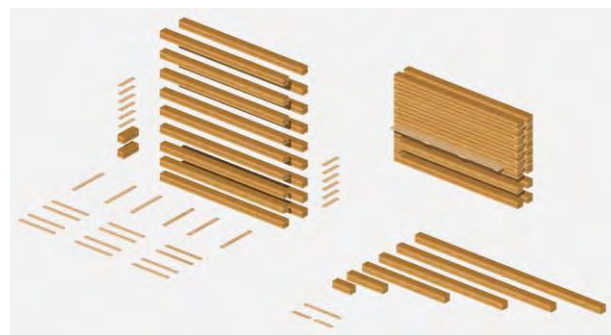


Figure 4: Quantification of Elements. MacKenzie King, Woodbury University (2009)

were modeled with components, it is possible to quantify the numbers with a few modeling moves. Students can quickly evaluate the base system and adjust the design to use either fewer, or different, elements to create the same goal.

6.2a. OUTCOME: MATERIAL CHARACTERISTICS

Course Objective: Students understand material characteristics, including structural strengths and weaknesses, and material life cycle analysis implications.

“Each material has different characteristics and requires separate considerations, but the ultimate objective in the engineering sense is to determine the most efficient and economical system that can be coordinated with the design solution.” (Architecture Programs, 2015). After visiting a local construction demolition recycling plant, students analyzed the various systems and materials available, making material selections based not only on aesthetics, but also on potentials for re-use or recycling. BIM offers the opportunities to quickly model specific standard structural systems (wood studs, metal studs, etc.) as well as non-traditional materials such as milk crates, wood pallets and glass rods. Each of these components can be modeled as an object that can be multiplied, rotated, etc. as well as eventually tallied. The objects can easily be swapped or substituted for design analysis and study. The students were asked to include an analysis and plan for the end use of each material included in the project. The BIM model can contain information on all the materials used, and can provide the information as a list of components. This makes it easy to track the materials and to tally them in a table where additional information can be added as needed.

6.2b. ASSESSMENT: MATERIAL CHARACTERISTICS

TS: BIM proved especially useful in this arena. The students gained a strong understanding of the basic structural systems and their potential aesthetic impacts. By modeling a variety of systems and evaluating them quickly via the model, students were able to quickly assess and to select the appropriate system that satisfied their design goals for the project. For this type of problem, BIM is superior to other 3d software options because it constructs elements as solids rather than surfaces. Student projects using programs like Rhino and Sketch-up lacked the specificity of components afforded by the BIM technology. Often, the surfaces in early student models appear slick and smooth, creating ambiguous forms with little suggestion of structure. Other 3d modeling programs also lack the ability to attach data to objects and to quickly generate

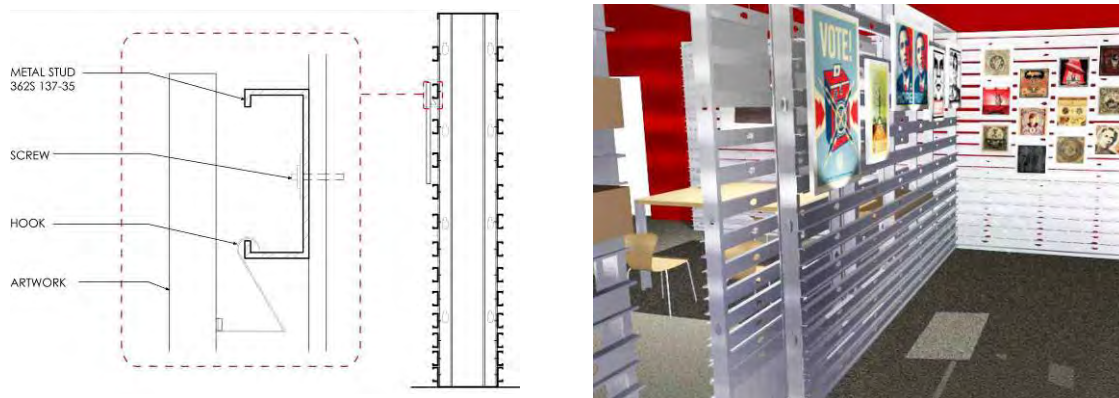


Figure 5: Details for hanging system. Mimi Ho, Woodbury University (2009)

lists for analysis. Students using BIM generated two to five times the number of 3D assembly studies than students who did not use BIM. (See Appendix A)

MK: Many students looked to unconventional building materials i.e. recycled milk cartons, wood shipping pallets, or cardboard fabric tubes as a response to the sustainable goals of the class. BIM allowed precise modeling of these materials, but did not reveal the structural weaknesses that appeared when the components were modified. Physical models of the design revealed that the proposed modifications (to satisfy aesthetic goals) caused structural failures and, therefore, the modifications weren't realistic. This question of structural integrity required creative detailing of the materials to provide support as the components were reconfigured. BIM was of tremendous value in the reconfiguration studies.

6.3a. OUTCOME: MATERIAL CONNECTIONS

Course Objective: Students understand how to design and represent material connections and details.

The design problem was small in scale to allow students time to explore the connections and to let the details influence their design decisions. The continuous surfaces often seen in Rhino models are replaced, as a result of the component focus of the Detail Design class, with materials in real dimensions including seams, connections, and mullions. Students began to see these realities as design opportunities rather than limitations. With time spent on 2D documentation reduced, the students could spend time on the model exploring and evaluating a variety of solutions.

6.3b. ASSESSMENT: MATERIAL CONNECTIONS

TS: In my experience, students have a difficult time early in their educational careers with the translation from 3D thinking to 2D sketching and back again. The ability to model connection elements using BIM greatly enhanced the students' understanding of the detail. Views of the model were composited with other images and source materials (ie. product information in the form of manufacturers' details) to provide rich documentation of the design.

MK: BIM technology allowed students to build detailed components in order to assess them for functionality and aesthetic impacts. Classmate Mimi Ho had a breakthrough in her project when designing with metal studs. The "open" side allowed for a greater variety of hanging options for artwork whereas the "closed" side created a more polished feel to the space defining partitions. Traditional 2D detailing standards were often inadequate in conveying the desired material connections with the use of unconventional building materials. The classmates using BIM software were able to isolate specific moments of the design to explain the component connections via a 3D detail. Final presentations reflected this capability quite well (See Appendix A).

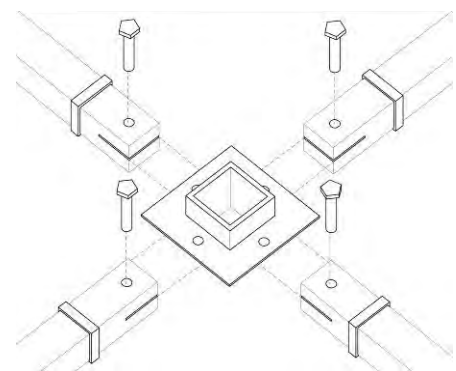


Figure 6: Using BIM, students can model the connections and evaluate their appearance, scale, and spacing as they impact the design. Knarik Harutyunyan, Woodbury University (2011)

7. CHALLENGES RELATED TO TECHNOLOGY

The challenge of incorporating BIM at the school level is limited access to support. Students require concentrated time with a new program in order to feel comfortable using it. Unlike at the professional level, students don't use the program eight hours a day unless the school provides the required support. Student Lauren Postlmayr noted, "Because I was new to the program [...] it hindered the design process because I was not always able to put the ideas in my head into the computer". "As with any sophisticated software, a significant learning curve is associated with BIM. [...] BIM requires a deeper understanding of the systems being modeled" (The Benefits). Students are more comfortable initially thinking of design as volumetric form. BIM works well when introduced as part of a systems-based course so that the natural orientation of the technology is supported by the curriculum and vice versa.

8. CONCLUSION

The addition of BIM in the Detail Design classroom improved the learning experience for the students in multiple ways, and the difficulties related to the learning curve of the software were overshadowed by the benefits afforded by the technology. The instructor could quickly understand the students' design intent via the 3D model, resulting in more efficient communication between the two. A component-based approach to design enables the type of investigation into building systems required by this technical course. BIM technology promotes component-based thinking, and the program enhanced the students' understanding of the relationship of structure to form. The ability to quantify materials and components using the 3D model made sustainable decisions related to material usage easy to analyze. The model allowed students to study the connections and evaluate details within a design project more fully than is possible with a small-scale physical model or through translation to 2D drawings. Ultimately, this benefit carried through to the final presentations where there was a marked difference between the students using BIM as compared to those who used other programs during the design studio. The information derived from a BIM model was visually richer, more easily understood, and quantifiably more extensive.

ACKNOWLEDGEMENTS

This paper contains student work from students at Woodbury University from 2009-2012.

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APPENDIX A

The table below evaluated a single class (Fall 2009) to maintain a level of consistency with project scope, instructor/evaluator, and required deliverables. Where a specific number of items were to be provided it is listed below, however, many students far exceeded what was required in order to explain their design intent. Comparing the mid-performing students, the overall amount of information produced by BIM Users was 128% greater, allowing the opportunity for even the low-performing BIM User to be within 10% of the mid-performing non-BIM user.

Student	BIM Users						Non-BIM Users			
	A	B	C	D	E	F	G	H	I	J
Type of Student: Typically High Performance (HP), Mid Performance (AP), or Low Performance (LP)	LP	MP	HP	HP	HP	MP	MP	LP	MP	LP
Final Presentation Requirements										
Floor Plan Provided - 1 pt, Rendered - 2pts	2	1	2	2	1	2	2	2	1	1
Sections (2) Each: Provided - 1 pt, Rendered - 2pts	4	4	4	6	4	4	4	0	4	0
Elevations (2) Each: Provided - 1 pt, Rendered - 2pts	0	4	4	4	4	0	4	0	4	2
Graphic Component - Axon / Diagram Provided - 1 pt	1	1	1	1	1	1	1	0	0	1
Details - Total	10	9	16	22	30	30	10	2	4	6
# of Traditional 2D Details	8	3	5	5	0	19	5	2	4	5
# of 3D Details	2	6	11	17	30	11	5	0	0	1
Assembly/Disassembly Diagram Provided - 1 pt	1	1	1	1	1	1	1	0	1	0
Renderings Provided - 1 pt for each	6	11	13	4	9	4	6	3	9	9
Unique Elements Extracted from 3D Model Provided - 1 pt for each	23	29	59	40	47	50	40	11	27	22
TOTAL POINTS	47	60	100	80	97	92	68	18	50	41

INTRODUCING LASER SCANNING TECHNOLOGY IN A GRADUATE BIM CLASS

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ABSTRACT

Laser scanning technology has emerged as a useful tool in documenting existing conditions of buildings. The main application for such documentation is to assess current as-built conditions of existing, mostly historical, buildings. The technology can also be used as an integral part of construction progress documentation in new projects. In order to equip students with knowledge on the latest technologies in the industry, laser scanning was introduced to students in a BIM class. Students were given a thorough demonstration on how the equipment functions. After that, several campus buildings' exteriors were scanned. Students had the chance to see the scanning in action. More importantly, the generated point-clouds from the scanner were given to students as part of the final project. Five teams were formed and each team was given a set of floor plans, with minimal details, of an existing campus building. The teams were then asked to take measurements from the point-clouds and model the buildings in Autodesk Revit. The lack of marked elevation drawings did not prevent the teams from modeling the buildings fairly accurately. The point-clouds gave the students an immense amount of information that were lacking in the provided documents. Even though the learning curve for navigating such point-clouds was a bit steep, the extracted information helped the students better understand the buildings' envelopes and see the real value of laser scanning technology.

Keywords: VDC, BIM, Laser Scanning, Point-Cloud, Education, Classroom

1. INTRODUCTION

Virtual Design and Construction (VDC) approaches with the help of Building Information Modeling (BIM) is on its way to becoming the standard in the construction industry today (Yee et al. 2013). The return on investment for such an approach has proved to be well worth it with benefits that include, but are not limited to, realistic and accurate project schedules, avoided clashes and more comprehensive project documentations. As the push for implementing VDC approaches increases, the demand for a skilled workforce in that area also increases. New graduates of construction management schools are expected to be up to speed with the ever evolving technology in their field.

Construction management schools are required to not only introduce the students to the existing software, but to also expose them to the upcoming technologies that would elevate VDC processes. One of these emerging technologies is laser scanning, which can add an unprecedented level of precision for building documentation. Exposing students to such technologies would give

them a competitive advantage in the job market. In addition, students are always encouraged to keep up with the ever changing technologies in the industry.

2. BACKGROUND

2.1 Construction Information Systems Class

Construction information systems is a graduate level course that introduces students to the expanding VDC domain. Students starting the class are expected to know how to read and interpret construction documents. The class starts with an introduction about the theory and application of VDC processes. The students then perform hands-on lab exercises using several software packages including Autodesk Revit® and Navisworks®. After that, students are handed out construction documents on a small building to model in Revit® and check the design in Navisworks®. These individual assignments are designed to enforce the material learned about modeling each building discipline. The course also introduces students to other VDC software including Vico Office® and Synchro Professional®.

The next part of the class exposes the students to the collaboration aspect of VDC. This collaboration exposes the students to the social factors that can make or break the VDC approach of a project. The students are divided into teams where each team would be assigned a larger, more involved project to model. Every team is required to deliver a BIM execution plan that includes the members' roles and responsibilities. The project duration is about 6 weeks and teams have to complete separate models of the different disciplines of an assigned building. The teams are then asked to submit a federated model that merges all the different models together. The project is graded on accuracy of modeling in terms of dimensions and information.

Lastly, the final test of the course examines the students' performance on the taught software under a time constraint. Students are allotted 3 hours to complete various modeling parts based on the provided construction drawings. All the assignments and project work would add up to this last modeling exercise that reflects the skill level achieved by each students.

2.2 History of Laser Scanning Technology

The two common operation principles for laser scanning are Time of Flight and Phase Comparison, or Phase Shift, laser pulse (Böhler and Marbs 2002). Time of flight laser scanning calculates the coordinates, in 3D space, of its surroundings based on the amount of time it takes the laser signal to return to the device after being reflected. This operation occurs thousands of times until the given range of data collection is met. Current algorithms and devices render at an accuracy with a standard deviation of a few millimeters using the time of flight calculation method (Böhler and Marbs 2002). The phase comparison method can be more accurate, while not requiring any different knowledge from the user, but at the cost of slower scan speed. The phase comparison method transmits a laser beam which is modulated by a harmonic wave. When the modulating beam returns to the device the phase difference between what was transmitted and what was received allows for the calculation of distance (Böhler and Marbs 2002). Scan accuracy is an important consideration when considering deploying a laser scanner and has been the topic of research for many years.

A study published in 2003 explored the accuracy of a range of laser scanning devices manufactured by five different companies (Boehler et al. 2003). The study demonstrated that the operating principle of the device was not the only way accuracy was impacted. Rather, the accuracy varied greatly based on the manufacturer of the chosen device. As laser scanning

technology has developed and higher accuracy has been achieved, through increased manufacturer abilities and better understanding of the influences on accuracy, laser scanning has seen an increase in use for a variety of purposes in the construction industry. Interest in the technology ranges from new construction to as-built verification and even archaeological and heritage applications.

In 2007 a guide to laser scanning for archaeological and architectural applications was published (Barber and Mills 2007). The advice provided in the guide described the limitations of the technology as well as the typical workflows which could be employed. In addition to utilization guidance, laser safety was also addressed in the publication. Prior to employing a laser scanning device it is important to know what class of laser is being deployed so that proper safety procedures can be observed. In recent years companies have begun releasing laser scanners which have a class 2 or class 1 laser, rendering the device safe under reasonable conditions (Barber and Mills 2007). This demonstrates an improvement over the use of class 3 laser devices, which were common during the onset of laser scanning technology, and required the use of eye protection to avoid injury. Deciding when and how to employ laser scanning is important and it was accurately stated that laser scanning itself is not always the best solution, being the means to an end rather than the final product itself (Barber and Mills 2007). In this regard it is important to understand that laser scanning is a tool which can lead to more accurate models when integrated with other computer modelling programs to produce more detailed deliverables.

As-built models are an important deliverable following the construction process and laser scanning has been researched as a tool to increase the accuracy of this deliverable. The limited utilization of BIM for facilities and maintenance of a building following construction was the focus of a study conducted by Giel and Issa (2012). In that study it was determined that the accuracy of the model was a concern and laser scanning was identified as a possible means to assess the accuracy of the as-built BIM (Giel and Issa 2011). Through the development of an as-built BIM, based on 2D as-builts, which was compared to a point-cloud, the researchers were able to identify the accuracy of the model and identify areas which needed to be updated to match as-built conditions. The researchers assessed whether laser scanning was an effective means of checking as-builts and were not convinced at the time that laser scanning had benefits over traditional as-built verification by hand. However, they went on to say that the vast amount of digitized information collected during the laser scanning process could prove helpful in the future (Giel and Issa 2011). A similar study, conducted in 2012, took the laser scanning process a step further by scanning throughout the construction process.

Laser scanning has the inherent problem of dealing with occlusions present during the scanning process which limit the available data. Gao et al. (2012) proposed using progressive scan data obtained by scanning the target building at intervals throughout the construction process in order to develop a more complete point-cloud for use in creating as-built BIMs. A case study was conducted, utilizing the outlined progressive laser scanning technique, of a renovation project on the researchers' campus. The researchers concluded that progressive laser scanning provided a point-cloud which could be used to develop accurate as-built models of all building elements, including MEP elements hidden behind surfaces (Gao et al. 2012).

Fallon (2012) outlined the numerous uses and benefits found for laser scanning in the construction industry. The outlined areas of use included; transportation, utilities and process plants, offshore oil production facility development, forensic evaluation and building renovation. Laser scanning has a variety of applications and has come a long way over the course of the past few decades. As the construction industry continues to evolve, the utilization of laser scanning will continue to develop as professionals and researchers seek means of ever increasing accuracy.

3. IMPLEMENTATION

Students were introduced to the background and basics of laser scanning technology. In addition, an entire class was dedicated to going through and working with Autodesk ReCap[®] software which allows the point-clouds can be viewed, stitched together and measured. The students were also introduced to the different point-cloud file types.

3.1 Class Projects

In order to make the most use and understanding of the laser scans, the class projects were treated with a historic preservation approach. The class was divided into 5 teams based on previous work or modeling experiences. Each team was assigned a campus building to model. The only provided building documentation consisted of minimal floor plans that were not to scale and had no dimensions. In order to compensate for that, teams were given point-clouds for their respective building. Moreover, teams were encouraged to visit their assigned building often and take pictures and actual site measurements to compare them with the provided point-cloud. Because the floor plans lacked any structural details, students were asked to make educated assumptions on the materiality of hidden elements in the building. Lastly, each team was provided access to an Autodesk 360 Glue[®] project to allow for easier collaboration during modeling. Using the cloud service would help students be more organized and communicate more efficiently. Table 1 summarizes the projects' aspects for each team.

Table 1. Class projects breakdown

Team	Number of Students	Building	Size (Sq. Ft.)	Number of Scans
1	4	Fine Arts B&D	23,500	3
2	5	Fine Arts A&C	34,300	4
3	5	Little Hall	25,000	3
4	5	Architecture	46,000	6
5	5	Turlington Hall	30,000	9

3.2 Scanning Campus Buildings

During the course, laser scanning technology was introduced to the students and they were given the opportunity to work with the technology in the field. The students were introduced to laser scanning technology during the class period and, with the assistance of the instructors, were able to operate the laser scanner outside of class to collect the point-cloud data for their respective projects. It was important for the students to be present during the in-class tutorial to learn safe and proper operating techniques, especially given that laser scanning technology was new to the majority of them.

During the class period the concepts of laser scanning were discussed and the specific laser scanner being used for the class, a Faro Focus3D[®], was deployed for demonstration purposes. A tutorial was then given on the proper operation procedures and the safety considerations which must be considered when operating a laser device were stressed. The menus and settings on the touch-screen user interface were displayed in order for the students to become comfortable with operating the laser scanner. During this process, each of the settings were elaborated on so that the students had an understanding of why certain settings may need to be altered prior to a scan. For example, scan resolution and quality settings must be adjusted based on the location of the scan

(i.e. indoor or outdoor), the lighting conditions present during the scan, size of the target building or area and the desired point density. As this was an introduction to these concepts the instructors remained available throughout the process to help the students make the appropriate decisions when it came time to collect the scan data.

Following the in-class tutorial the students scheduled a time to meet with the instructors to use the laser scanner to capture data of the specific building on campus they had been assigned. Prior to moving into the field the instructors worked with each group to develop a scanning plan. Figure 1 depicts the plan developed for the scanning of Turlington Hall. The markings on the plan depict the desired location for each scan and was in the field minor adjustments were made. Due to the size and exterior form of the building it was decided that fourteen scans around the exterior perimeter of the building and six scans in the open air atrium would be necessary in order to achieve the desired 3D point-cloud. At the time the scans were completed it was necessary to utilize registration spheres in order to process the scans and properly align them in the scan software. In this regard, it was important to consider where the spheres needed to be placed, as well as how they would be used throughout the scanning process. As scanning was conducted the location of the spheres was noted on the plan in order to make processing easier later. Due to a limited number of spheres it was important to carefully plan the placement of each sphere so that those no longer needed could be moved to other locations as scanning progressed counter-clockwise around Turlington Hall. In total exterior scans were completed for five buildings on campus. Each group was encouraged to make the same considerations and plan as depicted for Turlington Hall in Figure 1.

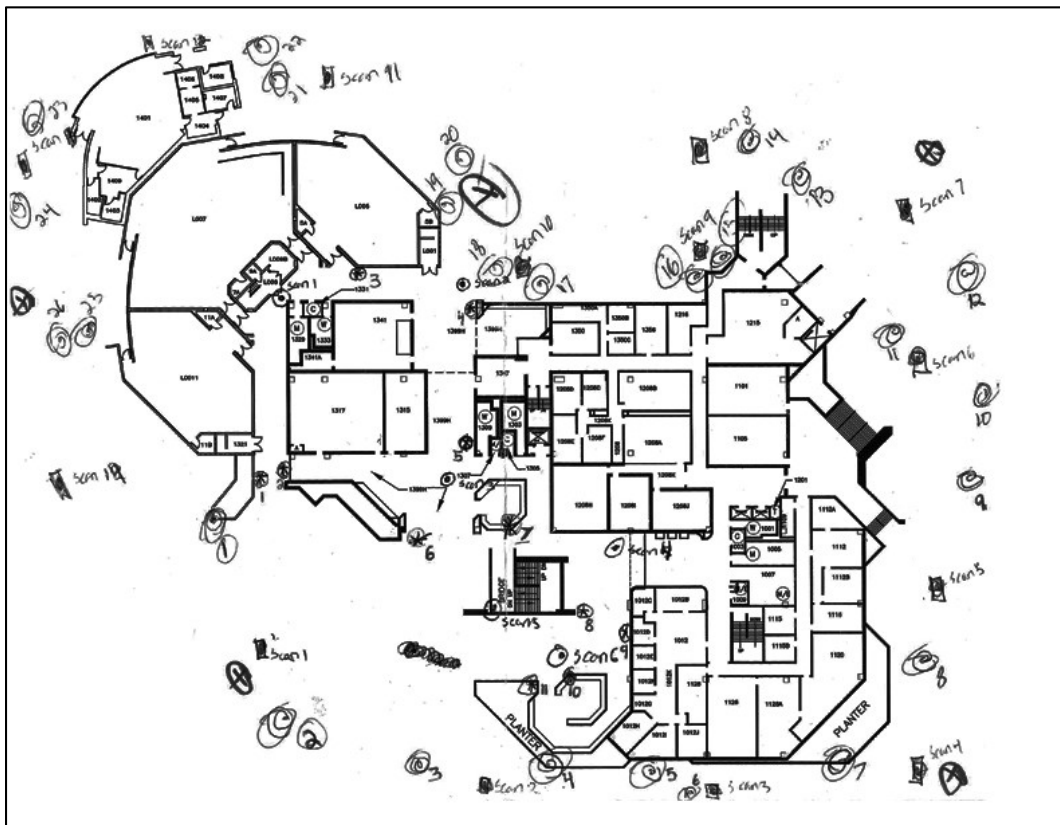


Figure 1. Laser scanning plan for Turlington Hall



Figure 2. Point-cloud for Turlington Hall

The scans were then processed and registered in order to align the scans and make them usable 3D point-clouds. Figure 2 is an image of the completed point-cloud for Turlington Hall. Following scan processing and registration the Faro scan data was subsequently converted into the ReCap Scan File (.RCP) format for use in Autodesk ReCap® and Autodesk Revit®. Figure 3 shows a point-cloud file used in Revit to determine the height of each floor level.



Figure 3. Point-cloud file in Revit

3.3 Results

All teams managed to complete their projects on time with more than acceptable results. Students used the point-clouds to measure elevations of points that they would not be able to measure on site. In addition, the measurement taken on site were mainly used to verify the ones taken from the point-cloud. After verifying several measurements, students confidence in the point-clouds'

accuracy increased. All measurements after that were taken from the point-clouds. The produced models were accurate within ½” of actual dimensions. Figure 4 shows a screen shot of the Turlington Hall model submitted by students.

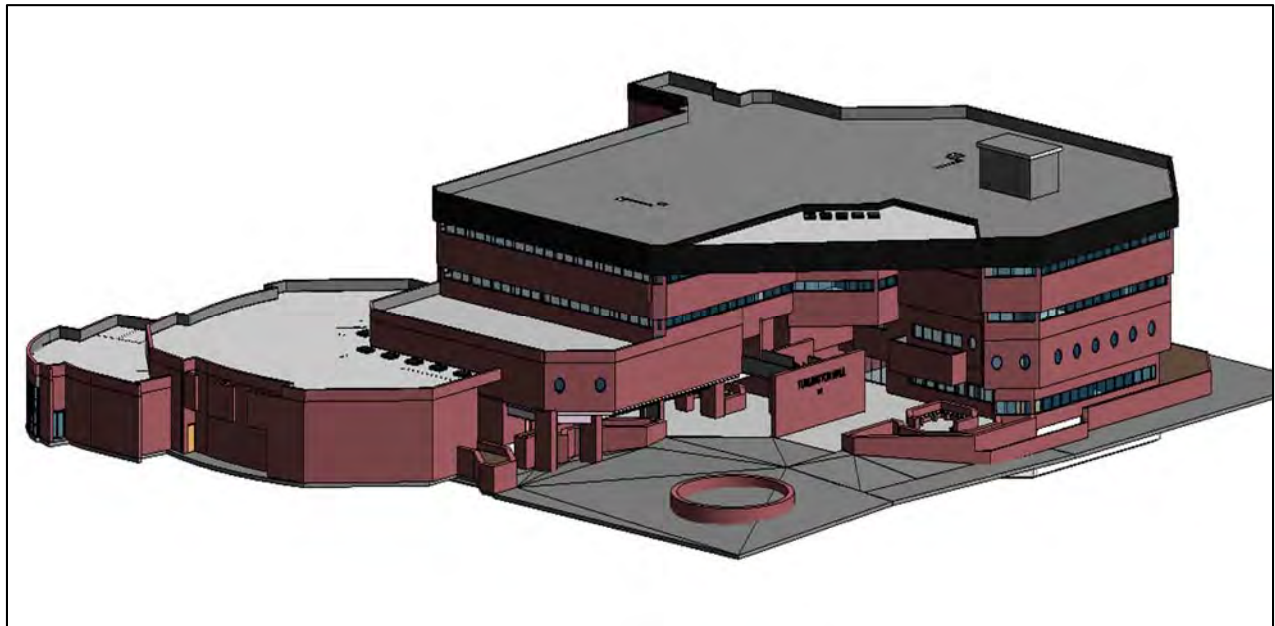


Figure 4. Completed model for Turlington Hall

The students reported some difficulties when working with the point-clouds. The first one was that it was somewhat difficult to make sure that the points used to measure were exactly on the same surface. That was due to the fact that the texture of scanned surfaces might affect the alignment of those points. Rounding and approximation had to be used to compensate for that issue. Another issue was the size of the point-cloud files. Some files exceeded the 3 Gigabytes sizes which made it harder to navigate in students’ personal computers. However, the computes in the lab were capable of handling such large data.

4. CONCLUSION

Exposing students in the construction management program to the latest technologies in the field will give them a competitive advantage in the job market. In addition, the industry would pick on these new technologies much faster with graduates that are familiar with their operations and uses. That would also lead to more enhancements and innovations to make these new technologies even more efficient. The study showed that students are eager to try new methods and approaches in the classroom as they are produced. The laser scanning technology has been positively received and proved to be useful to this course’s students.

The projects handed out in the course would have been impossible to model as accurately without the provided point-clouds. The lack of elevation and section views presented challenging obstacles, especially when trying to determine the floor levels. Taking actual site measurements were also very difficult, particularly for the exterior façade that in some cases extended 4 stories high. Therefore, students experienced the real value of the generated point-clouds. Having hands-on experience on getting the required information to model a building from a point-cloud gave students a new perspective and appreciation of the technology.

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BIM EDUCATION IN ASEAN: THE DEMAND FOR BIM PRACTITIONERS

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ABSTRACT

The need for greater efficiency in the Architecture, Engineering and Construction (AEC) industry has created global demand for qualified BIM Practitioners. Additionally, government agencies, building owners, and corporations are mandating implementation of Building Information Modeling (BIM) for all types of developments across the AEC industry. Currently, there are an insufficient number of BIM practitioners being trained within the Association of Southeast Asian Nation (ASEAN) countries such as Singapore, Malaysia and Vietnam. This has unnecessarily pressured the ASEAN AEC industry to fill the shortage with non-ASEAN staff and has drastically raised the overall cost for BIM operation within the region as the result. Furthermore, as demand for BIM practitioners continually increases, this will cause unequal shifts in resourcing BIM practitioners worldwide. An appropriate BIM education program is needed now to fulfill the current and future needs within the ASEAN region.

Ultimately, the question is what are the components the AEC industry needs to put in place in order to create an effective well-rounded BIM educational program within a suitable timeframe in order to fulfill the current and future demands for BIM practitioners not only in ASEAN but eventually across the globe? This paper focuses on the key components that are essential for the successful development and implementation of a truly qualified BIM educational program. Eventually, the goal is to develop and implement an internationally recognized, stand-alone, post-graduate education program and subsequent certification for qualified BIM practitioners. **Keywords:** BIM, BIM Education Model, BIM Professional, BIM Practitioner, BIM Educator, BIM Student, Academic Business Model, AEC Industry Involvement, BIM in Asia, BIM in ASEAN, Future of BIM Education.

1. INTRODUCTION

1.1 The Future of BIM is Now

According to the BIM Education Report 2013 by Kevin Rooney (NATSPEC) released in January of 2014¹, “*awareness and uptake of BIM is certainly increasing, with BIM already widely adopted in the Architecture, Engineering and Construction (AEC) industry or with industry/government preparing themselves for the imminent arrival of BIM*”. This statement confirms that BIM is no longer a buzzword but rather a permanent archetypical practice in the AEC industry.

¹ Kevin Rooney (NATSPEC), “BIM Education Global Summary Report 2013”, Version 01, NATSPEC Construction Information, (Issue Date January 2014).

1.2 The Arrival of BIM Education

There has never been a greater need for a dedicated BIM education system. A system that focuses purely on creating qualified BIM practitioners, similar to the process that qualifies other industry professionals such as Architects, Engineers, Managers and Contractors. *“It is clear that tertiary education institutions, with the support of government and industry, need to fully incorporate BIM education into their curricula”* as described by the NATSPEC report and further *“to provide the AEC industry with the ‘BIM-ready’ graduates required for the collaborative BIM working environments to which they will be part of in the future.”*

1.3 BIM Adoption in Asia and ASEAN

Singapore’s construction industry, governed by the Building and Construction Authority (BCA), became one of the first government agencies in the world to recognize the potential of model-based design before the term BIM was even introduced². In 2015, BCA plans to establish a series of roadmaps for BIM adoption and push its design and construction industry to mandate and implement the use of BIM for all construction projects.

Meanwhile, other Asian countries such as China, Hong Kong, India, South Korea and Japan have begun to established governmental level requirements for BIM in 2015. While various ASEAN nations such as Indonesia, Malaysia and Vietnam have started to evaluate and are expected to issue new BIM regulations by 2015³. However, at such low level of adoption, majority of the BIM uses in Asia and ASEAN are mainly just modeling and introductory level of coordination. Therefore, at the present moment, there’s a general focus on first fulfilling the demand for modelers and coordinators.

1.4 The Hurdle for BIM

He Xixing, general manager of Shanghai Jianke Engineering Consulting Company, Ltd., stated, *“it is critical to find adequately trained staff to support the BIM process. First, team members operating BIM need to have the skills and capabilities of using the technology. Second, they must also have a good understanding of construction processes. Third, users of BIM need good project management capabilities to work well as a team.”*⁴

This statement effectively summarizes all the necessary elements that are essential for well-rounded BIM training and education. Particularly in the developing nations of ASEAN, rapid acceptance of BIM in order to keep up with the rest of the industry has created an overwhelming demand for practitioners. Therefore, existing AEC industry professionals are pressed to take on BIM training⁴ and understandably not able to comprehend the wealth of BIM knowledge needed to perform at the highest level.

1.5 The Demand for BIM Practitioners

General reluctance to accept change within the AEC industry has resulted in a shortage of experienced and qualified BIM practitioners and educators, therefore, slowing the inevitable acceptance of BIM throughout the AEC industry. The ideal situation is for the entire AEC industry to fully adopt the BIM process along with a sufficient supply of BIM Practitioners with various knowledge and skill levels to service the entire industry. However, this is far from the current scenario, and as BIM becomes an essential process for the AEC industry, without the further advancement of education and training of qualified BIM practitioners, BIM adoption and implementation will suffer.

² AECbytes.com, Analysis, Research, and Review of AEC Technology, “Around the World with BIM”, <http://www.aecbytes.com/feature/2012/Global-BIM.html>, (May 9, 2012).

³ Asia Green Buildings, “BIM in Asia: The Game Changer Yet Unleashed”, <http://www.asiagreenbuildings.com/bim-asia-game-changer-yet-unleashed/>, (October 13, 2014).

⁴ Asia Green Buildings, “BIM in Asia: The Game Changer Yet Unleashed”, <http://www.asiagreenbuildings.com/bim-asia-game-changer-yet-unleashed/>, (October 13, 2014).

This means that the need for standardization of BIM education specifically dedicated for the development of qualified BIM practitioners must start now. Globally, it is inspiring to see governments mandating the use of BIM; however, if there are not enough qualified BIM practitioners to handle such demand, the true value and high potential of BIM will never be realized.

1.6 The Global BIM Education Model

BIM awareness, education and implementation are currently at different levels across the globe. Various countries such as Australia and Singapore often provide BIM subjects as a supplement to an undergraduate or postgraduate level degree for design or engineering. Other countries such as the US and Hong Kong provide higher diploma programs or professional certifications of BIM knowledge at an introductory level during employment⁵. These certifications are usually short-term less than a week type of crash courses offered by local professional organization chapters or software vendors to full-time professionals.

Overall, it is understood that some countries appear to have embraced the topic of BIM while others have begun to prepare for the imminent arrival of this “game changer”⁶. The topic of BIM is increasingly becoming a feature of undergraduate and postgraduate courses, but never as a primary subject or an explicit requirement.

1.7 The Current Self-Educated Practitioner of BIM

The majority of current BIM practitioners worldwide are self-trained, self-titled and self-promoted as BIM experts. At the moment, BIM education mostly focuses on the training of a particular BIM software platform and certifying that the person is qualified in the utilization of this particular BIM tool⁷. Outside of those certifications, obtaining BIM knowledge involves real work experience and further self-education through the use of various governmental guidelines and corporate execution plans.

Major universities have now incorporated BIM curricula in some form or another in their major design, engineering and construction management degrees but these courses are still seen as secondary elective subjects. Thus, there is a lighthearted focus by tertiary institutions on the real value of BIM curricula compared to the enormous impact and usage of BIM throughout the AEC industry.

Local professional organization chapters in various regions also offer fast-tracked courses providing BIM knowledge certifications for qualified professionals. Internally, large corporations with adequate training budgets send their own existing qualified staff to the local BIM training courses or hire private BIM training services.

The down side of this lesser-value approach of learning practice is obvious - most notably the short-term value it places on BIM knowledge. Without recognizing the necessity for a dedicated program similar to the education of Architects, Engineers, Managers and Contractors, the importance and potential of a highly valued BIM educated practitioner will never become a reality.

THE ESSENTIAL COMPONENTS OF BIM EDUCATION

1.8 Tailor-made Curriculum and Internship Programs

As stated in the BIM Education Global Summary Report 2013 by NATSPEC, a tertiary education system must be in place with full support from private industry alike in order to produce the “BIM-ready” graduates needed for BIM working environments.

⁵ Kevin Rooney (NATSPEC), “BIM Education Global Summary Report 2013”, Version 01, NATSPEC Construction Information, (Issue Date January 2014).

⁶ The Royal Institution of Chartered Surveyors, BIM Manager Certification, “RICS Certified BIM Managers”, <http://www.rics.org/uk/join/member-accreditations-list/bim-manager-certification/>.

⁷ Kevin Rooney (NATSPEC), “BIM Education Global Summary Report 2013”, Version 01, NATSPEC Construction Information, (Issue Date January 2014).

Moreover, tertiary educational institutions must support and create tailor-made curricula and internship programs by methods of sponsorships or grants from industry leaders. Most importantly, there is a lack of acceptance and agreement by the AEC industry on the unified standards for a qualified BIM practitioner as well as with a lack of capable resources to fulfill the demand.

The following describes a series of subjects that are essential to the success of a newly defined BIM education system as mentioned above. These subjects create an effective BIM curriculum topics that can be defined as sufficient BIM knowledge for qualified BIM practitioners in ASEAN countries and across the globe.

1.9 Industry-wide Standard Certification for BIM Practitioners

At present there are no industry-wide standards or testing requirements for BIM Practitioners. The closest certification of a qualified BIM Practitioner in the United States is the Associated General Contractors of America (AGC) Certificate of Management-Building Information Modeling (CM-BIM). This certificate is an “*assessment-based certificate credential that denotes knowledge and understanding of concepts related to BIM adoption, practice and process*”⁸.

Similarly, the Royal Institution of Chartered Surveyors (RICS) in the United Kingdom has developed the BIM Manager Certification “*in response to industry requirements to have a standard that demonstrates the skills and competence of construction professionals in using BIM*”⁹. Other parts of the world also have developed comparable regional certificate programs designating qualified BIM practitioners. However, none of these certifications are completely recognized outside their specific territories.

An internationally recognized certification is not an absolute necessity because different regions will have different BIM requirements and regulations. However, there is much in the BIM knowledge set that is common across the globe, and standardization of certification for BIM practitioners can ultimately clarify professional BIM practice by defining who demonstrates BIM knowledge and who requires additional training.

1.10 Government Support for BIM Education

The BCA in Singapore established governmental BIM regulations for all institutional and public projects and recently extended to all private projects as well. As a result, they eventually created professional and technical placement programs through the BCA Academy that support their entire industry. This arrangement at its core is a brilliantly ideal scenario.

However, because of the lack of interest and individual incentives for Singaporeans to become BIM practitioners, along with a marginal population of industry personnel, Singapore’s output and supply of BIM practitioners has not been sufficient compared to the demand of its BIM required projects. Nonetheless, Singapore is certainly on the right path and unquestionably has proven that government backing is a huge contributor to successful BIM adoption.

1.11 Specifically Tailored BIM Curriculum

It is understood that if one is fully immersed in a definitive task and has the self-interest to focus only on that task, one can develop the ability to earn the title of an expert, and this certainly applies to the acquisition of BIM knowledge. At present, the vast majority of BIM practitioners are full-time professionals in their respective fields who do not have the luxury to dedicate round-the-clock commitments for BIM training.

Specialized full-time curriculum and continuous long-term specialized courses dedicated to in-depth teaching of BIM subjects are recognized as ideal for truly qualified BIM practitioners.

⁸ The Associated General Contractors of America, Building Information Modeling (BIM) Education, “Certificate of Management – Building Information Modeling (CM-BIM)”, http://www.agc.org/cs/building_information_modeling_education_program.

⁹ The Royal Institution of Chartered Surveyors, BIM Manager Certification, “RICS Certified BIM Mangers”, <http://www.rics.org/uk/join/member-accreditations-list/bim-manager-certification/>.

1.12 The Real-world Approach for BIM in ASEAN

A real-world approach for the BIM process should be developed and strengthened during the early stages of the BIM curriculum. Ideally by way of collaborative lectures from industry leaders outlining real situations from across the globe¹⁰ with emphasis on case studies within the ASEAN region.

The ASEAN region comprises of several diverse countries with conflicting working methodologies created by various regulatory approaches for each region. Thus, it is critical to cover a wide range of actual scenarios involving topics of real projects depicting uses of BIM methodologies. Additionally, covering related localized technologies, job placement conditions, specialized skill developments and all necessary subjects involving the regional development of the BIM process.

BIM industry professionals are encouraged to contribute and provide on-going dialogue and guidance for students on best practices, future challenges and the importance of developing specific skills for day-to-day practice in real BIM working environments¹¹.

1.13 The Essential BIM Curriculum Components

The quintessential ASEAN BIM curriculum model should focus primarily on two key components. First is the adoption and acceptance by the ASEAN AEC industry of various recognized accreditation programs for BIM practitioners similar to the aforementioned AGC and RICS certifications. Second is the creation of a specific and well-rounded BIM curriculum along with real-world experiences involving industry leaders and corporations within the ASEAN region.

The creation of a specific curriculum requires essential aspects of typical BIM projects. As discussed earlier, existing BIM education programs are often segmented into individual specialties. Furthermore, there are no existing programs covering the entire spectrum from modeling to management that can be defined as a comprehensive BIM education¹².

There are many legitimate reasons for this argument and the most obvious is the full-time commitment. Since the majority of the existing BIM practitioners are professionals holding full-time positions, round-the-clock commitments are extremely rare. Nonetheless, in order for a program to be recognized as delivering a complete knowledge of BIM, it should cover every aspect of what a BIM practitioner is responsible for on a daily basis – proficiencies including but not limited to basic knowledge of BIM's history, concepts and strategies as well as modeling techniques, procedures, data management, coordination, and supervision of the entire BIM project from beginning to end. Without a doubt, these knowledge are not easily obtainable with just a few days' worth of lecturing and exercises from such current BIM certification formula.

1.14 The Essential Levels of BIM Curriculum

The following are general levels that are necessary in order to define a comprehensive BIM curriculum. The BIM practitioner should be educated in three essential areas; Modeling, Coordination and Management. Each of the topics described below are only general subjects that will ultimately have sub-topics describing in-depth contents.

1.14.1 Level I – Building Information Modeling (BIM)

This beginning level of the BIM curriculum focuses primarily on general knowledge of BIM and the modeling process¹³. Additionally, introduction knowledge of workflows, standards and data management are essential in order to maximize the effectiveness of the modeling procedures. A typical Modeling curriculum covers the following primary topics:

¹⁰ Kymmell, W., "Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations", McGraw Hill, New York (2008).

¹¹ Hietanen, J. and Drogemuller, R., "Approaches to a university level BIM education", *IABSE Conference*, Helsinki, (2008).

¹² This is purely my assessment from reviewing and analyzing majority of existing global BIM programs.

¹³ George Mason University, "Building Information Modeling", http://mason.gmu.edu/~mcasey4/bim/CEIE499-690BIM_syllabus.pdf, (June 2010).

- BIM Course Level I-A: Introduction to BIM
- BIM Course Level I-B: Building Information Modeling and Procedures
- BIM Course Level I-C: BIM Data Management

1.14.2 Level II – BIM Coordination

This intermediate level focuses on the collaboration and work flow optimization of the BIM process along with detections, calculations, estimations, and scheduling¹⁴. Additionally, logistics and sustainability are absolute necessary for this level of knowledge. A typical Coordination curriculum covers the following general topics:

- BIM Course Level II-A: BIM Collaboration
- BIM Course Level II-B: BIM Calculation, Estimation and Scheduling
- BIM Course Level II-C: Sustainability for BIM
- BIM Course Level II-D: BIM Coordination

1.14.3 Level III – BIM Management

This advanced level focuses on sophisticated modeling procedures and unique technologies that allow for further advancement of the existing modeling process. Furthermore, the overall development of communication, standards, protocols, workflows as well as scope creation and training for the entire project team are indispensable at this level. A typical Management curriculum covers the following central topics:

- BIM Course Level III-A: BIM Advanced Modeling
- BIM Course Level III-B: BIM Technology
- BIM Course Level III-C: BIM Management and Training

As mentioned, each of the topic above are generalized for the purpose of this paper. However, within each topic noted, there are sub-topics that describes the in-depth contents. For example; “**Level III – BIM Management / BIM Course Level III-C: BIM Management and Training**” will include sub-topics such as:

- BIM Execution Plan (BEP)
- BIM standards and protocols
- BIM proposals and tendering
- BIM scopes and requirements
- Contracts and risk allocations
- BIM workflow and team formalization
- Interoperability, organizational data and standards
- BIM training and recruitment
- Project management platforms
- Collaboration, meetings, agendas and schedule tracking
- Project close-out and data archiving

The placement and advancement of the student at each level is predicated on the grading criteria based on experiences, knowledge, skills and the passing of the specific level testing requirements¹⁵. The levels completed determine the skills and competencies of each student. Based on qualifications and recommendations, the student are granted permission to advance to the next level. Those who do not meet

¹⁴ Kymmell, W., “Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations”, McGraw Hill, New York (2008).

¹⁵ Denzer, A. S. and Hedges, K. E. “From CAD to BIM: Educational Strategies for the Coming Paradigm Shift”, AEI 2008: Building Integrated Solutions, (2008).

advancement requirements are recommended to enter the working environment in order to develop the necessary skill sets and allow to return to complete all other levels upon recommendations.

1.15 The BIM Curriculum Structures

In order to present a well-rounded BIM education program, the structure of all levels of the curriculum are categorized into focuses of *real-world experiences, class lectures, keynote speakers, and workshops*. *Real-world experiences* are essential to the education of professionals in any industry¹⁶. As stated earlier, in order to provide field experience within the BIM profession, industry-related companies will need to be engaged and aid in the development of the curriculum as well as to provide workshop trainers and on-the-job-training opportunities. *Class lectures* are fundamental personalized sessions for the students focusing on modeling, coordination and management techniques being utilized throughout the globe. *Keynote speakers* are lecture/discussion sessions for the entire student body. The speakers are leaders in their respective fields addressing trending topics within the industry ranging from the latest and greatest technology to job placement strategies in order to prepare for the real-world. During the *workshops*, students participate in tailored programs for each individual's distinct situations that focus on developing their specific BIM skills with real building information models¹⁷. These workshops allow the students to go at their own pace led by experienced professionals from the AEC industry or related corporations.

Furthermore, the standout BIM education formula should identify and create partnerships with as many as possible of the various recognized BIM programs across the globe.

1.16 Participation of the BIM Industry Professionals

As with any program, the measure of success or failure cannot be determined without the involvement of qualified experts and experienced personnel. The challenge here is that since BIM is a relatively new profession, the number of truly qualified practitioners who have field experiences are rather limited.

BIM is a practical profession that requires real-world know-how in order to solve and clarify technical issues, thus the involvement of industry professionals with region-based experiences as educators are vital. It addresses and demonstrates the significant differences between BIM practices in say, ASEAN compared to non-ASEAN regions and provides students with unique regional perspectives.

1.17 Partnerships with Industry-Related Corporations

In addition to the participation of industry professionals, the supports of related AEC corporations are fundamental to the success of a well-rounded BIM program. This support can be in the form of internships, financial support and/or employment upon graduation as well as opportunities to further develop their skills. This approach has many tangible benefits at both ends of the spectrum for the sponsored corporations and all parties involved.

2. CONCLUSION

2.1 The Inevitability of BIM Education

Despite the wide range of benefits of utilizing BIM and the attention it is getting from the AEC industry, as mentioned, overall adoption of BIM is rather fragmented across the globe¹⁸. As we discussed, one major cause of this sluggishness is the unavailability of qualified BIM practitioners. Asia, including ASEAN countries, are recognized as the largest emerging markets in the world. This region has become the hot spot for finance, manufacturing and developments. Ironically, with the exception of Singapore¹⁹ this region is one of the slowest adopter of BIM.

¹⁶ Hietanen, J. and Drogemuller, R., "Approaches to a university level BIM education", *IABSE Conference*, Helsinki, (2008).

¹⁸ Asia Green Buildings, "BIM in Asia: The Game Changer Yet Unleashed", <http://www.asiagreenbuildings.com/bim-asia-game-changer-yet-unleashed/>, (October 13, 2014).

¹⁹ McGraw Hill Construction, SmartMarket Report, "The Business Value of BIM for Construction in Major Global Markets": 50-53, 56-57, (2014).

Largely, due to the lack of qualified BIM practitioners, this obstacle has impeded on the growth of BIM adoption throughout Asia while prolonging the rapid adoption of this crucial “game changer” for the entire AEC industry. Consequently, a highly valued, internationally recognized, and well-rounded BIM educational program geared towards the development of truly qualified BIM practitioners now becomes a necessity for the advancement of BIM as a whole in ASEAN, Asia and the rest of the world.

ACKNOWLEDGMENTS

This paper cites various levels of education programs, conference proceedings, and journals of the overall nature of BIM curricula and related tertiary BIM education throughout the globe. Included are sources from the United States, Australia, United Kingdom along with various Asian nations such as Japan, South Korea, China, Hong Kong and ASEAN countries such as Singapore, Malaysia and Vietnam.

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