Impact of Quantity Takeoff Software on Student Performance in a University Construction Estimating Course: A Case Study

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Introduction

The use of software technology has been increasing in the construction industry. University construction education programs have begun implementing the new technologies, albeit at a delayed rate. The researchers acknowledge the importance of technology in today's industry. However, the latest innovations can sometimes be a deterrent to student understanding of the underlying principles on which the innovation was built. Technology can be an aide in better understanding a scenario, or optimizing the completion of certain menial tasks. It should not, and currently cannot, replace the basic human cognitive ability to reason and understand highly complex situations.

The researchers wanted to study the impact that technology in the classroom has on student performance (as measured by a complex estimating project assignment). Students' self-reported understanding of estimating, and any previous estimating experience they may have had, were used as factors to isolate the role of automated quantity takeoff has on student performance. The researchers found that regardless of their perceived level of understanding or prior experience, students performed best on the group project when they used a combination of manual and automated takeoff methods. The researchers propose that construction estimating educators (and others in similar fields) should use technology as a tool to supplement (instead of supplant) sound traditional estimating principles.

Literature Review

In 2011, researchers with the University of Nevada, Las Vegas and Georgia Institute of Technology surveyed a group of architects, engineers and contractors to determine, amongst other things, their companies' use of Automated devices, the education level and skills of their companies' IT staff, and their companies' use and benefits of construction related software. The survey revealed that, "ninety-one percent of industry respondents felt that CM (Construction Management) students must receive significant software training as part of their undergraduate program"[5]. Another survey of industry professionals conducted by researchers at California State University, Chico (CSU) found that the number one skill companies wanted graduating CM students to possess is estimating[6]. With the construction industry's desire for CM students to be well versed in estimating and the use of software upon graduation, it is important to understand the impact of software on the students' learning and performance.

Research has shown that CM students are more likely to be visual learners, supporting the perspective that quantity takeoff (QTO) and estimating software can be an effective tool in educating CM students[1,7]. The software visually displays construction information, concepts and principles. Students also seem to embrace the use of software to perform estimates. Two studies conducted that allowed students to choose which method to use for their estimate showed that as high as ninety-three percent of students chose to use either a combination of software and hardcopy, or software alone[1,2]. Utilization of QTO and estimating software encouraged students

to appreciate the importance of the estimate's organizational and logical structure, as well as making the connection to the assignment's real world application[2]. QTO and estimating software also allow educators to incorporate more realistic aspects of an estimate into assignments[4]. Similar findings were made in another study where the researchers concluded that students who learn to use construction related software are better prepared for changing practices in an industry constantly in a state of flux[7].

The use of QTO and estimating software to teach CM students how to estimate also appears to have a positive effect on their performance. CSU conducted a study that showed no difference in the accuracy of quantity takeoffs between students that chose to use some form of Building Information Modeling (BIM) or QTO software and students that chose to perform the quantity takeoff by hand. The researcher did offer the possibility that the similarity in accuracy between the two groups may have been due to the groups being given the correct quantities and acceptable ranges in advance. What the study did show is that students that used some form of BIM or QTO software completed the quantity takeoff about twenty-five percent faster than students that chose to perform the quantity takeoff by hand[1]. The time saved by students using some form of BIM or QTO software allows them to focus on conceptual problem-solving aspects of an assignment, having a positive impact on the quality of the students' estimates[4].

The literature review suggested two opportunities for additional studies that can add to the existing body of knowledge on using QTO and estimating software to teach CM students. The first opportunity is to examine the results of CM students using software to perform more complex quantity takeoffs and estimates[4]. The second opportunity is to examine the results of CM students when minimizing the amount of information and guidance given to the students at the beginning of the project. These two opportunities will be the focus of this paper.

Research Objective

The research objective was to provide further knowledge on the utilization of information technology in construction estimating courses. Specifically, the researchers wanted to identify if technology had an impact on student performance. The researchers analyzed various data in an effort to provide further understanding on the use of technology in construction estimating courses. The research variables were student project grades, final course grade (excluding the project grade), and responses from a survey that captured students' self-reported understanding of estimating, and any past estimating experience they may have had.

Methodology

The researchers teach a three credit hour, junior-level construction estimating course at a large research university based in the United States. The course is part of the construction school, which is housed in the engineering school. Prerequisites of the course are Heavy Construction Equipment, Methods and Materials, and Building Methods, Materials, and Equipment. The Estimating course covers CSI MasterFormat Divisions one through nine. The students complete quantity takeoffs or full estimates including material, labor and equipment costs, along with overhead and markup for the following topics:

- Site work
- Earth work
- Concrete
- Concrete form work
- Masonry
- Structural steel
- Carpentry
- Thermal & moisture protection
- Doors
- Finishes

The researchers developed this study to understand any potential impact technology has on student performance for estimating tasks. A student's grade is based on three factors: homework and labs (25 percent), two exams (45 percent), and a group project (30 percent). For the purposes of this study, any extra credit was excluded from the grading.

The researchers analyzed a majority of the data after the semester's final grades were submitted and closed. The results of this study are based on the group project results, and a student survey given in week eight (of sixteen) of the course. The researchers used quantitative data (student grade percentages and student surveys), using the course as a case study approach.

Analysis of Final Project Results

The project is designed to provide students with an appropriate exposure (given their limited experience) to a 'real-world' QTO and resultant estimate. The major project requirements include:

- A Letter of Submittal
- Title Page
- Abstract
- Table of Contents, List of Figures, List of Tables
- A written report outlining procedures and methods used including a description of the takeoff methodology and what was learned during the project
- A comprehensive, detailed list of all assumptions made
- A detailed estimate for each construction division (CSI 16 Divisions/50 Divisions), excluding those subcontracted
- Request and inclusion of subcontract quotes for the electrical and mechanical work.
- An organized table displaying final job costs for each division and cost component (labor, equipment, material), mark-up, and the final total cost
- Pie charts graphically displaying the percentage cost breakdown by division, cost component, and cost component per division
- An appendix of all pages used for quantity calculations (can be hand written scratch paper but maintain a certain degree of cleanliness and order).

Students were permitted to choose their own groups, such that each group had a minimum of two individuals, but no more than six. There were eight groups, for a total of twenty-nine students.

The researchers evaluated each group's project report and categorized their predominant approach to performing the quantity takeoffs. There were three categories:

- Manual – the group primarily employed hardcopy plans, using rulers, calculators, and other manual QTO methods
- Automated – the group primarily used On-Screen Takeoff (or similar software) to calculate the QTOs
- Both – the group used a combination of Manual and Automated QTO methods

Initial Introduction of the Quantity Takeoff Software

Students were introduced to the quantity takeoff software technology during week eight of the course. One of the researchers provided a one hour demonstration of the software for class one week prior to the students' hands-on lab. The hands-on lab was the assigned homework for the Concrete lecture. The researchers provided individual licenses, and licenses for the computer lab, for On Center's On-Screen Takeoff (OST) software program. OST was selected due to the researchers' previous experiences with the software. There are numerous functions in OST; the major functions (and those most frequently used by students in this study) include[3]:

1. Digital import of plans, or images with known physical dimension / scales
2. Network-based organization of projects and various bids (see Figure 1).

Bid No.	Project Name	Status	Job No.	Pages	Conditions
OST Projects					
OST Sample Projects v2					
1	**Walls & Ceilings**	In Progress		2	20
2	Concrete	In Progress		5	26
3	Roofing	In Progress		1	18
4	Plaster & EIFS	In Progress		2	2
5	Painting	Bidding		4	10
6	Flooring	Pending		3	8
7	Rough Carpentry	Bidding		5	54
8	Finish Carpentry & Millwork	Bidding		3	37
9	Masonry	Bidding		2	2
10	Electrical	In Progress		2	26
11	Mechanical	Bidding		1	14
12	Waterproofing	Bidding		1	5

Figure 1. Database of project files and associated bids.

3. Creation of length, area, and count takeoff conditions, which return a wide range of units of measure. See Figure 2.

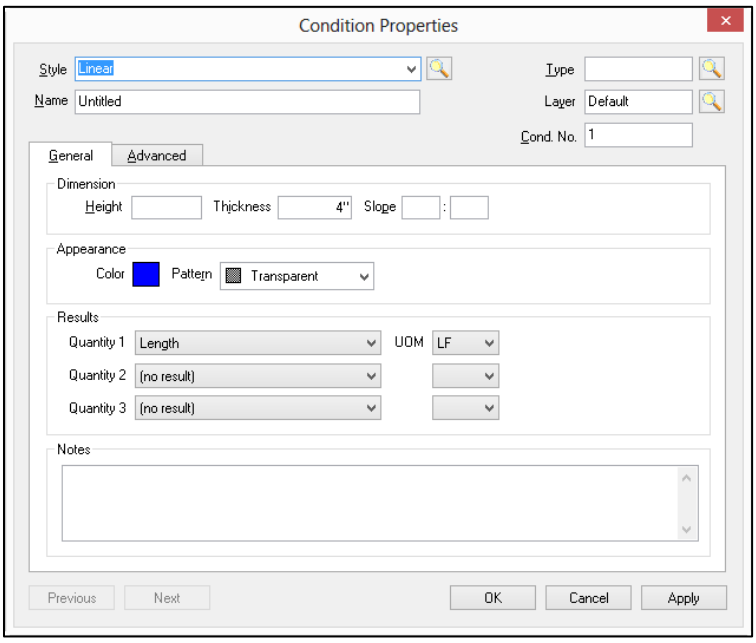


Figure 2. Creation of takeoff condition.

4. Fast takeoff of regular and irregular shapes, curves, or segments. Figure 3 shows the user taking off a ceramic tile grid area.

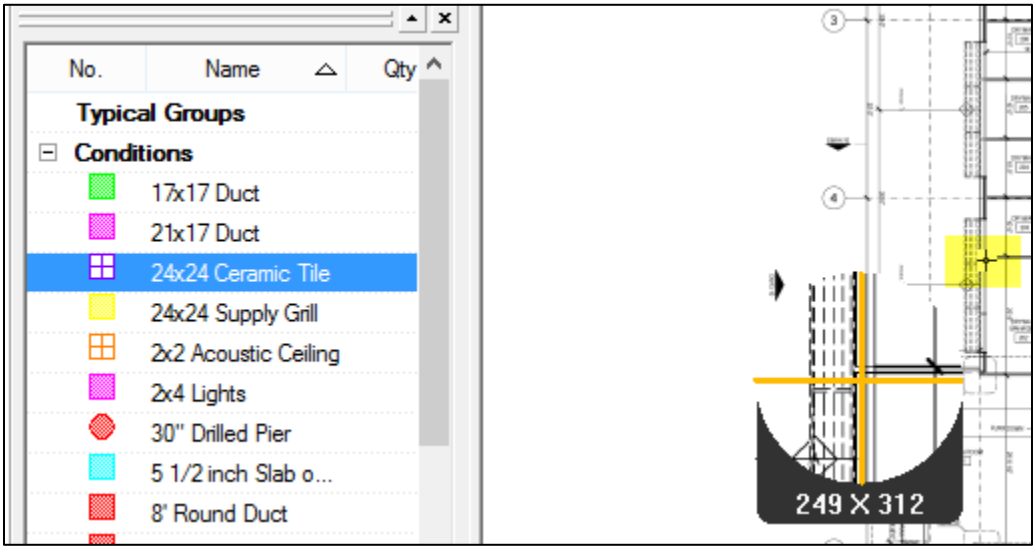
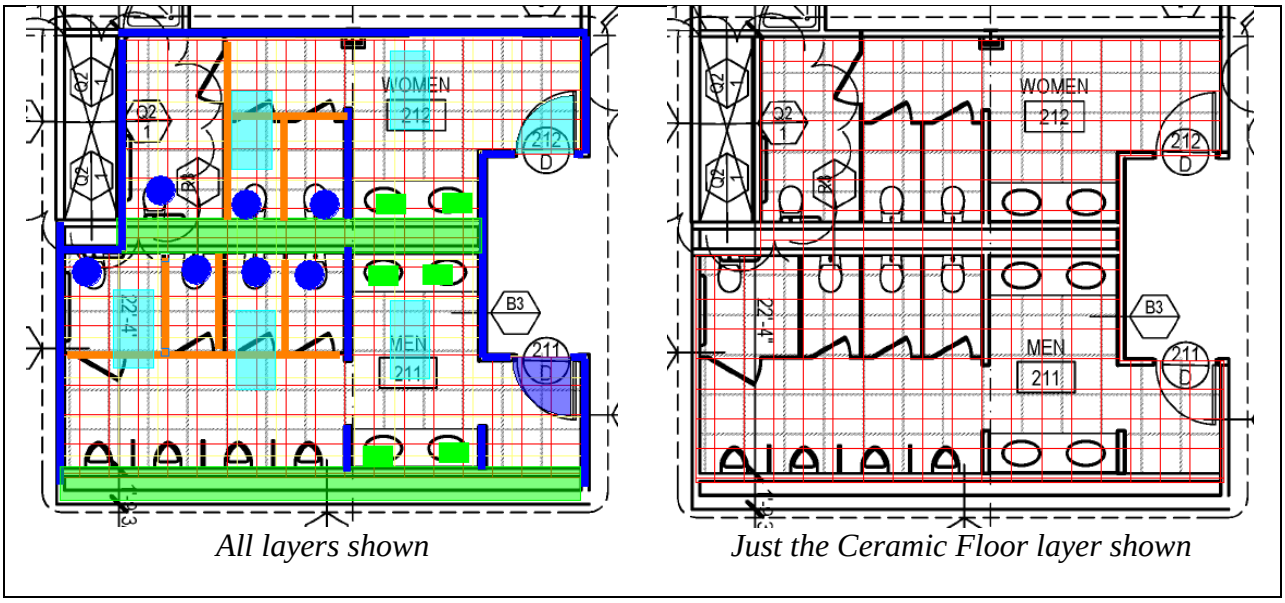


Figure 3. Area takeoff with grid example.

5. Backing out areas (for example, removing light fixtures from a ceiling tile count).
6. Layering of takeoffs. This allows the users to show or hide certain types of takeoffs according to their assigned layer. For example, the user could choose to just show the ceramic floor takeoff. See Figure 4.



All layers shown *Just the Ceramic Floor layer shown*

Figure 4. OST permits the use of layers to show or hide certain information.

7. Named views for navigation between plan sheets.
8. Overlay of an updated plan sheet against an original plan to identify changes.

For the hands-on lab, students were divided into two groups, and were given two similar (but different) lab assignments based on the concrete lecture material. One assignment was to be completed with manual quantity takeoff methods (i.e., rulers and calculators), while the quantities for the second assignment were calculated with OST. Both assignments required the calculation of concrete cubic yards for various footings and a slab.

Data Collection

Data for the project grades and the final grade came from the various scored assignments. The project was graded according to the following rubric:

- 50 percent – quantity takeoff (quantitative)
- 50 percent – overall structure and communication of the estimate (qualitative)

The group's use of a particular quantity takeoff method (Manual, Automated, or Both) was not given any consideration in determination of the project grade. The unit of observation is the takeoff method groups. The takeoff method designation was determined by the researchers' analysis of each project group's predominant approach to quantity takeoff.

The survey asked students, among other factors, their overall "understanding of estimating" and "do you have any previous experience estimating?" Students rated their understanding on a scale from one to nine, with nine being the highest level of understanding. The individual numeric values between one and nine were not qualitatively described to the student respondents. These self-assessed ratings were based solely on the student's own perception of their skills. Responses relating to the question on previous experience was categorical ("Yes" or "No"). The

survey, and responses, were distributed and collected at the next class period (after the hands-on lab with OST), four days later.

Results and Analysis

The researchers designed this study to analyze the role that quantity takeoff software plays in the classroom, and its overall impact on student learning. Four variables are considered: project grade, final course grade (excluding the project), student's self-reported overall understanding of estimating, and students' previous experience estimating. The final course grade, the students' understanding of estimating, and the students' prior experience with estimating variables are included to emphasize the positive impact that using a combination of Manual and Automated takeoff methods may have on student performance. Table 1 presents these variables, grouped by the team's dominant method for QTO. ANOVAs are conducted for each variable, grouping them by students that used "Both" and "Manual or Automated" takeoff methods. The table shows the mean scores for each variable. "Previous Estimating Experience" is the percentage of respondents (from that particular group) that indicated experience with estimating. "# of Groups" is the number of student groups that used the given Takeoff Method.

Table 1. Performance Variables Categorized by Group Takeoff Method

Takeoff Method	# of Groups	Project Grade	Final Grade (no Project)	Understanding of Estimating	Previous Estimating Exp.
Manual	3	81.0%	79.3%	6.0	25%
Automated	3	85.5%	81.1%	6.4	50%
Both	2	90.3%	77.9%	5.4	22%

The first factor considered is the project grade. The average project grade for groups using Both takeoff methods was 9.1 percent higher than groups using a single takeoff method (Manual or Automated), and 11.5 percent higher than groups using just manual takeoffs. The results were also statistically significant via ANOVA with a *p*-value of 0.007.

Next, the average final course grade (exclusive of the project grade) is presented to gain some insight of how individual student capability impacts their team's project performance. The researchers wanted to identify if a certain quantity takeoff method was preferred by higher performing students. Recall that the student groups (and their takeoff method) were not randomly created. The students selected their own groups and collectively chose their takeoff method. The results in Table 1 show no clear pattern and the ANOVA resulted in a *p*-value of 0.6582.

The researchers also analyzed the students' self-reported rating of how well they understand estimating. Students who used Both quantity takeoff methods had the lowest reported understanding of estimating (5.4 out of 9), while those who used Automated takeoff generally had the highest reported understanding (6.4 out of 9). However, the ANOVA yielded a *p*-value of 0.2194.

Finally, students' self-reported past experience was considered, again categorized by their project group's predominant takeoff method. While students with previous experience tended to use Automated takeoff methods, the ANOVA (experience for "Both" and "Manual or Automated" samples) yielded a *p*-value of 0.5089.

The average project grade was 85.6 percent, with a standard deviation of 8.3 percent. The final overall grade (excluding the project) was 79.4 percent, with a standard deviation of 11.2 percent. Figure 5 presents the grade distribution, categorized by "Letter Grade."

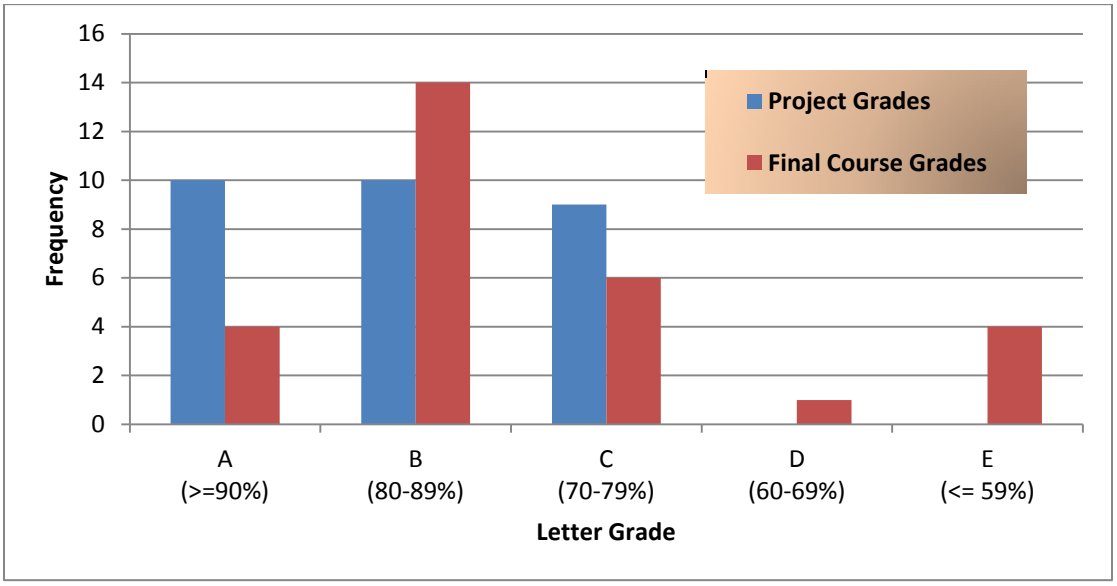


Figure 5. Project and Final Grade Distribution

Discussion

Results appear to indicate that using a combination of Automated and Manual quantity takeoff methods yield optimal estimates and understanding of the construction tasks (as measured by the project grade). The authors are not suggesting that it is the utilization of a particular software program that increases performance, but rather students who use varying approaches to quantity takeoff are more successful. Again, note that the tools used to determine the takeoffs were not given any consideration in the project grade – fifty percent of the project grade was based on the group's ability to succinctly communicate their estimate with the appropriate assumptions and calculations (i.e., a bid package that is professional, informative, and easy to follow from an owner's perspective).

The project groups' predominant method for quantity takeoff did not seem to be affected by overall student capability (as measured by their final grade, excluding the project grade). The researchers feel that use of the final grade is a sufficient measure of student capability as it factors in numerous homework assignments and exam scores. The quantity takeoff method was also not noticeably affected by the students' self-reported understanding of estimating, nor was any previous estimating experience they may have had.

Interestingly enough, the group project is most similar to a real-world estimating scenario that students would encounter. The results highlight three important considerations for construction estimating education:

1. Technology should be a tool that supplements the basic principles of estimating. The researchers' did not introduce the technology until approximately 2/3 of the key estimating principles were introduced in the class. The software was presented as a way to optimize certain tasks that students were already relatively familiar with. The researchers surmise that earlier introduction of the software would have actually been a hindrance to student understanding.
2. Emphasis in the education of students with previous estimating experience should be placed on not using software as a 'crutch.' That is, if a student has had previous experience, they may have developed certain habits that are not conducive to optimal estimates (and therefore rely more on technology). Special attention should be brought to the fact that the basics of understanding should be first understood before using software.
3. Technology is part of the industry, and expanded use of software will continue. Therefore, it is important that today's construction and engineering programs appropriately incorporate technology as an integral part of student education. An informal survey of recent graduates identified that software was a predominant activity in many individuals' jobs.

Though not the focus of this study, the use of Automated quantity takeoff software permits the instructors to provide more direct and specific feedback of a student's work. By layering takeoff by quantity groups, students could quickly show the instructors their reasoning and approach when seeking help. Students certainly have the same opportunity when using Manual methods for takeoffs, but the plan sheets can quickly become busy with highlights and measures of the numerous QTO calculations.

Conclusion

The primary objective of this research case study was to analyze the impact quantity takeoff software has on student performance in a university construction estimating course. Quantitative data was collected from student project grades, final semester grades (exclusive of the student project), and a student survey that measured students' self-reported understanding of estimating and identification of any previous estimating experience. Key findings indicate that appropriate use of Automated and Manual quantity takeoff methods resulted in higher project grades, while student performance, understanding, and previous experience did not clearly have an impact on the project grade. The project is a rough approximation of a real-world estimating scenario.

The results contribute to the body of knowledge by providing substantive evidence that the education of fundamental estimating principles should be supplemented with software and other technologies. The findings also indicate that student capability, understanding of estimating, or previous experience does not necessarily affect an educator's ability to incorporate technology.

Limitations

There were some inherent limitations in this exploratory study. First, the sample size is fairly limited. The survey is based on twenty-nine students, divided into eight different groups, using three different quantity takeoff methods. A second limitation is that the groups and takeoff methods were not random (as to more specifically isolate the effect of different takeoff methods).

Recommendations for Future Research

Future research is recommended to expand the population by additional classes within the researchers' University, and external programs as well. Additional research that quantifies the 'complexity' of a certain estimating task, and the impact software has on its overall accuracy (in terms of quantities) may also be beneficial.

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