What Impact Does Using Building Information Modeling Have on Teaching Estimating to Construction Management Students?

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In this paper the author discusses the results of a study that was conducted in Fall Semester 2007 as part of curriculum development for the Construction Management (CM) Department at California State University, Chico. The purpose of the study was to examine the influence of construction visualization tools, i.e. on-screen take-off and Building Information Modeling on the estimating skills of CM students. This exploratory paper takes a first look at the effectiveness of construction visualization tools as a teaching aide for construction estimating courses. Data was collected from fourth year CM students on their completion times and their accuracy on a construction estimating QTO assignment. Although, the scope of the study was limited, the results showed that construction visualization tools appear to have a positive influence on learning estimating. The results of this survey are particularly relevant because of the similar requirement in all CM Departments to teach the fundamentals of estimating, plan reading, construction methods, sequencing, and quantity take-off. The author believes that this paper will assist other CM Departments in making better curriculum decisions related to their estimating courses. The author utilized an evaluation survey of undergraduate CM students and historical documentation to support the positions presented in this paper.

Key Words: Construction Visualization, Building Information Modeling, On-Screen Take-off, Curriculum Development, Construction Education, and Construction Estimating.

Introduction

Estimating skills are an important part of the skill set of any successful Construction Management (CM) student. Estimating is where the students' ability to understand basic construction methods, materials, and processes is applied. Lacking proficiency in estimating skills puts the CM student at a severe disadvantage in the later stages of their construction education and the early stages of their work career. Estimating skills were rated #1 by industry professionals, who were asked in an industry survey to rate the top five skills they expect new CM graduates to possess (Souder & Gier, 2006).

Relatively new technologies for construction visualization like Building Information Models (BIM) and on-screen take off (OST) when used in estimating courses, appear to have a positive influence on the estimating skills of CM students. BIM is really nothing more than a database of information about the project. Hunt explains, "Information about a project can be entered into a model, which is actually a single, dynamic database. The information can then be extracted through any number of forms: plans, schedules…or cost."(Hunt, 2005). Some construction visualization tools, like on-screen take off (OST) are meant to operate in a similar paradigm as 2D hard copy plans only in electronic format. Many of the skills used for OST are the same as when using hard copy plans. Whereas, when a building model is developed as a 3D, 4D (Time), or 5D (Costs) model,

it is really a paradigm shift. The model can not only act as a 'smart model' for organizing information about the construction of the building, such as materials, methods, schedules, costs, and processes, but also function as a model-based control system during construction. "BIM combines graphical project data such as 2-D and 3-D drawings with non-graphical information including specifications, cost data, scope data, and schedules. Most importantly, it creates an object-oriented database, meaning that it is made up of intelligent objects—representations of doors, windows, and walls, for example—capable of storing both quantitative and qualitative information about the project." (Elvin, 2007). The author believes that using construction visualization tools within a CM curriculum improves the CM students' ability to read plans, develop an estimate, and comprehend the construction process more fully.

To explore this hypothesis, the author analyzed the results of this study from several different points of view. The educational perspective came from a study of related information in the literature. The point of view of the faculty came from interviewing the CM faculty who teach BIM, OST, and Construction Estimating to the CM students. The perspective from the student's point of view was obtained from observing the students using BIM and OST in the classroom and analyzing the speed and accuracy of their results. Discussing BIM and OST with people in industry, who are actually using these technologies on their projects, helped develop the industry perspective. Also, as a foundation for this study the author undertook a literature search of books, periodicals, and web sites that focused on construction visualization tools, building information modeling, on-screen take off, estimating skills, virtual construction, and construction project planning.

The Impact of Building Information Modeling

From the literature it appears that the main use of BIM currently is as a pre-construction planning tool. The author's literature search revealed the fact that little has been studied about using BIM for estimating or its impact as a tool for teaching construction topics. This gap was the focus of this study.

BIM is heralding in a new age of analysis, process management, and pre-construction activities that can be accomplished more efficiently and accurately to achieve the best possible solution. (Gier, Loftin, & Coogan, 2006). Estimating skills are necessary for the successful execution of the construction business. Construction visualization tools like BIM and OST that can improve estimating skills, will make an impact on the effectiveness of CM students to do estimating on their jobs. "The ability to predict the cost of constructing a project is an essential construction management skill." (Holm, Schaufelberger, Griffin, & Cole, 2005). The growing competitiveness and increased complexity of projects in the construction industry will push the requirement to find more efficient ways to do estimating.

Discovering if BIM Impacts Estimating Skills

Construction Management Faculty at California State University, Chico, who are interested in using BIM to teach construction topics recently focused on the study question, "What Impact Does Using Building Information Modeling Have on Teaching Estimating to Construction Management Students?"

The author organized a study of fourth year CM students in the Fall Semester of 2007 to see the impact BIM and OST tools might be having on the students' estimating abilities. The goal was to study completion times and accuracy on a concrete foundation QTO assignment in a construction estimating course. Some students chose to use BIM or OST, while others did not. The amount of exposure to BIM and OST varied between individual students. Most CM students would likely have had some exposure to OST and BIM, whereas some fourth year students may have taken up to three BIM courses.

Completion time was selected as a criteria because, "the QTO is the most tedious and time-consuming part of the lump-sum estimating process." (Holm, Schaufelberger, Griffin, & Cole, 2005). So, any time gain doing the QTO is very important in improving the overall time it takes to complete an estimate. Accuracy was selected as the other criteria for the study because, "The inexperienced estimator may be tempted to group items that are similar but do not have the same dimensions to make the work easier. This can introduce significant errors into an estimate, which may be detrimental to the accuracy of the process. The estimator must take time to record each item of work accurately." (Holm, Schaufelberger, Griffin, & Cole, 2005). BIM appears to improve the accuracy of the QTO because it separates and records work items as an intrinsic part of the model building process.

The initial impression of the CM faculty was that BIM and OST were probably helping students do their quantity take-off (QTO) calculations better on the sample construction project. However, could the results actually be measured, i.e. could you verify the results by quantifying the time it took to do their QTOs and the accuracy of their QTO calculations. "…educational researchers infer how an individual processes information by measuring or observing resulting actions, or responses." (Davidson-Shivers & Rasmussen, 2006).

Impressions about using BIM or OST tools were not gathered formally from the students, although verbal feedback and observations were noted. The author did not let the students know that the study was about the impact of using BIM or OST on estimating skills. They were only told to keep track of their time to do each QTO activity on their timecard as part of the concrete foundation QTO assignment.

The Method

The author prepared a timesheet to obtain information from fourth year CM students regarding the time it took them to complete a concrete foundation quantity take-off (QTO) in their Construction Estimating course. The intent of this study was to compare internally the mean times between the QTO method subgroups, i.e. those students using a BIM method vs. those students using other methods, such OST, a hybrid of OST and traditional tools, or only traditional hard copy plans. Fourth year CM students were selected because they were enrolled in Construction Estimating and had some previous exposure to the various construction visualization tools. By conducting this study the author wanted to determine what impact, if any, BIM and OST had on the students' time to complete the QTO assignment and their accuracy.

Data collection consisted of two parts, timecard information and concrete foundation QTO sheets. The study was designed to collect information about speed and accuracy. The first part was the timesheet the students completed while doing the QTO assignment. See Appendix A for the timesheet. The second part was an analysis of the results of this assignment, which were their quantities from the concrete foundation QTO sheets. The particular data that the author was focusing on collecting was not only the time it took them to do the various tasks, but also the method they used. The author was also interested in noting what relationship, if any, existed between the times it took them to complete the QTO assignment and the method and tools they chose to use on the assignment.

The study was tied to the sample construction project plans and specs, which the students use in several classes in their CM curriculum. The sample construction project used for the assignment is a 15,000 square feet office building. Students in their 2nd year Contract Documents and Specifications course, i.e. plan reading, use this same sample construction project, on which the QTO assignment is based. The fourth year students use this same project in their Construction Estimating course, their Scheduling course, and their Cost Management course. To the students the study looked like just another estimating assignment, but with the added task of keeping a time card.

In the Fall Semester 2007, one hundred and sixty-five (165) fourth year students were given the QTO assignment in their respective sections of Construction Estimating. The students were not required to participate in the study. The study sample population was comprised of fifty-two (52) students who did participate. Students were allowed to self-select the QTO method and tools they wanted to use to complete the assignment. Of the students that participated in the study, nine (9) students chose to use traditional hard copy plans only, thirty-three (33) students used a hybrid method (OST & Traditional), eight (8) students chose to use OST only, and two (2) students chose to use BIM only. There were only two students that chose to use BIM because learning BIM requires some advance preparation. Since the three BIM courses are electives and new to the CM curriculum at CSU, Chico, only a limited number of students are prepared to use BIM in their other CM courses. A total of f fifty-two (52) student time cards and thirty-seven (37) student QTO sheets were used to compile the following data.

Study Results

For the timecard information, students were asked to track their time as they did the various tasks of the concrete foundation QTO assignment. The timecard results for the fourth year CM students in the study are shown in Table 1 below.

Table 1
Summary of Mean QTO Assignment Completion Times vs. QTO Method Used

QTO Method	Total Number of Students	Minimum Time	Maximum Time	Sub-Group Mean Time	Percent Difference in Mean Times
A. Traditional Hard Copy Plans	9	5 hrs 0 mins	30 hrs 50 mins	16 hrs 15 mins	0.0 % (Base)
B. Hybrid (OST & Traditional)	33	1 hrs 0 mins	97 hrs 30 mins	15 hrs 35 mins	+4.1% (Faster)
C. OST Only	8	7 hrs 0 mins	17 hrs 15 mins	12 hrs 2.5 mins	+25.9%(Faster)
D. BIM Only	2	11 hrs 45 mins	12 hrs 26 mins	12 hrs 5 mins	+25.6%(Faster)
Totals	52	100%			

The time card results are fairly consistent in that the author noticed that in general, the more students use construction visualization tools on their assignment the faster their mean times were. Those students who chose to use only a traditional hard copy plans method have a subgroup mean time of 16 hours and 15 minutes, which is slightly longer than the Hybrid sub-group with a mean time of 15 hours and 35 minutes. The author also noticed that the third subgroup, i.e. those using only OST did better than both previously mentioned subgroups, with a mean time of 12 hours and 2.5 minutes. The BIM sub-group was slightly slower than the OST subgroup with a mean time of 12 hours and 5 minutes. The author attributed the consistency of the data to the observations that using construction visualization tools made it slightly faster for students to find, measure, count, and organize the items in the QTO assignment. The author concluded that using BIM and OST was having a positive effect on the completion times for the QTO assignment.

Table 2 contains a summary of the QTO data collected from the student's QTO sheets for selected work items and the instructor's target quantities. The average accuracy for each QTO method is also shown.

Table 2
Summary of Mean Quantity Results vs. QTO Method

Work Item	Traditional Hard Copy Plans	Hybrid (OST & Traditional)	OST Only	BIM Only	Instructor's Target Quantities
A. Excavation (CY)	612 CY	733 CY	699 CY	711 CY	572 CY
B. Formwork for Continuous Footings (SFCA)	9,184 SFCA	9,746 SFCA	8,181 SFCA	10,748 SFCA	9,773 SFCA
C. Concrete for Continuous Footings (CY)	196 CY	219 CY	215 CY	219 CY	197 CY
D. Anchor Bolts (Each)	810 EA	813 EA	739 EA	688 EA	935 EA
E. Concrete for 4" Slab (CY)	176 CY	178 CY	170 CY	187 CY	174 CY
Average Accuracy per Method	97.6%	105.7%	98.4%	105.2%	100%

The accuracy of the quantity results also appear consistent, ranging from underestimated by 2.4% to overestimated by 5.7%. Students using the traditional method or the OST method tended to underestimate the target quantities at 97.6% and 98.4%, respectively. Students using the hybrid method or the BIM method tended to overestimate the target quantities at 105.7% and 105.2%, respectively. The OST method produced the most accurate results at only 1.6% below the target quantities. These results show in general that each method was fairly accurate when compared to the instructor's target quantities, which were obtained by a hybrid QTO method.

The author attributed the accuracy of the quantity results to the fact that the instructor's target quantities were available in a sample estimating notebook as part of the lab environment. Students could self-check their QTO calculations throughout the estimating process. They were allowed to recalculate their quantities until they approached the target quantities. In a learning environment this helps a student to check if they have left out anything, over-counted, under-counted, or double-counted an item. The students were told that an acceptable accuracy range was to be within 3-7% plus or minus of the instructor's target quantities.

A mean accuracy rating for each method was calculated by comparing the mean quantity results for each work item to the Instructor's Target Quantities, then averaging it over all five work items. Those students who used only the traditional hard copy plans method have a subgroup mean accuracy rating of 97.6%, which is slightly more accurate than the hybrid sub-group with a mean accuracy rating of 105.7%. The BIM sub-group also had a slightly better mean accuracy rating than the hybrid sub-group with a mean accuracy rating of 105.2%. The author noticed that the third sub-group, i.e. those students using OST only, was the most accurate of all the sub-groups with a mean accuracy rating of 98.4%.

The author concluded that no one QTO method appeared to be significantly more accurate than another. It is interesting to note that the author observed that those students using the traditional method, the hybrid method, and the OST method made several recalculations to get within 3-7% plus or minus of the target quantities, whereas the BIM students did only *one* QTO calculation to get within 3-7% of the target quantities. The significant aspect of this point is that the author observed that for those students using the BIM method that BIM appeared to act as a framework to organize their construction knowledge. They had to understand the construction project in more depth to build the model. When they were done building the model, the QTO quantities calculation was simply a derivative report of their modeling efforts.

Overall, from the above student results, it does appear that the students who used BIM or OST tools did the QTO assignment with about the same accuracy, but about 25% faster, than those students not using BIM or OST tools.

Discussion

What impact does using building information modeling have on teaching estimating to CM students?

The Educational Perspective

The literature search showed that using Building Information Modeling would be valuable for estimating, if it helped students improve the speed at which they understood what they were looking at in a set of construction plans. Gagne, Briggs, & Briggs state, "information processing refers to the mental operations that individuals go through as they apply knowledge, skills, and abilities."(Gagne, Briggs, & Wager.1992). If a student uses BIM or OST tools to help them visualize the work items being constructed, then it seems logical to think that with practice the student would interpret the plans more quickly and more accurately, i.e. as demonstrated by doing the QTO assignment quicker and more accurately.

"BIM facilitates the student's understanding of what is being constructed by drawing on their ability and experience to visualize in 3D." (Gier, 2007). The student who understands the plans better will be able to perform better, i.e. complete the QTO

assignment faster and more accurately. The educational literature showed that "…if we can *do* something with the information, we can obtain feedback about how well we understand." (Silberman, 1996). Educational research also indicates that the quality of the learning activities, e.g. demonstrations, active learning exercises, and assignments are important to student success. "…the more ways learners can represent their conceptual understanding, the better they will understand." (Jonassen, Peck, & Wilson, 2008).

The Faculty Perspective

Overall, the three CM faculty teaching estimating felt that BIM and OST could be effective tools for teaching estimating because it shows construction information, concepts and principles visually. From the faculty's standpoint using BIM and OST as teaching tools enhances the ability of the faculty to demonstrate and "show" construction principles and concepts to the students. "It is as close to the benefits of an actual project field trip as an "electronic" field trip can be." (Gier, 2007). The faculty also felt the students demonstrated improved QTO assignment completion times and the accuracy of the QTO results because of the visualization and analysis features that are inherent in using BIM.

Using new technology in the classroom has some implications for both faculty and students. Teachers need to give up some of their authority and control over all the learning activities in the classroom. In a technology-based course, "…teachers' roles shift from dispensing knowledge to helping learners construct more viable conceptions of the world." (Jonassen, Peck, & Wilson, 2008). CM faculty must re-define themselves, not as the keepers of knowledge, but as the coaches and facilitators within a learning environment.

Students need to assume more responsibility for their learning in courses that use new technology. "Learners must develop skills in …setting goals for themselves and regulating their activities and effort in order to achieve those goals;" (Jonassen, Peck, & Wilson, 2008). Many students are not ready for the responsibilities of this new learning model. Faculty must encourage this behavior by using well-designed assignments that use new technologies, such as BIM and OST.

The Student Perspective

The student's perspective on using BIM or OST for estimating appears to be a fairly natural transition. The more BIM and OST training they have had before arriving in the estimating class, the more readily they opted to use these tools. In general, students use what works best for them to accomplish the assignment. Those students with little background with construction visualization tools tended to use traditional methods to do the QTO assignment. They did not attempt to learn BIM or OST skills for the estimating class. Note that BIM and OST skills were not taught in the estimating class, although some demonstrations, handouts, and training videos were made available to the student.

While observing the students' perspective in the estimating class, the author noted the following. *First,* there is a time commitment on the student's part to become proficient in BIM and OST software. *Second,* students do not retain BIM and OST skills from course to course, unless there is a need or opportunity to use it.

The Industry Perspective

Industry professionals who were asked to identify the top five skills they expected new CM graduates to possess rated estimating skills #1 (Souder & Gier, 2006). The Construction Employers Association (CEA) sponsored this industry survey. BIM is having a lasting impact on the construction industry in many ways. Companies like Turner, DPR, Webcor, RQ Construction, and Walt Disney Imagineering have started to use BIM in their various construction processes, such as, quantity take-off, estimating, project management, project scheduling, conflict detection, and analysis efforts to increase overall productivity. The industry is also starting to recruit CM students with BIM skills to fill needs within their companies.

Building Information Modeling, while still seen as a cutting edge planning tool, is having some very subtle impacts on the way the industry does business, i.e. the process of construction. From discussions with industry personnel, enhanced collaboration and project understanding among the key players, such as owners, architects, engineers, constructors, and subcontractors is one of BIM's major impacts. BIM is also starting to impact the way construction firms manage their projects.

Conclusions

This study's purpose was to explore the impact of using BIM to teach estimating to fourth year CM students by conducting an analysis of their completion times and accuracy results on a QTO assignment. This study's data supported the initial impressions and hypothesis. Using BIM and OST in estimating classes appears to have had a small positive effect on the speed of completing a QTO assignment for a group of CM students at California State University, Chico. Because of the limited scope of the study other variables, such as previous construction experience, individual aptitude, and student time commitment, etc., may also have influenced the results.

This study was limited because of the small survey size, the length of the survey, and individual student variables, such as work experience, which were not a part of the study. It appears a more detailed study is needed to make conclusive statements about the actual impact of BIM and OST on teaching estimating. The breadth of each student's previous construction experience was not considered in this study. Previous construction experience, as well as other variables that impact learning estimating, deserve further study. The author also recommends that further studies on this topic be done on a more complex project with a larger and more diverse study group.

The author concluded that BIM and OST appear to be effective educational tools for teaching construction estimating because it puts in motion a fundamental educational

principle, that of active learning, “when learning is active, students do most of the work. They use their brains…studying ideas, solving problems, and applying what they learn.” (Silberman, 1996). Using BIM and OST did seem to follow other educational principles, for example, “Simulations can be used to challenge learners and involve them in learning activities.” (Davidson-Shivers & Rasmussen, 2006).

Also, Maddux, Johnson, & Willis recognize that “Computers have the potential to revolutionize teaching and learning. …because they are uniquely effective tools whose power is so flexible…” (Maddux, Johnson, & Willis, 2001). This flexibility makes new technologies, like BIM and OST, so important for teaching estimating. They allow the computer to serve as a plan viewer, calculator for areas and volumes, a measuring stick, a filing cabinet, an organizer, indexer, sorter, and displayer of project information. This gives the estimator powerful tools to help decrease the time to complete their estimates, while also increasing the accuracy of their estimates.

The study team surmised that with continuous incremental improvements to the implementation process, BIM could prove to be an effective, untapped resource for teaching estimating. Building Information Modeling is transforming construction education and the industry. The advantages of using BIM outweigh its disadvantages. Construction visualization tools, like BIM and OST, provide excellent visual methods for teaching estimating. It improves the time it takes to complete the QTO with no reduction in the accuracy of the quantities.

Even though BIM is currently a hot topic within the construction industry, its benefits as a teaching tool are still relatively unknown. BIM is getting easier to learn and to use, but an investment by CM Departments is still required to get faculty better trained, lab exercises developed, and lab facilities expanded. Graduating CM students with BIM skills will be a fundamental task of CM Departments in the near future, just as it is today’s task to graduate them with proficient plan reading skills. In the future, having BIM skills in the workplace will be as common as having plan reading skills are today. CM Departments must make a critical decision now, to start to imbed BIM and OST into their CM curriculums to reap the benefits of this new technology and meet the industry’s demands for BIM trained graduates in the years to come.

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Appendix A

CMGT 450 Construction Estimating

Name: ______________________________

QTO Topic: Concrete

QTO Data Collection Form

*** Method Options**

HC = Hard Copy
EC = Electronic Copy
OST= On-Screen Takeoff
BIM = Building Information Modeling

Task #	**Task Description**	**Method***	**Date**	**Time (hours and minutes)**