Utilization of Standard Plans to Facilitate Student Understanding of BIM Processes

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ABSTRACT

In order to meet the technical needs of a developing industry, it is essential that Building Information Modeling (BIM) be included in construction curricula. Recent research identifies the most effective instructional strategies for implementing BIM by presenting possible pedagogical models for teaching technology in the AEC industry. From the replacement of traditional drafting and graphic communication coursework to the full integration of BIM processes in all phases of Capstone courses, the manner in which BIM is being taught is diverse among different educational institutions. In this paper, the authors present a summary of their experiences teaching a revised BIM curriculum to graduate level students at University of Florida's Rinker School of Building Construction. The pedagogical method that was tested involved the utilization of a simplified set of building plans created specifically to introduce students to Autodesk Revit Architecture, Structure, MEP, QTO and Navisworks software packages. By utilizing a standard building plan set specifically created for the course, students learned the principals of multidisciplinary workflow and best modeling practices in a small accomplishable context. Supplemental teaching materials helped to reinforce foundational concepts such as plan reading, estimating, scheduling, and construction coordination. The creation of a set of standard building plans for the curriculum assisted in eliminating many of the documented hurdles associated with current pedagogical approaches.

Keywords: Building Information Modeling (BIM), construction education, curriculum, construction technology

1. INTRODUCTION

Construction, more than any other profession is unique in that to be successful, those managing the project must be knowledgeable in many different disciplines. Additionally, the number of software packages required within the industry has also increased. Therefore, technology integration into the American Council for Construction Education (ACCE) curriculum continues to be a topic of interest, especially as it relates to the best instructional strategies for student learning outcomes. It has been widely established that inclusion of Building Information Modeling (BIM) into construction curricula is necessary; however, research continues regarding the best approach for implementation. In review of the pedagogical literature, the apparent trend within most institutions is a scaffolding approach with a basic IT/foundational course and then building upon that knowledge with an applied use of BIM within additional coursework. The Rinker School at the University of Florida has found that for its foundational course, by establishing a standardized set of building plans for the curriculum, students were able to better understand the specific foundational tasks and instructors were able to utilize a specific instructional strategy to achieve the desired performance outcomes. Standardized plans,

instructional strategies, and specific rubrics provided a best practice outcome by which the program documented improved efficiency and performance in BIM classes.

2. LITERATURE REVIEW

2.1 The Need for a Pedagogical Model in Teaching BIM

According to McGraw Hill's 2009 Smart Market Report, roughly 49% of the AECO industry is now using BIM in some fashion. Of the contractors surveyed, half reported using BIM or BIM–related tools and nearly one third of them reported authoring their own models (McGraw Hill Construction 2009). Given this rise in BIM implementation, particularly by contractors, it is imperative that construction students now be taught the BIM skills required of their future careers.

However, the integration of BIM into curriculum creates several challenges for educational institutions including: deciding the number of courses and when to teach them, as well as the many differences that BIM requires in traditional teaching methods due to the software's broad capabilities. Additionally, the complexity of BIM software requires a certain level of expertise to instruct. In a survey of ACCE programs, 55% of respondents that reported having no current courses on BIM indicated the reason to be a lack of qualified instructors to teach them (Bercerik-Gerber et al. 2011). At Auburn University students were introduced to BIM through an initial Construction Information Technology (CIT1) course, and were then provided the option to complete a thesis with inclusion of the BIM software applications (Taylor et al. 2008). Although the trend shows that students are introduced early on in their curricula to BIM in a more basic format, pedagogical challenges still exist. The current options appear to range from utilizing the Autodesk tutorials to accomplish specific tasks, to creating a complete model from an actual set of as-built documents. These strategies demonstrate the current struggle with the course delivery of a complex technology course.

Previous studies have also outlined many of the obstacles to implementing an acceptable instructional model and the perceived obstacles that exist from both the administrative levels and from the students' perspective. In a survey conducted by Minnesota State University asking ASC members about BIM implementation, 53.3% of the respondents stated that the lack of textbooks and other educational resources for students was one of the perceived obstacles of adding BIM to the curriculum (Sabongi 2009). Most BIM courses have a list of recommended textbooks for reference but there are no specific written course tutorials for BIM that walk students through the foundational software requirements. At Western Illinois University, students expressed difficulty in learning many of the Revit functions as a beginner and were also disappointed with the lack of reference materials. Although Autodesk provides tutorials, students wanted more written materials for immediate help (Woo 2007). Additional barriers preventing schools from implementing BIM curricula included a lack of space in the current curriculum and a general lack of accreditation specificity (Bercerik-Gerber et al. 2011).

2.2 Current Pedagogical Trends

In a 2009 survey of ACCE accredited programs and National Architecture Accrediting Board (NAAB) accredited programs, a total of 56% of schools reported offering BIM courses in some form. Of the construction programs surveyed, 60% indicated that they offered BIM courses, mostly at the senior level often as an elective (Bercerik-Gerber et al. 2011).

The introduction of Autodesk Revit software, for many programs, is an established trend and appears to be provided as an introductory IT/BIM course with the inclusion of continued use through upper level coursework and capstone projects. Thus, most programs provide the basic introduction followed by integrated BIM courses including multidisciplinary approaches. Auburn University introduces computing topics in their Construction Information Technology Course (CIT1) and then provides the fundamental BIM modeling in their CIT2 course. This aligns with the overarching trend mentioned above. Additionally, due to the broad context within both courses, there are no books providing optimum content; therefore, a set of customized tutorials, exercises and assignments on each topic has been developed by instructors. Taylor et al. (2008) also stated that students continue to use the skills in homework, projects and especially in their capstone experiences.

Similarly, Barison and Santos (2010) identified three distinct types of BIM courses currently being offered among different educational programs around the US. They were categorized by their level of difficulty. It was suggested that BIM curricula first address the individual abilities of modeling and analysis and then in later years build upon that knowledge to address collaboration and team building skills. Introductory courses, implemented by most institutions, are usually lumped into traditional *digital graphics representation* coursework designed to teach students the preliminary BIM modeling skills, plan reading and construction documentation. Intermediary level courses stress *integrated design studio building technology* fundamentals needed by future BIM analysts. Lastly, advanced BIM coursework stresses the skills of interdisciplinary collaboration and construction management needed by BIM managers (Barison and Santos 2010). Stanford is one such program which has been successful in integrating advanced BIM content with traditional project management coursework (Peterson et al. 2011). Other programs are even beginning to incorporate the ideas of social interaction to supplement BIM curriculum with the integration of Building Interactive Modeling (BiM), in the second life platform (Ku and Mahabaleshwarker 2011).

2.3 The Standard Curriculum Approach

Although not all programs use the approach, the predominant trend (including at the University of Florida) is to focus initially on the basic modeling content to establish a good foundation which would guide students to create their own resources for additional learning in other courses and capstone experiences. In a student survey at Auburn University, students responded regarding their capstone study that 55% of the content they learned was obtained through a self-taught method (Azhar and Hein 2010). Although this method is used consistently by many schools, some have reported mixed results. George Mason experienced difficulty with their sequential courses and noticed that near the end of the program, students seemed to have forgotten their basic CAD and computing skills (Casey 2008). However, if applied using a similar approach to the BIM Staircase for applied levels of learning as referenced by Hjelseth (2008) throughout the student's program, a greater application of the foundation can be utilized in the courses implementing BIM content. The importance of correct information in the model provides additional reasoning to focus on the foundational tasks of the program. Ideally, if utilizing Bloom's Taxonomy, the goal should be to ensure mastery of the lower level objectives through a good platform in the principles of BIM (skill) and then building upon the base knowledge to allow for the mastered BIM skill to be understood as an element (tool) to be used in many other aspects of the industry (Forehand 2005).

3. METHODOLOGY

The University of Florida's M.E. Rinker, Sr. School of Building Construction has been committed to gradually refining its curriculum to incorporate BIM at all levels since 2007. Recently, its graduate elective course *Construction Information Systems, BCN6785*, has undergone a dramatic transformation. The course is a three credit graduate elective which was traditionally taught in a lecture-based format and covered a wide variety of advanced information technology topics. Since 2009, the curriculum has slowly integrated more lab content on BIM using a variety of teaching methodologies.

In the Spring 2011 semester the instructors of this course began a new teaching methodology which utilized a standard of set of curriculum building plans specifically designed to provide an introduction to tasks in the Revit Architecture, Structure, and MEP software packages. Although the primary objective was to provide students with a fundamental knowledge base of how to create a multidisciplinary BIM using standard 2D documentation, students were also exposed to Autodesk's QTO and Navisworks software to exemplify how a BIM model could be used to aid estimating, scheduling and coordination processes. The class presented a unique opportunity for one of the authors as she was able to participate in the course as a student. The remaining authors provided content delivery and instruction for the course. This presented opportunities for dialog regarding best practices and methods for construction students.

While some lecture material was provided to students outlining the theoretical principals of BIM, example BIM case studies, and guest speakers from the industry, the bulk of the course was taught in a lab environment demonstrating a variety of software packages. For the purpose of this course, all Autodesk products were implemented because of their contribution of free educational licenses to the student community. The foundation for course instruction was rooted in the utilization of a small set of construction documents for a 7600 SF three-story commercial office building with relatively repetitive floors and symmetrical layout, designed specifically for the course by the instructors. The objective was to create a building simple enough for a novice modeler given the time constraints of the course but which utilized all modeling object categories available in Revit and reinforced the importance of construction fundamentals. Figures 1-3 show images of the simplified office building designed and used by the instructors in *BCN6785* to achieve this goal.

Figure 1: Architecture Model

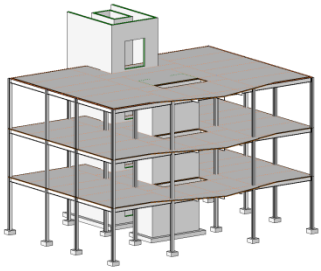

Figure 2: Structure Model

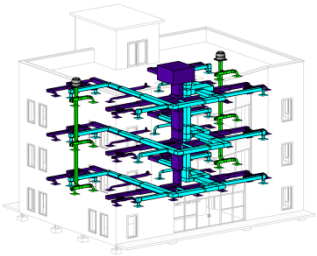

Figure 3: Mechanical Model

A simple set of construction documents created in the different Revit platforms was provided to the students at the beginning of the semester as the foundation for all class assignments. The drawing package included approximately 4 sheets each for the architectural, structural and mechanical disciplines. Each discipline included plans, sections, details and schedules required to complete the model. Additionally, the design included explicit characteristics such as a symmetrical layout to provide practice for mirroring and modify features and similar floors to encourage students to exercise the copy and paste aligned tool. To supplement each set of plans,

a corresponding assignment sheet was created outlining the specific tasks that were required. The instructors used this detailed rubric to demonstrate the importance of accurate modeling practices.

The six assignments which utilized these standardized building plans were assigned in a sequence which corresponded to the lab schedule. Therefore, each assignment was designed to build upon the skills reinforced in the previous assignment and corresponding lectures, forming a foundational knowledge base for students. Assignments 1-3 required students to virtually construct the architectural, structural, and mechanical disciplines' models respectively using their corresponding Revit platforms. Once the federated model was complete, Assignment 4 utilized Autodesk's QTO software to complete an abridged quantity takeoff of the building. Assignment 5 utilized Navisworks to complete a 3D animation and conduct a coordination review of their completed BIM and Assignment 6 involved the creation of a 4D simulation of the project schedule using the timeliner tool in Navisworks.

Each assignment was developed to ensure that specific modeling/software tasks were reinforced from the lecture and were included in the grading rubric. For example, Assignment 1 was centered on constructing the Architectural model. Thus, one of the requirements listed in the assignment sheet was the addition of interior walls with proper structure, dimensions and nomenclature. The grading rubric would then assign a total number of points to the one task, in this case 5, and sub-divide for the details of that task, e.g. correct placement-2 points, correct structure-2 points, correct height-1 point. This ensured that students learned through focused tasks and did not become overwhelmed by the construction drawings. In addition, it made the task of grading for instructors less subjective and more manageable.

For Assignments 1-3, in addition to their submission of the physical models, students were also required to maintain a log of the hours they spent modeling each discipline in an MS Excel spreadsheet which described each task that they completed and the amount of time it took. These logs were later referenced by instructors to gauge how long it took students to become familiar with the different software packages and on average how many times they sat down to model. The log also served as a vehicle for communication between the instructors and individual students. Students were asked to record any questions that arose during their completion of each assignment in a separate tab in the log spreadsheet, similar to an RFI. An answer field was included providing a place for instructor feedback. Figure 4 shows an example of a student's log with the instructor feedback.

Date	Modeler	Sht #	Question	Answer	Issue Closed?
2/2/2011	NRB	1	What are the walls being centered from? i.e. stud	Not Centered, dimensioned from exterior	YES
2/14/2011	NRB	1	How do you edit coulum grids on a linked structure model?	You can't edit anything in the linked model without going to its live model. Therefore, you need to trace the grids over.	NO
2/14/2011	NRB	1	Why are there holes in my wall when I edit the structure of the wall?		NO
2/14/2011	NRB	1	Do we have to annotate each view or just the handout material?	just the handout material. Use what was indicated on the assignment sheet.	NO
2/14/2011	NRB	1	What is the best way to edit joints of materials?	I think trim is a helpful tool for this.	NO
2/15/2011	NRB	1	How do you create the cap for the parapet?	You would need to place a sweep in the structure of the wall. This was not required.	NO
2/16/2011	NRB	1	In the Arch. Model we have to make shaft openings, does the elevator shaft cut into the 1st floor slab?	Yes. But I was not clear about this is in the details. So no points were removed.	NO
2/17/2011	NRB	1	How do you create the reference line in section view?	You hould be able to create reference planes in any view from the home tab.	NO
2/18/2011	NRB	1	What are the dimensions for the foundation slab under the stair shaft, it is not in structure nor in arch. Drawings?	its tagged as 36" x 12"	NO

Figure 4: Example Student Log with Instructor Feedback

4. RESULTS

4.1 Learning Objectives

The primary objective sought by the instructors of this course was to teach the skills required to create a multidisciplinary BIM in order to give students an understanding of the complexity of BIM as well as the level of detail and accuracy required for it to be used effectively by contractors. Therefore, though they may not be asked to construct a model in their future careers as contractors, they must at least have a sensitivity to the time and effort that is required by subcontractors and designers in order to better manage them. This skillset was reinforced by Assignments 1-3. As a secondary objective, the instructors also intended to foster an understanding of the value of a BIM model to a contractor. This was reinforced by Assignments 4-6 which utilized the model for estimating, coordination and scheduling. When considering the revised Bloom's Taxonomy (RBT), the authors found the approach of a regimented focus initially on the lower level categories of remembering, understanding, and applying Revit tasks to be very beneficial. However, when students implement aspects of BIM into additional courses and projects after *BCN6785*, they can further their learning on the continuum of Bloom's Taxonomy to include the higher levels of analyzing, evaluating and creating (Forehand 2005).

4.2 Course Schedule

A rigorous course schedule was followed over the span of the 16 week semester in order to cover the variety of materials. Therefore, the lab schedule for *BCN6785* was quite demanding. Eight classes revolved around modeling fundamentals and multidisciplinary workflow in Revit Architecture, Structure and MEP. Once a complete federated model was constructed, the students were able to utilize it in the remaining five weeks of class for QTO and Navisworks exercises to demonstrate how BIM might benefit them as future construction managers.

Though covering five software platforms in this accelerated time period was extremely difficult, the instructors wanted to challenge students at the graduate level. In fact, *BCN 6785* traditionally has a diverse sample of students participating, providing a multidisciplinary dialog not available at the undergraduate level. Table 1 shows the undergraduate degree of the students who participated in the course during the Spring 2011 semester. The students had undergraduate degrees in Architecture (55%), Construction (30%), Civil Engineering (6%) and other areas such as Business (9%). However, all of the students had some modeling experience or were familiar with CAD based software either through their undergraduate education or by taking a prerequisite drawing course.

Table 1: BCN6787 Class Demographics

Background	**Number of students (% of total)**
Construction	10 (30%)
Architecture	18 (55%)
Civil Engineering	2 (6%)
Other	3 (9%)
Total	**33**

Table 2 breaks down the number of hours spent learning different tasks in the different software packages during in-class exercises. Roughly 72% of in-class time was spent teaching BIM skills. The other 28% was centered on more traditional theory, case studies and emerging topics related to BIM.

Table 2: Estimated Time Spent Learning Different Skills in Class*

	Task	Time Spent Learning (Hrs)	% of total time
BIM Lab Content	Modeling Architecture	8	21%
	Modeling Structure	3	8%
	Modeling Mechanical	6	15%
	Estimating	3	8%
	Scheduling	3	8%
	Construction Coordination	2	5%
	Presentation	3	8%
Supp. Content	Other	11	28%
	Total	**39**	(13 3hr classes)

*This is a rough estimate based on the number of hours spent in the lab covering certain topics

4.2 Student Learning Outcomes

Table 3 shows, based on metrics generated from the students' assignment logs, the average amount of time spent by students completing each discipline's model for modeling assignments 1-3. It is evident that students had the most difficulty completing the Architectural and Mechanical disciplines because of their higher level of detail. Students also expressed more difficultydeveloping the mechanical model because of a lack of in-depth exposure to MEP systems in the current curriculum. Analysis of the student assignment logs also indicated that over time it took students fewer hours to complete similar tasks in Revit. Therefore, repetition of certain concepts drove the exercises as well as the in-class content.

Table 3: Time Spent Modeling Each Discipline Using Curriculum Standard Plan Approach

	Arch. Model (hrs)	Struct. Model (hrs)	Mech. Model (hrs)
Mean	16.4	6.6	14.6
Median	16.25	6	13.5
Std Dev	6.93	3.34	4.76

5. CONCLUSIONS

The combined knowledge of instructors and student experience of the authors provided an interesting dialog about the successes and challenges of the proposed pedagogical model. Based on a comparison of grade statistics from previous years in which BIM was integrated in the course curriculum, the new revised utilization of standardized plans proved to be a much more effective teaching tool. The success of the streamlined and efficient process was evident not only through the student feedback, but also through the student time logs as well. The course showed significant improvement over past experience by the instructors teaching BIM using other methodologies.

Many challenges existed in the implementation of the revised BIM curriculum for *BCN6785*. The burden of teaching five separate software packages in the span of a single semester left many challenges for the instructors and students alike. In addition, the time period in which the course was offered presented other impediments. *BCN6785* is offered for a single three hour block one evening per week. Therefore, there was little room for students to get the extra practice required by the software without out-of-class exercises. However, using the revised standard curriculum plans helped in reinforcing any material that may have been forgotten in the preceding classes. An additional challenge was the increased potential for academic dishonesty.

Therefore, the students were informed early in the class of Revit's "show history" function which allowed the instructors to monitor every instance a file was saved and on which computer in order to avoid the potential problem of students sharing electronic files.

The success of using a simplified set of construction documents designed specifically to learn Revit tasks was recognized by both students and instructors alike. In the future, the authors intend to further study how students learn each software platform and the time it takes them to master certain fundamentals, while revising this curriculum. This will be achieved through a more structured modeling log to track more interesting BIM learning curve metrics.

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