122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #12084

Term Project Design for Undergraduate Building Information Modeling Education

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Abstract: As Building Information Modeling (BIM) has been identified as a new paradigm which could significantly improve productivities and efficiencies in the architecture, engineering and construction (AEC) industry, the methods of teaching BIM start to get attention in academia. It is important for the students to get familiar with the BIM authoring tools in order to achieve the benefits of BIM. To effectively teach the BIM authoring tools, BIM instructors are always required to spend a huge amount of time in lab sessions. However, it is hard for instructors to decide at the beginning of the classes about how much time should be assigned on mastering each function of BIM authoring tools. This study aims to quantify the modeling time of students for each modeling function in their term projects, and further identify the time distribution in the modeling process. Students' modeling progresses in term projects have been monitored for two semesters. Each student is required to report their time spent on each of the element categories of their models. The analysis of this study will provide BIM instructors a guidance to design term projects in BIM courses. Furthermore, it is expected to help arrange the time distribution of lecture and lab session for different functions of the BIM software. BIM instructors can provide more appropriate project sizes and requirements for the students to achieve in a reasonable lab time.

Keywords: BIM education, Computer lab education, project-based learning

Introduction

As Building Information Modeling (BIM) has been identified as a new paradigm which could significantly improve productivities and efficiencies in the architecture, engineering and construction industry, many construction related programs started to integrate BIM components into their curriculums[1]. According to the results from a survey distributed to members of the Associated Schools of Construction (ASC), as of 2008 less than 1% of the construction programs had a stand-alone BIM course, while 9% incorporated BIM as a component of their existing courses[2]. By 2013, 54 % of construction programs had dedicated and fully developed BIM classes included in their curriculums, while 52 % claimed BIM content was embedded in conventional courses[3]. New positions, such as "BIM engineer" or "BIM manager", are now available to current college graduates that might develop into their career paths. As the stakeholders in the architectural, engineering and construction (AEC) industry, especially medium to large size contractors, are progressively taking advantage of BIM technology, the structured BIM education at construction programs is progressing at a slower pace. It is critical to address this need with an efficient and effective BIM course.

As the demand for graduates with BIM skills increases, it is important for the current construction programs to provide effective courses that can help students develop the BIM knowledge and practical skills looked for by the industry. The paper "An introduction of a BIM course to a construction management program with a diverse student body" mentioned that one of the significant challenges faced by a BIM instructor was to estimate the time requirements for the homework and project assignments[4]. This is especially true for the student body in the Construction Science and Management (CSM) program at University of Texas at San Antonio (UTSA). More than half of the students have part-time or full-time employment while attending school, and they also have large variance in computer skills.

This paper observed the students' performance on their BIM term projects over two semesters in order to answer the following research questions:

- What factors affect the student's term project performance?
- Does previous work experience, or current working load affect the students' performance?
- Which parts of the current lab time allocation should be changed?

Different from BIM courses offered to Architecture students, the modeling performance was evaluated by the modeling efficiency of required objects and their accuracy rather than the design aesthetics. The students modeling efficiency was evaluated using the time distribution of the various modeling tasks required of the term project.

Project-based learning provides project tasks which are closer to professional reality, and is more directed to the application of knowledge and skills[5]. Therefore, term projects were adopted in this course to enhance the students' learning. In the current AEC practice, clash detection and estimating are the major areas for general contractors' BIM implementation. Two term projects were designed to address these needs. One term project focused on clash detection, 4D schedule and animation in Autodesk Navisworks with real life examples[6]. The other term project focused on BIM model creation and analysis. It is the project presented in the current paper.
Most of the time, general contractors do not get complete design models for their estimating tasks, especially for CM-at risk or Design-Built type of projects. Therefore, it is necessary for the general contractor to add components to the incomplete BIM model in order to get more accurate estimating results. As such, it is necessary for construction students to learn and understand the BIM model creating process.

The purpose of this paper is to provide a reference for the lab project design of BIM courses. Instructors can refer to the results of this paper as for guidance in designing their term project sizes and allocated lab time. The results should help instructors determine the BIM modeling functions that should be addressed in class in order to make the lab sessions more productive.

Methodology

Surveys were conducted at the beginning of each semester in order to get the students' background information. Survey results are used to evaluate other factors that might affect the students' term project performance. From the spring 2013 and spring 2014 semesters, there were 36 effective responses to the survey. The same term project was assigned to students both semesters, and the students were required to keep modeling time logs for the various BIM functions and authoring tools used during the term project. Pearson correlation analysis was performed to determine the relationship between the students' project grade and the modeling time, as well as with the factor provided by the survey answers.

The Pearson's correlation coefficient, $\rho_{x,y}$, between two variables *x* and *y*, is obtained by dividing the covariance of the variables by the product of their standard deviations [7]:

$$\rho_{x,y} = corr(x,y) = \frac{cov(x,y)}{\sigma_x \sigma_y} = \frac{E[(x-\mu_y)(x-\mu_y)]}{\sigma_x \sigma_y} \quad (1)$$

where, *cov(x,y)* is the covariance, and σ_x and σ_y are the standard deviations of *x* and *y* respectively. The correlation coefficient ranges from -1 to 1. An absolute value of the correlation coefficient close to 1, suggests a strong correlation between the two variables. Literature has suggested that when $\rho_{x,y}$>0.3, the correlation is moderate, and when $\rho_{x,y}$>0.5, the correlation is strong [8].

Student background

Of the 36 students that answered the beginning of class surveys, five students had some previous Revit® experience, while the remaining students had not used this software platform before the course. Also, seven students used AutoCAD® or Sketchup® prior to the BIM course.

Figure 1 and Figure 2 show the years spent at UTSA and the years spent within the CSM program, respectively, at the time they took the BIM course. The majority of the students (68.7%) had spent 5 or more years at the university, and none of the students had less than three years at the University. Regarding the CSM program, all of the students had at least two years in the program, with the majority (87.6%) of the students in their fourth or fifth year.

Also, 56% of the students reported having prior full-time work experience, and 62.5% of the students reported holding a full- or part-time job while taking classes. Thus, it is very important that the instructor uses the students' time wisely in order to help the students gain the knowledge and skills required by the course within a reasonable time frame.

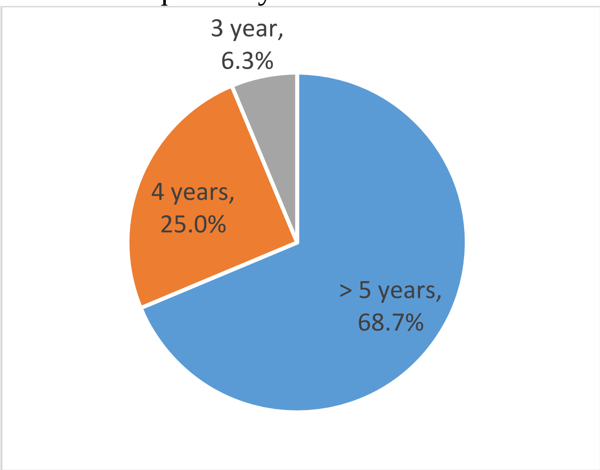

Figure 1 *Years at UTSA.*

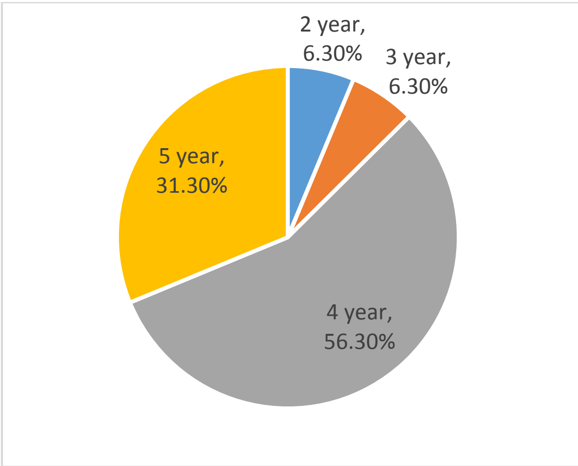

Figure 2 *Years in CSM Program.*

Course Components and Grading Structure

The “BIM for Construction Management” course was offered as a three-credit hour elective course. The main target audience was senior and junior students in the CSM program, who already completed basic construction courses including plan reading, estimating, scheduling, and project management. The course was structured as a lecture-lab combination, two 75-minute long sessions per week. The fundamental concepts and implementation issues were discussed in the lecture portion, while the practical BIM skills were developed in the laboratory portion. As this was the only BIM course in the curriculum at the time of its offering, the course was designed to cover a wide variety of BIM topics including clash detection and constructability, design and visualization, model based quantity takeoffs (QTO), estimating, and 4D scheduling. The software platforms covered in this course include Autodesk Revit® (Architecture and Structure) and Navisworks®. Other complementary software packages such as MS Excel, Sketch-up and MS project and P6 were also used. This paper focuses only on the Revit® architecture modeling performance. Other platforms will be studied in future semesters.

The laboratory portion of the course was used to develop the BIM fundamental software skills, and to develop a clear understanding of the BIM implementation challenges. Two different approaches were used to achieve these lab goals. During the first half of the course, students were asked to complete an individual project using BIM authoring tool Autodesk Revit® focusing on Revit architecture and structure components. This project was used for in-class demonstration, and its purpose was to provide basic modeling skills, and an understanding of the program’s database structures. Also, the project provided insight into the process of coordination among different trades in a typical construction project. Then, during the second half of the course students were asked to complete an individual design term project using Revit®. Each student had to build his/her own building model based on the term project guidelines provided by the instructor. The term project requirements are presented in the following section.

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 a term project with two milestones (40% of the grade). All the lecture and lab sessions were conducted in a computer lab, and each student had access to a working computer throughout the semester. Considering that the hands-on experience requires the use of and proficiency with the computer software packages, the homework and project assignments carried the larger weight on the final grade. Since the course was offered as a construction course, grading of the project models focused on the modeling of required objects and accuracy rather than the design aesthetic value.

Term project Requirements

Each student was required to build the architectural model of a 3-story office building with a surface area between 20,000 sf and 40,000 sf. The project BIM models developed by the students were expected to contain the following required elements:

a. **Grids:** Proper dimensions and nomenclature must be used. (2 points)
b. **Levels:** All levels must be modeled at the proper elevations. (2 points)

c. **Exterior Walls**: A new wall type must be created, and its structural composition edited. All walls must stop at each level. Points will be deducted if exterior walls are modeled three stories high. (2 points)
d. **Interior Walls:** Interior walls must be used to divide the spaces. (2 points)
e. **Furniture:** Furniture for the office spaces must be placed in the model. (2 points)
f. **Floors:** Floor objects must be constructed of realistic building materials, and correct thickness. Including *openings* for the stairs. (3 points)
g. **Roofs:** Two new roof types must be created using the details provided by the instructor. (3 points)
h. **Doors and windows:** Doors and windows shall be placed in their proper locations, using the proper family types. After completing the project, door and window schedules shall be created in the project to include the same parameters indicated in the given documents. (3 points)
i. **Curtain walls:** A straight curtain wall or curved curtain wall shall be created, and a curtain door included on the wall as the main entrance to the building. (4 points)
j. **Stairs:** Floors shall be connected using Stairs, in any design shape (Straight, U-Shaped, or Circled). (3 points)
k. **Ceilings**: 2' x 2' acoustical tile shall be used. (2 points)
l. **Section View:** A section view of the stairs must be created. Both flight of a U-shaped stair could be seen using this view. (2 points)
m. **Door Schedule**: A door schedule providing relevant information shall be created (Mark, Type, Level, Manufacture, Width, Height, Count, Cost Door type); create a cost estimate for all the doors using reasonable unit prices for the design. (2 points)
n. **Wall Schedule**: A wall schedule providing relevant information shall be created (use the same fields as your homework); create a cost estimate for all the walls using reasonable unit prices for the design. (3 points)
o. **Accurate dimensions on all pertaining views**: (4 points)
First dimension line (i.e. closest to the building): dimensions of the rooms and thicknesses of the walls
Second dimension lines: openings in the exterior walls (windows and doors).
Third dimension line: distances between the grid lines
Fourth dimension: overall dimension of the building.
p. **Tags**: Tags, in sequential order, must be included for all the doors, windows and rooms (room name, number and room area). Rooms shall be renamed to reflect their usage, e.g. Conference Room, Office, etc. (2 points)
q. **3D Camera View**: Create a view looking from the front of the building. (2 points)
r. **Sheets:** At least two sheets must be created, one for the floor plans and one for the elevation and section plans. (2 points)
s. **Exterior Rendering**: A realistic exterior view shall be created at a "medium" detail level, and saved to as a JPG file. (2 points)
t. **Create a Walkthrough:** starting from outside of the building, fly into the building through the main entrance, visiting the main areas such as offices and conference rooms, and moving onto the second floor by the stairs. (3 points)

All of the elements modeling skills required in the term project were previously taught and practiced by the students during the first half of the course using the demonstration project. The lab project demonstration times allocated to each of the modeling elements are shown in Table 1. The actual time required by students for each element during the term project was different due to the varied computer skills and software competency of each person. **Table 2** shows the average time spent by students on each of the modeling elements required in the term project

Table 1. *Lab Demonstration Time for Different Modeling Elements.*

Model Element	Time (min)
Grid, Levels, Exterior and Interior Walls	75
Floors and Roofs	75
Doors and Windows	20
Stairs and Railings	75
Revit Schedules and QTO	75
Annotations	30
Documents Generation	30
Rendering	20
Walkthrough	75

Table 2. *Students Average Times on Different Model Elements for Term Project (n=36)*

Model Element	Time (min)	Effort Percentage
Datum Elements and Setup	37.3	4%
Exterior Envelope	114.2	12%
Interior Partition	100.1	10%
Curtain Wall	67.2	7%
Curtain Door	34.0	4%
Stair	72.8	8%
Furniture	129.8	13%
Dimension	30.6	3%
Door and Wall Schedules	51.0	5%
Tagging	53.2	6%
Doors and Windows	65.2	7%
Floors	37.0	4%
Ceiling	36.7	4%
Views (Section and 3D View)	15.8	2%
Roof	44.1	5%
Sheet	30.2	3%
Walkthrough	45.2	5%
Average Project Time	964.4	100%

Term Project Results

As shown in **Table 2**, students spent most of their time placing furniture (13%), and creating the exterior envelope (12%) and interior walls (10%). However, from the instructor's project guidelines, these three parts together are only worth 12% of the total grade. Some of the time spent creating exterior and interior walls, might be due to the thinking process required in the layout design of the project. However, it is obviously not worthwhile for construction management students to spend two hours placing furniture on a model. For the model components taking most of the students' project time, the instructor shall address during laboratory demonstrations the methods for performing these tasks. Also, the expectations for these parts shall be made clearer in future assignments. Based on the data collected, the instructor builds a better understanding of the students' working process and time allocated to each part, which then allows the instructor to modify the lab demonstrations and project guidelines accordingly.

Pearson's correlation analysis was performed on the variables representing the factors that were supposed to have an effect on students' grades. **Table 3** shows these variables and the resulting correlation values obtained when the survey answers and project performance data was used. The correlation results show that a student's term project grade does not significantly relate to any of the following factors: total project time invested by the student, previous AutoCAD experience, previous Sketchup experience, their current working load, nor their previous Revit experience.

The only factor that has a significant correlation with a student grade is their previous construction industry experience ($p=0.04<0.05$, $r=0.534$). The results indicate that the more construction industry experience the students have, the better grade they achieve. Their work and construction experience helped them during the modeling process. Surprisingly, previous software skills related to BIM software did not help them obtain a higher grade. However, previous software knowledge reduced their modeling time significantly.

Table 3. *Pearson Correlation Analysis Results.*

Correlations		Grade	Total Time	AutoCAD Experience	Working Experience	Revit Experience	Sketchup Experience	Current Work
Grade	Pearson Correlation	1	-.182	.073	.534*	.489	-.018	-.298
	Sig. (2-tailed)		.294	.821	.040	.064	.949	.280
Total Time	Pearson Correlation	-.182	1	-.752**	.340	.156	.122	-.118
	Sig. (2-tailed)	.294		.005	.215	.578	.666	.674
AutoCAD Experience	Pearson Correlation	.073	-.752**	1	.120	.408	-.120	.000
	Sig. (2-tailed)	.821	.005		.711	.188	.711	1.000
Working Experience	Pearson Correlation	.534*	.340	.120	1	.426	-.289	-.158
	Sig. (2-tailed)	.040	.215	.711		.113	.297	.574
Revit Experience	Pearson Correlation	.489	.156	.408	.426	1	.431	-.337
	Sig. (2-tailed)	.064	.578	.188	.113		.109	.219

Sketchup Experience	Pearson Correlation	-.018	.122	-.120	-.289	.431	1	.000
	Sig. (2-tailed)	.949	.666	.711	.297	.109		1.000
Current Work	Pearson Correlation	-.298	-.118	.000	-.158	-.337	.000	1
	Sig. (2-tailed)	.280	.674	1.000	.574	.219	1.000	
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).								

Finally, **Table 3** also shows that previous AutoCAD experience has a strong negative relationship with the total modeling time ($p=0.005<0.01$, $r=0.752$). This means that students with previous AutoCAD® experience learned the BIM authoring software much faster than other students. Based on these results, a technical drawing class with AutoCAD components would help the study of BIM tools, and the introduction of BIM software in a previous class would decrease the time students spend working on the projects.

Discussions and Conclusion

It is necessary for the current construction program to provide an effective course that can help students achieve the BIM knowledge and skills in response to the industry demand. One of the significant challenges for a BIM instructor was to properly estimate the time requirements for the homework and project assignment, and as such provide a fair grading scale for the student work.

This paper finds a student's previous software experience, including AutoCAD, Sketchup, and Revit, has no significant influence on their BIM course modeling performance. But a student's previous AutoCAD experience has a significant negative relationship with the total modeling time required to finish the term project. This result indicates that if a student has previous AutoCAD experience, he/she learns BIM software faster than students without previous AutoCAD exposure. In addition, this study uncovered some issues with the current lab design for and term project guidelines. The students' modeling records show that they spent much more time than expected on several model elements such as furniture and wall layouts. Clearer instructions are needed during lab demonstrations, and in the term project guidelines, to clarify the requirement for these parts in order to reduce the unnecessary modeling time spent by students.

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