

Improving Student Estimating Accuracy through Hands-On Learning: A Case Study

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Active learning, commonly referred to as hands-on learning, is arguably the most effective method of curricula delivery for construction students. This paper describes a hands-on exercise developed to promote course learning objectives in an undergraduate estimating course, and improve student estimating accuracy. The students (in groups) were tasked with developing self-perform estimates for constructing a small section of cast-in-place wall reinforcing and formwork, actually building what they had estimated at the Auburn University Field Lab, and comparing their estimated costs to actual costs. The research methodology included students completing pre-exercise and post-exercise surveys to discern the effectiveness of the exercise. Statistical analysis of pre-exercise and post-exercise student surveys showed that completion of the exercise did promote two of four course learning objectives, and that comparison of estimated vs. actual costs highlighted areas where students could improve their estimating abilities. Future research will include replicating this study during future semesters of the course, along with developing similar exercises based on different scope of work.

Key Words: Estimating, Construction Education, Active Learning, Field Lab, Project Controls

Introduction

Hands-on learning opportunities are a staple of most collegiate construction education programs in the United States. Hands-on class or lab sections are typically where construction students first learn construction concepts through experiential learning (Glick et al., 2010), which provide students with a more intuitive sense for potential construction issues (Hubbard & Hubbard, 2009).

Students gaining real world experience as undergraduates will lessen their learning curve once entering the industry, making them more efficient and productive practitioners (Brncich et al., 2011). Oppenheim & Grosskopf (2007) states “Laboratories provide active learning and enhance the student’s ability to remember and understand material” and “Perhaps the most efficient course delivery method is to integrate the laboratory into the course lecture, such that laboratories support lecture concepts in a timely manner." Tatum (2014) echoes this sentiment, stating that "To efficiently prepare students to integrate well into the construction industry, a comprehensive and structured construction curriculum should provide students with the necessary environment and resources. The program can facilitate students' application of what they learn by providing additional training in the form of labs as reinforcement."

Active learning is defined as any instructional method that engages students in the learning process, in contrast to traditional lecture-based course delivery, where students passively receive information from the instructor (Prince 2004). Several studies into alternative curriculum delivery methods in construction education have shown the value of hands-on learning, as opposed to traditional delivery via lectures. Wentz & Alter (1998) describe HVAC lab courses at the University of Nebraska and Purdue University, in which they assert that combining lecture and lab instruction experiences seem to be the most effective and efficient means to stimulate a construction management undergraduate. Farrow et al. (2010, 2011) described studies into curriculum delivery preferences of "net generation" construction students (i.e., millennials), and found that these students have a penchant for hands-on learning, where their vision of content delivery includes introduction of a topic during one class period, and an activity in the following class period where they can apply the concepts learned. Tingerthal et al. (2013) and Ghosh et al. (2015) describe learning activities promoted with "vertical integration", where younger and older construction students interact across courses through hands-on exercises.

A major focus in the McWhorter School of Building Science at Auburn University has been to integrate more hands-on learning across the curriculum. In 2012, the school acquired a 3-acre site on the Auburn University campus for use a "field lab". The field lab functions as a pseudo jobsite, which is meant to provide a learning environment where lessons can be reinforced by doing, instead of just hearing in the classroom. Typical exercises conducted at the field lab include setting temporary formwork for elevated pan slabs and cast in place walls, installation of erosion control measures, and structural steel erection. Safety is paramount, and incorporated into each exercise.

The balance of this paper describes one such exercise, the purpose of which was to promote the importance of understanding field activities when developing construction estimates. This exercise was completed during summer semester 2016 as part of an estimating course, referred to as Project Controls I in the McWhorter School of Building Science curriculum, which had an enrollment of 18 students. Each student that completed the exercise also completed a pre and post-exercise survey to determine the effectiveness of the exercise in meeting certain course objectives, and to gauge the efficacy of the exercise itself.

Research Objective and Methodology

The main objective of this research was to determine the effectiveness of hands-on learning exercises in undergraduate construction estimating coursework to facilitate improving estimating accuracy. This objective was tested through the development and completion of an exercise related to the installation of rebar and formwork for 16 feet of 4-foot-tall cast in place wall, shown in Figure 1, at the McWhorter School of Building Science field lab. The exercise excluded concrete material and placement.

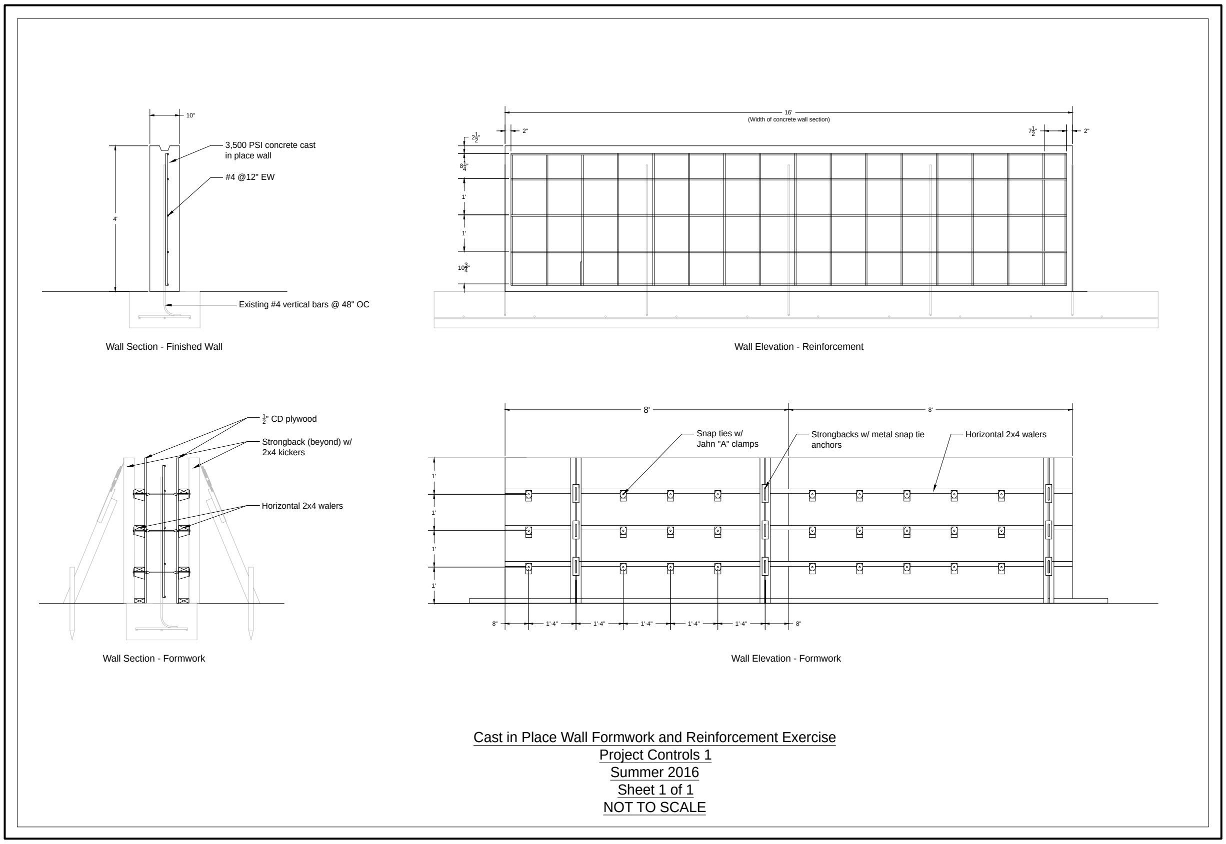

Figure 1. Sketch of reinforcing and formwork provided to students

The exercise consisted of five sequential parts:

Part I – Development of a self-perform estimate

Students were broken into three groups of six students each. Groups were chosen at random by the instructor. Each group was provided with a sketch of the rebar and formwork to be installed (shown in Figure 1). This wall section closely aligns with typical sections in the construction documents being used to develop a complete estimate throughout the course. Each group was tasked with (1) completing a quantity takeoff for all necessary materials, and creating a material purchase order, and (2) developing a cost estimate of including materials, labor, contingency, overhead and profit, (i.e., a bid) to complete the work. The students were not to include direct waste factors in the material and labor line items of their estimates but were to include a single contingency factor to the overall estimate as they deemed appropriate for the task. The students were familiar with reinforcing and formwork typical of the exercise, but had not actually constructed either prior to the exercise.

The groups were provided with some material prices, but were required to find the remaining prices on their own through either online searches or contacting local suppliers. The groups were also provided with labor wage rates for use from the *2016 RSMeans Building Construction Cost Data* book, which was the pricing resource used throughout the course. The groups were to designate one student as the foreman, four students as concrete laborers, and one student as a “recorder”. The recorder would solely be responsible for tracking actual labor productivity and material usage during the exercise and was not included as a paid crew member included in their cost estimates. The groups were to develop labor production rates (i.e., output per labor hour) based on their crew composition, and determine the total labor costs to include in their estimate. Each group submitted their material purchase order and complete cost estimate at the end of the class period the exercise was introduced.

Part II – Completion of the pre-exercise survey

Each of the 18 students completed a survey (provided in Appendix A) of 11 closed-ended questions regarding how well prepared they felt they were to meet certain course learning objectives, their expectations of the accuracy of their group's estimate, whether or not their group had developed an execution plan to complete the exercise when developing their estimate, and how successful they felt their group would be in meeting their estimated costs. Each question was scored on a Likert scale from one to five.

Part III – Completion of the exercise at the field lab

Each group constructed the rebar and formwork at the field lab during the next class period. Three-hours of time was allotted to complete the exercise, which included assembly and disassembly of the rebar and formwork. The material purchase orders developed in Part I were provided to the Field Lab manager prior to the exercise. The Field Lab manager had the requested materials delivered to the work area, and labeled per each group. The recorders tracked all of the material usage and labor productivity throughout the exercise.

Part IV – Comparison of estimated vs. actual costs

Each group reviewed the actual figures tracked by their recorder during the following class period. The groups were asked to determine their as-built cost for the work using their actual material and labor production quantities, the material costs they used for their estimate, and the RSMeans labor wage rates. The instructor developed a simple spreadsheet which included each groups' bid estimates, and the as-built costs. As a class, each group's estimates and actual figures were reviewed and discussed. Instructor facilitated discussion to encourage students to understand the importance of tying field operations to construction estimates.

Part V – Completion of the post-exercise survey

Each student completed a similar survey to that shown in Appendix A at the conclusion of the estimated vs. actual discussion. The essence of each question was the same between both surveys, the only differences being slight adjustments to the wording such as "now that you have completed the field lab exercise…".

The results of both surveys were collected by the instructor, and compiled into one Microsoft Excel spreadsheet for analysis. Microsoft Excel was also used for basic calculations, such as determining mean scores for each question. SPSS was utilized to determine if a statistical difference existed between the pre and post-exercise responses, specifically a Mann-Whitney U Test analysis. Mann-Whitney U Tests are very similar to t-tests, but used when comparing mean values of two groups with data that is nonparametric (i.e., has a rank-order scale), such as a Likert scale (Wilcox, 2009). A 90% confidence interval (p-value less than .1) was used to determine if a statistical difference existed between the two surveys.

Estimated Cost vs. Actual Cost Results

Table 1 provides the results of the student's estimated costs (tabulated in Part I) vs. the actual costs borne from completing the exercise (tabulated in Part IV), including the percent difference between the costs for material, labor, total cost (which includes both material and labor), total bid, and overhead and profit (O&P), and contingency. The total bid price includes the total cost plus O&P.

The total bid prices between the pre and post exercise estimates were kept the same for the analysis, with any changes being realized in the O&P and contingency figures. This was done to show the students how differences in estimated vs. actual pricing would be tracked by a contractor (e.g., if your estimate is lower than the actual cost, the O&P and contingency for your project will suffer due to increased costs, if your estimate is higher than the actual cost, your O&P and contingency will increase due to lower costs).

As shown, Groups 1 and 3 both had actual costs higher than originally estimated, lowering their O&P and contingency amounts by 11.51% and 71.22%, respectively. Both groups had lower costs related to materials (10.49% and 11.68%), but higher costs related to labor (31.11% and 31.46%). None of the groups were "in the red" for the total project, as all still had positive O&P and contingency based on their actual costs.

Table 1. *Comparison of original estimates vs. actual costs*

	Material	**Labor**	**Total Cost**	**Total Bid**	**O&P and Contingency**
Original Estimates					
Group 1	$739.32	$338.33	$1,077.65	$1,318.38	$240.73
Group 2	$711.41	$586.25	$1,297.66	$1,511.77	$214.11
Group 3	$442.22	$475.85	$918.07	$1,055.77	$137.70
Actual Costs					
Group 1	$661.76	$443.59	$1,105.35	$1,318.38	$213.03
% Difference	*-10.49%*	*31.11%*	*2.57%*	*0.00%*	*-11.51%*
Group 2	$602.74	$557.90	$1,160.64	$1,511.77	$351.13
% Difference	*-15.28%*	*-4.84%*	*-10.56%*	*0.00%*	*64.00%*
Group 3	$390.59	$625.55	$1,016.14	$1,055.77	$39.63
% Difference	*-11.68%*	*31.46%*	*10.68%*	*0.00%*	*-71.22%*

Survey Results

Table 2 provides the mean scores and p-value from the Mann-Whitney U Test analysis for the first four questions of the survey. The Likert scale for these questions ranged from one to five, where a response of one equated to "not prepared at all", a score of three equated to "sufficiently prepared", and a score of five equated to "completely prepared". (Note: The Likert-scale mean scores have been provided in lieu of the rank-order sum calculations from the Mann-Whitney U Tests due to space limitations in this document, as well as to provide clear survey results to the reader.) As shown, questions 2 and 3 showed a statistically significant difference between the pre and post surveys.

Table 2. *Survey response answers regarding preparedness to meet certain course learning objectives*

		Pre-Exercise Average	Post-Exercise Average	p-value (From Mann-Whitney U Test)
1	Understand the role of estimating in the construction industry	4.278	4.556	0.185
2	Collect the information required to perform a quantity take-off from project plans	3.667	4.222	0.047
3	Use appropriate procedures to perform manual quantity take-offs which are appropriately organized	3.5	4.056	0.070
4	Review quantity take-offs to identify errors.	3.389	3.722	0.198

Table 3 provides the mean scores and p-value from the Mann-Whitney U Test analysis for questions 5 through 9 of the survey. The Likert scale for these questions ranged from one to five, where a response of one equated to "completely inaccurate", a score of three equated to "sufficiently accurate", and a score of five equated to "completely accurate". As shown, only questions 5, 6, and 9 showed a statistically significant difference between the pre and post surveys. Questions 5 and 6 dealt with material quantity takeoff and unit pricing, and question 9 dealt with developing the total estimated cost for the work, which included both material and labor quantity takeoff and pricing.

Table 3. *Survey response answers regarding estimate accuracy*

		Pre-Exercise Average	Post-Exercise Average	p-value (From Mann-Whitney U Test)
5	Material quantity takeoff	4.333	3.5	0.004
6	Material Unit Prices	4.278	3.667	0.020
7	Labor productivity	3.444	3.111	0.291
8	Labor Unit Prices	4	3.5	0.160
9	Total estimated cost for the work	4	3.167	0.005

Table 4 provides the mean scores and p-value from the Mann-Whitney U Test analysis for question 10 of the survey, which dealt with the development of a plan to complete the exercise during the development of the group's estimate. The Likert scale for this questions ranged from one to five, where a response of one equated to "unsuccessful", a score of three equated to "sufficiently successful", and a score of five equated to "completely successful". As shown, there was not a statistically significant difference between the pre and post surveys.

Table 4. *Survey response answers regarding project execution success*

		Pre-Exercise Average	Post-Exercise Average	p-value (From Mann-Whitney U Test)
10	Level of success	4.111	3.824	0.226

Discussion of Results

All three groups overestimated the materials necessary to complete the exercise by at least ten percent, as shown in Table 1. Group 1 and Group 3 both underestimated the amount of labor that it would take to complete the exercise by over 31 percent. Group 3 had the lowest total bid of all of the groups at $1,055.77, but also had the lowest O&P and contingency, nearly 40 percent lower than Group 1 (i.e., the second lowest bid). Group 2 had the only positive increase in O&P and contingency at 64 percent, but also had the highest bid of all three groups.

The results displayed in Table 2 highlights the effectiveness of the exercise to promote course objectives. The post-exercise scores for all four questions are higher that the pre-exercises scores. Question 1 regarding “understanding the role of estimating in the construction industry” did not have a statistically significant difference between the pre and post surveys, but as shown, the mean pre-exercise scores were already very high (i.e., 4.278 on a 5-point scale). The mean post-exercise scores would need to be nearly five for there to be a statistically significant difference, meaning that all of the students in the course would be completely prepared in understanding the role of estimating in the construction industry. This type of response is probably not realistic for a group of undergraduate students, many of whom stated that this course was their first exposure into estimating. Questions 2 and 3 regarding “collect information required to perform a quantity takeoff from project plans” and “Use appropriate procedures to perform manual takeoff which are appropriately organized” both showed a statistically significant difference between the pre and post surveys. Question 4 regarding “review quantity takeoffs to identify errors” did not produce a statistically significant difference. Both of the pre and post exercise scores for this question were low, between three and four on the five-point scale.

The results displayed in Tables 3 and 4 highlight the value of completing such an exercise in an estimating course. Questions 5 through 9 dealt with the accuracy of the estimates developed by the students, where the pre-exercise survey asked how accurate the students felt their estimates were, and the post-exercise surveys asked how accurate their estimates actually were. Question 10 in the pre-exercise survey asked how successful the groups would be in meeting their estimates based on an execution plan developed during estimate development, and the post-exercise survey asked how successful they actually were. The pre-exercise scores for all six questions were higher than the post-exercise scores, and a statistically significant difference was shown on questions 5 and 6 (dealing with material quantity takeoff and pricing) and question 9 (dealing with total estimated cost for the work). These results show that the students may have been overconfident or overly optimistic with their initial estimates, but after collecting the actual data from the exercise and comparing with their estimates (shown in Table 1), the students were able to realize where their deficiencies were. There was no statistically significant difference between the pre-exercise and post-exercise scores for questions 7 and 8 (dealing with labor productivity and pricing), but as shown, the mean pre-exercise scores for questions 7 and 8 were both significantly lower than the mean pre-exercise scores for questions 5 and 6. This suggests that the students were already less confident in their ability to estimate labor as opposed to materials, which arguably is the most difficult aspect to estimate on any project.

The authors feel that the comparison of the pre-exercise estimates and post-exercise actual costs provided the most value to the students. The students were able to realize the importance of understanding field operations and execution planning when developing project estimates, and the financial risks to projects when these items are not considered completely during the estimating process. In the authors’ opinion, the experience of seeing how challenging it is to achieve complete precision and accuracy in estimating on this small project enlightened the students to a greater appreciation for the estimating process. Though several of the questions from the post survey show a lower score (i.e., less confidence) by the students, this should be considered normal, and even appropriate. The students may have felt less confident immediately following the exercise, but as a teaching moment, the students will take these results and apply them to future estimates, either in the classroom or the field. As stated by

Brncich et al. (2011) and Tatum (2014), these types of experiences will lessen the students learning curve once entering industry, making them more effective practitioners.

Conclusions, Limitations, and Future Research

Hands-in learning is a critical aspect of any construction management curriculum. This paper describes a hand-on exercise completed in an estimating course at Auburn University, where the focus was to foster the improvement of student estimating accuracy through comparing self-perform estimates with actual material usage and labor productivity. Statistical analysis of pre and post-exercise surveys showed that completion of the exercise itself (including post-exercise analysis with the students) facilitated the achievement of course objectives, and assisted students in understanding where deficiencies existed in their estimating abilities.

This study was limited to only one section of Project Controls I. Future research will include replicating this study during additional sections of the course, as well as completing similar exercises with different scopes of work such as metal stud framing and drywall and/or erection of structural steel framing

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Appendix A: Survey

Field Lab Estimating Exercise Questionnaire #1 (Prior to Field Lab)

Based on what you have learned in this course to date, rate how prepared you are able to:

Understand the role of estimating in the construction industry	1	2	3	4	5
Collect the information required to perform a quantity take-off from project plans	1	2	3	4	5
Use appropriate procedures to perform manual quantity take-offs which are appropriately organized	1	2	3	4	5
Review quantity take-offs to identify errors.	1	2	3	4	5
	Not Prepared at All		Sufficiently Prepared		Completely Prepared

What are your expectations regarding the accuracy of the following items based on your group's estimate:

Material quantity takeoff	1	2	3	4	5
Material Unit Prices	1	2	3	4	5
Labor productivity	1	2	3	4	5
Labor Unit Prices	1	2	3	4	5
Total estimated cost for the work	1	2	3	4	5
	Completely Inaccurate		Sufficiently Accurate		Completely Accurate

Did your group create a plan of execution to complete the exercise when developing your estimate?

YES NO

If yes, how successful will your group be in meeting your estimate by using this plan?

Level of Success	1	2	3	4	5
	Unsuccessful		Sufficiently Successful		Completely Successful

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