A Study of Using BIM as an Innovated Teaching Tool in an Estimating Class – A Preliminary Report

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The construction process involves using two dimensional drawings to construct three dimensional objects. Teaching the reading and interpreting of these drawings and using the drawings in estimating is done in class by verbal explanation and demonstration with minimal use of three dimensional drawings for illustration. Existing research shows that visual illustrations significantly contribute to teaching construction topics by improving the demonstration of complicated concepts such as building components. To provide a greater coverage of building information modeling (BIM) in the curriculum of an ACCE accredited construction program, and to test the effectiveness of an innovative approach to teaching plan reading and estimating, faculty members of this program integrated BIM into an estimating class by having the students first create a BIM model of a portion of a selected building project, then perform the quantity take-off for that portion. Outcomes of the integration are measured by a comparison of quiz grades from the trial class with those of previous semesters, and by students' responses to a questionnaire. This paper presents the development and implementation of this innovated construction estimating course. It also reports preliminary finding of the effectiveness of using BIM as a teaching tool in this course.

Key Words: Construction Education, Construction Estimating, Building Information Modeling, Case Study

Introduction

Two-dimensional (2D) drawings are widely used for teaching courses in construction management programs across the United States. Teaching the reading and interpreting of these drawings and using the drawings in estimating is done in class by verbal explanation and demonstration with minimal use of three dimensional drawings for illustration. Interpretation of 2D drawings by students varies based on their educational background, previous practical experience, and visualization capabilities, among other factors. Students are required to develop (3D) models mentally by visualizing the different components of the building. With the ever-increasing complexity of the modern building projects, students with little or no practical experience often face challenges and spend more time developing 3D visual models.

With the advent of the modern multimedia technology and Building Information Modeling (BIM), we as construction educators now have new and exciting ways to present information to our students. Existing research has shown that visual illustrations significantly contribute to teaching construction by improving the demonstration of building components. It is believed, therefore, that having the students develop BIM models while learning estimating would enhance their ability to read and interpret project plans and their ability to perform estimating tasks. BIM is a process that provides a framework to develop data rich information models that foster the integration of information from conception to decommissioning of the facility. Some of the BIM characteristics, such as easy access to information, visualization, and simulation capabilities, provide opportunities to address the challenges faced by students during the visualization process.

The recent rapid evolution of Building Information Modelling (BIM) software and its adoption among the building disciplines suggests that BIM holds tremendous promise for the future of Architecture, Engineering and Construction (AEC) industry. Due to its many uses and capabilities, contractors and construction associations are at the forefront of the BIM debate (Taylor *et al.*, 2008). BIM technology not only facilitates design, the coordination

of potentially conflicting systems within a building, and the generation of quantities for estimating, it also has the potential of more effectively teaching the students to read and interpret two dimensional plans for estimating and construction. According to a survey by McGraw-Hill Construction (2008), BIM is being broadly adopted across the construction industry and its use is expected to exponentially expand across the AEC industry in the coming years. "For construction education, BIM offers the opportunity to unify disparate technologies to provide a coherent Information Technology (IT) skill set for construction students to address the range of problems in the life cycle of a building." (Azhar & Richter, 2009) BIM also provides a framework that combines visualization and parametric modeling in a way that allows students to simultaneously consider the interdependent processes of planning, analysis, design and construction (Casey, 2008; Azhar & Richter, 2009).

Some research has been done to study the impact of using building information modeling on teaching estimating to construction management students. Gier concluded that BIM appeared to be an effective educational tool for teaching construction estimating (Gier, 2008). With continuous incremental improvements to the implementation process, BIM could prove to be an effective, untapped resource for teaching estimating. The advantages of using BIM outweigh its disadvantages. Construction visualization tools, like BIM, provide excellent visual methods for teaching estimating (Gier, 2008).

BIM in BSCI Curriculum

The McWhorter School of Building Science (BSCI) at Auburn University is in the process of reviewing and revising its curriculum to reflect recent changes in the industry. The construction industry reports that one of these changes is the increasing use of BIM in project delivery, and recommends a coverage of BIM that exceeds what is currently offered in the BSCI curriculum. Various ways of teaching BIM in its construction management curriculum have been tried by BSCI (Liu & Kramer, 2011). BSCI began teaching BIM in the Fall of 2007 by introducing Autodesk Revit in the second Construction Information Technology (CIT) class, and by allowing selected students to complete a special Thesis involving the development of BIM models for their projects. The students completing a "BIM Special Thesis" have been able to develop advanced skills in using BIM and to explore the advantages of using BIM for building design and construction. The students not doing a "BIM Special Thesis," while gaining exposure to BIM, have not had this same opportunity. More time with BIM is needed to develop advanced skills in and understanding of this new technology for all BSCI students.

BSCI curriculum currently has a two course sequence to teach construction estimating. In the first course, students perform a complete manual take-off and pricing for a sample project, and complete a simple bid day exercise. In the second course, students develop a complete estimate for a project using computer estimating applications, participate in a bid day exercise, and are introduced to project management topics.

In order to provide a greater coverage of BIM in the curriculum and to test the effectiveness of an innovative approach to teaching plan reading and estimating, two BSCI faculty have conducted a case study to integrate BIM into the first estimating class. In this study, BIM components replaced the pricing and bidding portions of the first course that are duplicated in the second course. This paper presents the development and implementation of the BIM components in this class. It also reports preliminary findings of the effectiveness of using BIM as a teaching tool.

Case Study Methodology:

The objectives of this study of introducing BIM into this construction estimating course are as follows:

- To determine if BIM and estimating can be successfully taught together

- To determine if BIM integration enhances learning plan reading and interpretation

- To determine if BIM integration enhances learning estimating quantity take-off

- To expand BIM coverage in the curriculum

- To provide cross training in estimating and BIM for the participating faculty members

The researchers selected qualitative and quantitative as the methodology. The qualitative study would collect students' perception of the BIM course materials and teaching approach through a 19-question questionnaire administered at the end of the semester. During the quantitative study, students' skill in construction material quantity take-off was to be tested by means of periodic quizzes. The results of these quizzes would be compared with results of quizzes from previous semesters to determine the effectiveness of the approach.

Because it had been noted in this class that the average GPA level of students of the spring class and the afternoon section is usually higher than that of the fall group and the early morning section, the researchers decided to conduct the similar studies in two consecutive semesters: Fall 2010 and Spring 2011comparing the results with historical data from corresponding semesters and section times. The researchers planned to conduct the case study in four stages, as shown below.

Stage-1: Develop BIM and revise estimating course materials during the summer of 2010
- Selection of a construction project for the class

- Development of a comprehensive BIM model for the selected project

- Development of course instructional materials, assignments and quizzes

Stage-2: Test the course materials in the fall semester of 2010
- Course materials to be presented by use of project plans and specifications and a BIM model

- BIM modeling procedures are demonstrated

- Students create a BIM model for each section of the project, perform a manual quantity take-off for each section

- At the end of the semester the students have a complete BIM model and a complete quantity take-off for the project

- Use a questionnaire to gather students' perception of the new course materials and teaching approach

Stage-3: Revise class materials and procedures and test them the spring semester 2011
- The results of the questionnaire and the quizzes to be analyzed to determine what changes need to be made to increase the effectiveness of the course materials

- New materials, if needed, to be developed during December, 2010

- Test the revised course materials during the spring semester 2011

- Use the same questionnaire to gather students' perception of the new course materials and teaching approach

Stage-4: Research data analysis

## Course Development and Implementation

As planned by the two participating BSCI faculty, this innovative estimating course would be co-taught with one covering material take-off using 2D plans and specs, while the other teaching BIM for the modeling of the sample project. The distribution of the lectures/contact-hours on the quantity take-off versus BIM contents would be approximately 2:1.

The Auburn University Intramural Fieldhouse (fieldhouse) project was selected as the building for the class. It is a one-story building containing lockers, offices, restrooms and one storage room. It is approximately 3,000 ft^2, with load bearing masonry walls, concrete footings, concrete slab, wood trusses and a low slope roof. The project has been used in this class in previous semesters, providing the grade data for a quantitative comparison of student performance with and without BIM.
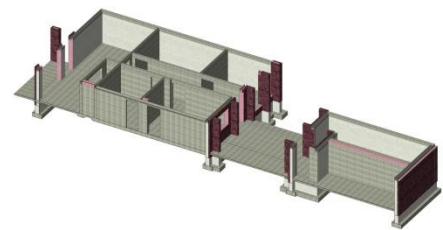
The researchers first created a comprehensive building information model of this building in Revit 2010. Then they developed a set of course instructional materials around the model. See Figure-1 for renderings of the Revit model. Based on the teaching objectives and the building's own characteristics, these teaching materials mainly focused on teaching students to model the structural system and the building components categorized as Construction Specifications Institute (CSI)'s divisions 4 through 8 (concrete, masonry, metals, wood and plastics, thermal and moisture protection, and door and windows). Because most of the students in this class had never touched BIM or Revit before, the tutorials also included basic introduction of BIM technology and fundamental Revit features.
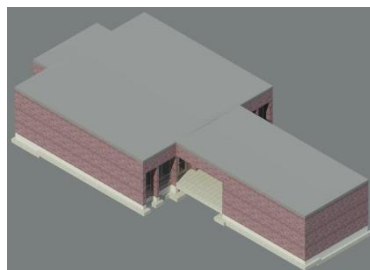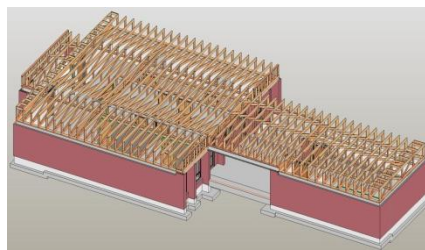
1 a. Isometric view   *1 b. Wood trusses*   *1 c. Walls and footings*

Figure 1: Renderings of the building information model of the fieldhouse building in Revit.

The BIM lectures were divided into five sections. Details of these five sections are listed in Table-1. Each lecture section was followed by a BIM assignment that required students to model the building components covered in the specific lecture. After each section, the conventional construction estimating methods of those building components that students just modeled were introduced by the other faculty member. In this way, students are believed to have visualized the building project through modeling and therefore would be able to provide more accurate estimating. Following the last BIM assignment, a BIM Final Project was assigned to allow students to model those items that had been left out from the previous assignments, such as roof and ceiling.

Table 1

Topics and length of BIM sections taught in the innovated construction estimating class

Section	CSI Division(s)	Topics/Components to Model	Number of Lectures	Total Lecture Hours
1	-	BIM introduction and Revit fundamentals	3	6
2	3	Concrete footings, CMU foundation walls, and concrete slab	3	6
3	4	Walls (exterior and interior), brick piers, and concrete bond beams	2	4
4	5&6	Structural steel, wood members, wood trusses, and wood sheathing and decking	2	4
5	7&8	Doors, windows, and other miscellaneous items	2	4
		Total:	**12**	**24**

Results and Discussion

Qualitative Study

At the end of 2010 fall and 2011 spring semesters, students were invited to fill out a questionnaire to report their perception of the BIM contents in the class. A total of 82 students voluntarily completed the questionnaire. Due to the page limit, this paper only reports the preliminary results and analysis of selected questions from the questionnaire. A comprehensive report of the qualitative study results and analysis will be addressed in a forthcoming journal article.

Question #1: Had you used any 3D modeling program prior to this class?

Out of the 82 students, only 19 (23%) had experience with 3D modeling and majority of it was on Google Sketchup. This indicated that most of the students (77%) had little or no 3D modeling knowledge coming into this class.

Question #3: The BIM class lectures *helped me in understanding and using Revit.*

See Figure-2 for a graph of the result of this question. This question received very a positive response: 72% of the students agreed with this statement; 13.4% had neutral attitude, and only 14.6% of the students disagreed. This result indicated that BIM lectures conducted by the instructor were effective and helpful to deliver the subject.
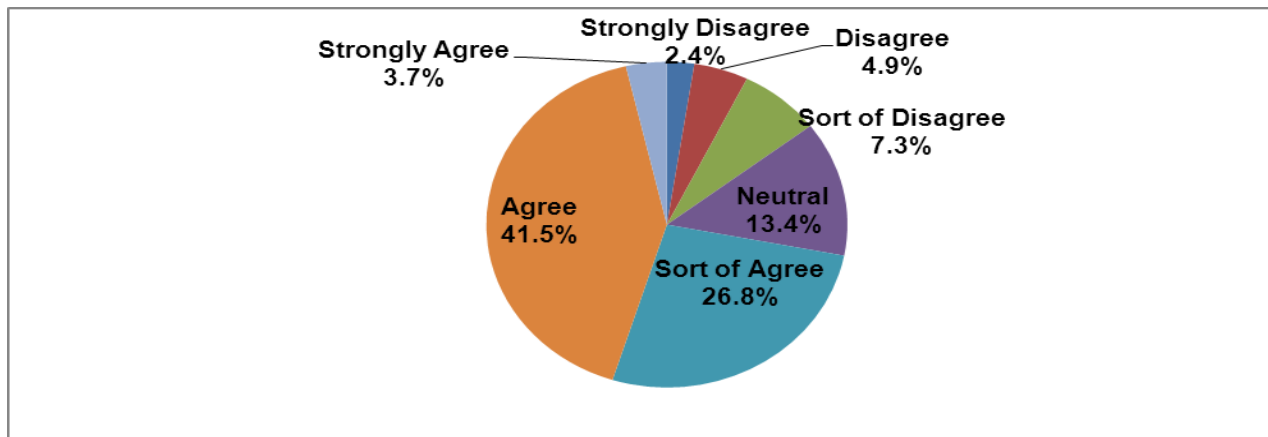
Figure 2: Distribution of students' responses on if "*The BIM class <u>lectures</u> helped them understand and use Revit*"

Question #4: The BIM class <u>hand-outs</u> helped me in understanding and using Revit.

This question received the most positive response among all questions in the survey: 92.6% positive, 3.7% (total of 3 students) neutral and 3.7% (total of 3 students) negative. See Figure-3 for a graph of the result of this question. Out of the 82 students who completed the questionnaire, 32 of them strongly agreed with this statement, 29 agreed and 15 sort of agreed. This result indicated that the instructional materials on BIM developed for this class was very successful, and students really appreciated the thoroughness and comprehensiveness of these step-by-step BIM tutorials.
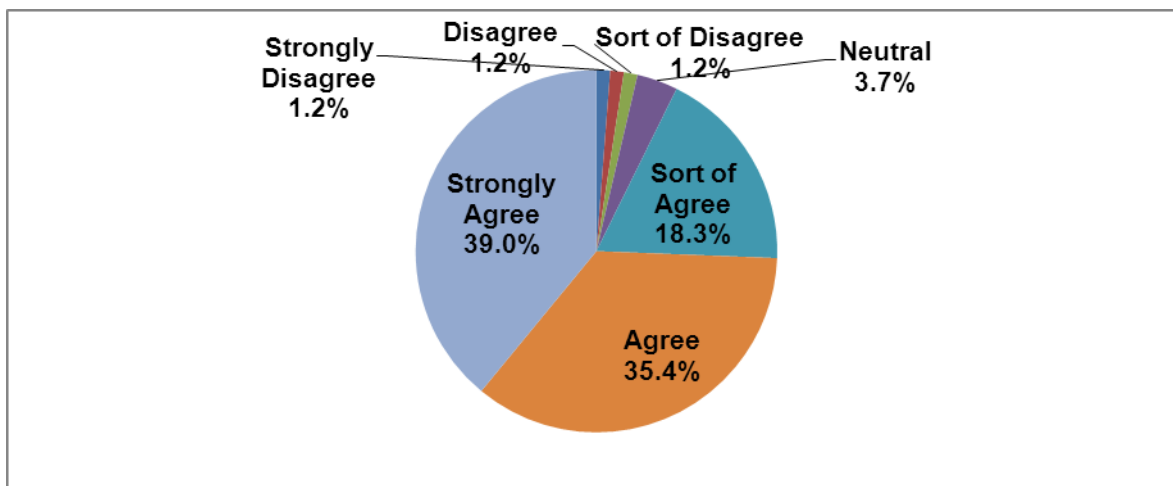

Figure 3: Distribution of students' responses on if "*The BIM class <u>hand-outs</u> helped them understand and use Revit*"

Question #6: Creating the Revit models (of the fieldhouse) helped me understand the plans and specifications.

74.4% of the responses were positive, 9.8% were neutral and 15.8% were negative, as shown in Figure-4. This is a good indicator that the project has achieved one of its major objectives as it has helped students understand the construction plans and specs by developing BIM models. This result showed that students had appreciated BIM contents as an addition to the class which also enhanced their learning of the construction estimating topics.
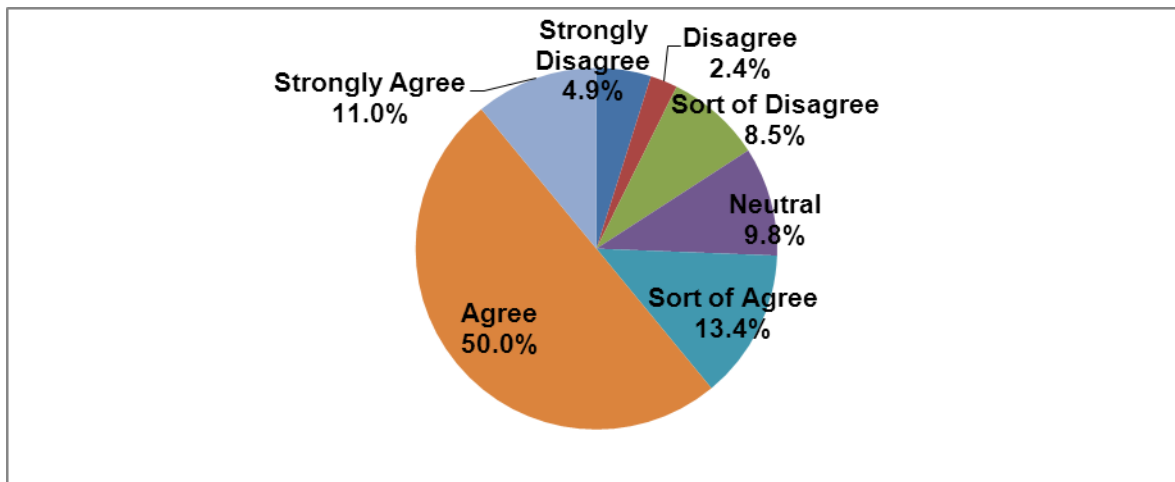
Figure 4: Distribution of students' responses on if "*Creating the Revit models helped them understand the plans and specifications*"

Question #7: Creating the Revit models helped me understand and visualize the building, therefore made me more prepared for performing the quantity take-off assignments.

Figure-5 shows a graph of the result of this question. Students also gave very positive responses to this question: 72% of them agreed with the statement, 14.6% had neutral attitude and only 13.5% disagreed. This result again showed student's appreciation of using 3D visualization to improve teaching and learning of construction topics.
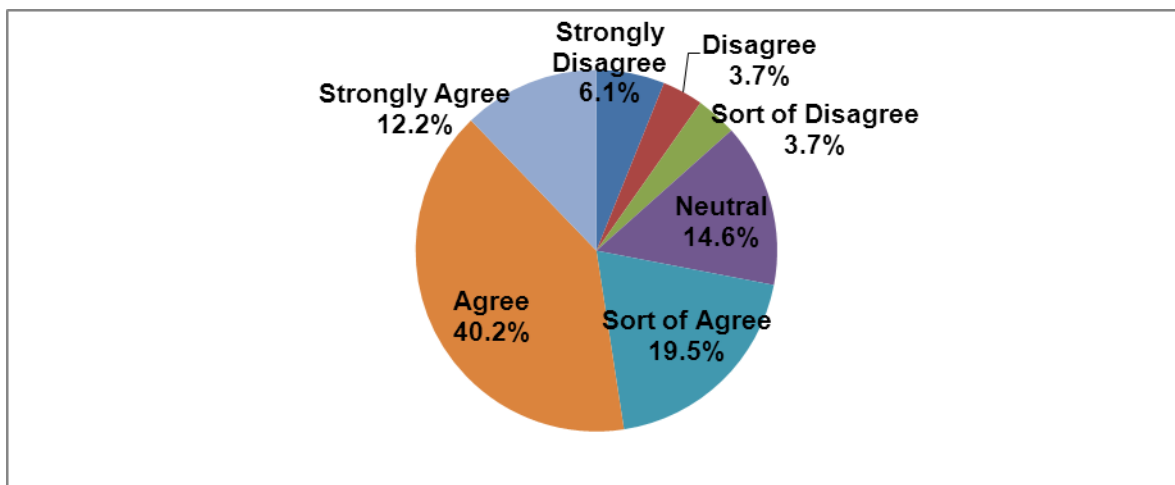

Figure 5: Distribution of students' responses on if "*Creating the Revit models helped them prepare for performing the quantity take-off assignments.*"

Question #8: Creating the Revit models helped me understand and visualize the building, therefore made me more prepared for performing the quantity take-off quizzes.

Questions-8 was similar to question-7 and also drew the similar result. 62.2% of the responses were positive, 23.2% were neutral and 14.6% were negative, as shown in Figure-6.
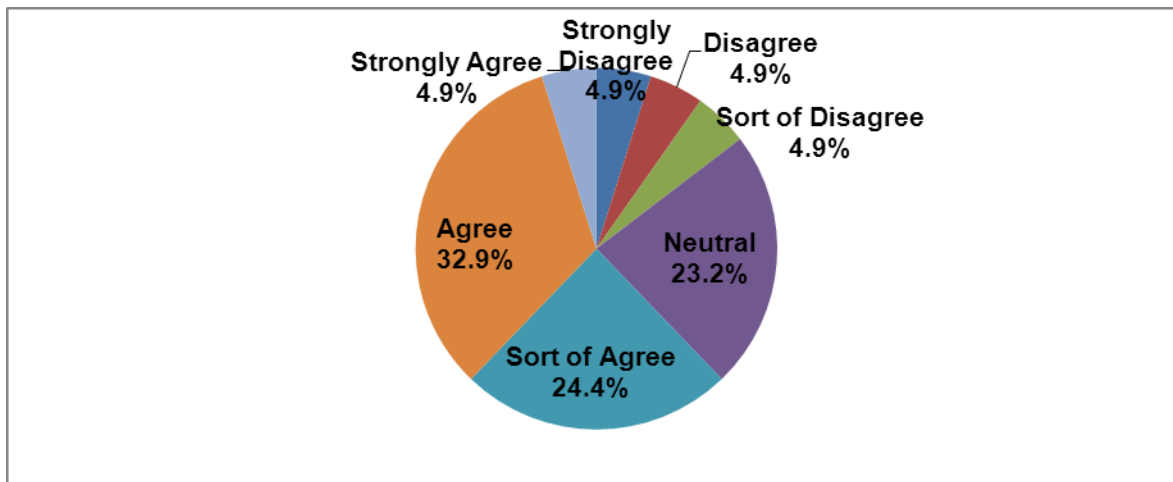
Figure 6: Distribution of students' responses on if "*Creating the Revit models helped them prepare for performing the quantity take-off quizzes.*"

Quantitative Study

The quantitative study used the means of students' performance on periodic quantity take-off quizzes to determine the effectiveness of using BIM to teach construction estimating. Four in-class quantity take-off quizzes had been given each semester. Out of these four quizzes, only quiz-2 and quiz-3 covered the contents affected by BIM lectures, containing topics involved in CSI divisions 3 and 4, and 5 through 9 respectively. The Fieldhouse building was only used in the three fall semesters (2010, 2008 and 2007) and two spring semesters (2011 and 2010) in the class. Therefore, researchers only studied and analyzed students' scores of the quizzes 2 and 3 in these semesters. As noted above, there is a historical disparity between the GPA's of the fall and spring semesters, and the early morning and afternoon sections. Therefore, the researchers decided to break down the quantitative data by semester and meeting time. The data is shown in Table-2.

Table 2

Class information and students' grades of the targeted quizzes

Semester	Class Started	Total Number of Students	Average Student's GPA	BIM Lectures?	Average Students' Score on Targeted Quizzes		
					Quiz-2	Quiz-3	Avg. of Q-2&3
Fall '10	1:00 pm	30	3.7	Yes	86	94	90
Fall '08	1:00 pm	30	3.55	No	97	92	94.5
Fall '07	1:00 pm	30	3.64	No	89	90	89.5
Spring '11	7:00 am	30	2.95	Yes	73	85	79
Spring '10	7:00 am	30	3.36	No	84	90	87
Spring '11	1:00 pm	30	2.92	Yes	86	91	88.5
Spring '10	1:00 pm	30	3.35	No	90	96	93

Note: Yellow highlights the class sections that had BIM lectures.

It was noted that the average GPA's for the fall 2010 semester and the previous two fall semesters were not significantly different. The average quiz grades were higher in the non-BIM semesters for Quiz 2 and marginally

higher for Quiz 3 for the BIM semester. However, the average GPA's, Quiz 2 averages, Quiz 3 averages were significantly higher for the non-BIM Spring Semester sections than for the BIM spring semester.

The results of this comparison did not show a marked improvement in performance using BIM. The marked difference between BIM and non-BIM semesters for the spring may be explained by the difference in average GPA's indicating lower performing students in the BIM sections.

Conclusion

In order to provide a greater coverage of BIM in their construction curriculum and to test the effectiveness of an innovative approach to teaching plan reading and estimating, two BSCI faculty have conducted a case study to integrate BIM into the a construction estimating class. The qualitative data collected through a student questionnaire supported the impressions and hypothesis:

- Creating BIM models can help students understand the 2-dimensional construction plans and specifications
- Creating BIM models can help students understand and visualize the building, therefore made them more prepared for performing the quantity take-off assignments and quizzes.

Also, it was indicated by the qualitative results that the BIM instructional materials developed and BIM lectures delivered were appreciated by the majority of the students in this class. Students highly valued this BIM addition to the conventional 2D plans and specs dominated estimating course. Students also expected BIM to be more used to enhance teaching and learning in other classes in the curriculum.

However, the data collected in the quantitative study of this research did not support the hypothesis. BIM contents did not make significant positive impact on the students' skill in quantity take-off that was reflected by the means of in-class quizzes compared to historical record. Furthermore, because pricing was removed from the original class schedule to make room for BIM, professors in subsequent courses note that the students who participated in this experiment perform well on the Revit portion of a BIM class but have difficulty learning the pricing in the second estimating class.

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