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Improving Estimating Competency Through Experiential Learning Projects in Construction Management Education

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This study examines the effectiveness of a two-phase experiential learning project in Construction Management (CM) education. In phase one, Computer Information Systems (CIS) students developed an estimation database using historical data from three Massachusetts schools. In phase two, CM students applied this tool alongside traditional estimation methods for the Florence Roache Elementary School Project. Twenty CM students each produced three independent estimates using the student-developed MIS Estimator, MSBA Bid Results Data, and RS Means Square Foot Estimator. Analysis against AACE International Class 4 accuracy standards (-15% to +30%) showed the MIS Estimator and MSBA achieved mean differences of -13.96% and -26.42%, respectively from the Florence Roche Feasibility Study PSR (Preferred Schematic Report) Probable Cost Estimate, while RS Means (-67.65%) exceeded recommended variance limits. Student performance in conceptual estimating showed marked improvement, with final exam scores increasing from a three-year historical average of 75.16% (2021-2023) to 97.7% in 2024. The findings demonstrate the potential of incorporating student-developed tools in construction education while highlighting areas for future refinement in estimating pedagogy.

Key Words: Construction Education, Experiential Learning, Database Development, Estimating, Interdisciplinary Projects

Introduction

Construction Management (CM) students develop the essential skill of project cost estimation throughout their education. This foundational competency involves predicting both needs and resource requirements, which are critical elements for project budgeting, competitive bidding, and planning. As construction projects become more complex, conceptual estimating has become a vital tool, helping professionals make informed decisions in the early phases of project development.

The need for enhanced conceptual estimating skills reflects broader trends in professional education. Kolb (2014) described how career progression typically begins with applying specialized knowledge from formal education, but eventually reaches a critical juncture where job demands necessitate a more holistic learning approach. This career evolution pattern is especially relevant in CM, where technological advances and increasing project complexity demand professionals to develop practical skills through hands-on experience while adapting to evolving industry demands.

Wentworth Institute of Technology (WIT) currently offers limited coverage of conceptual estimating, with the topic only briefly introduced in the curriculum. Recognizing the growing importance of this skill in the industry, this research presents an innovative approach to expand students' exposure to and understanding of conceptual estimating techniques through experiential learning.

The Florence Roache Elementary School Project in Groton, Massachusetts presents an innovative case study to address this curricular gap and enhance estimation instruction within WIT's CM education. In Massachusetts, information about public schools is considered public record, with details about the Florence Roache Elementary School Project publicly accessible online. (Groton-Dunstable Regional School District, 2020a; Groton-Dunstable Regional School District, 2020b). This transparency provides a valuable real-world context for the educational initiative, allowing students to engage with actual, current data in their estimating exercises.

This initiative engaged two student groups in sequential experiential learning activities. In Spring 2024, Computer Information Systems (CIS) students gained practical software development experience by creating the Management Information Systems (MIS) Student Estimator, a database tool incorporating historical data from three Massachusetts schools. In Summer 2024, CM students then applied this student-developed tool alongside two industry-standard approaches: MSBA (Massachusetts School Building Authority) Bid Result Data, RS Means Square Foot Estimator (an industry-standard construction cost database) (Gordian, n.d.). This sequential approach provided both student groups with valuable real-world experience while creating and using practical estimating tools. This study examines the effectiveness of this experiential learning approach in enhancing CM education through practical application and the use of student-developed tools

Literature Review

As the construction industry evolves with increasing technological complexity, educational programs need to adapt to prepare students for modern construction challenges, particularly estimating. Recent research by Ahn et al. (2012) emphasizes the critical need to align CM curricula with industry expectations, focusing on developing key competencies through hands-on, experiential learning approaches. The foundation for construction cost estimating education is built upon established industry standards, particularly the AACE International Recommended Practice No. 18R-97 Cost Estimate Classification System (AACE International, 2005). This system defines five distinct classes of estimates based on project definition, with Class 5 representing the lowest level of project definition (0-2%) and Class 1 representing the highest (50-100%). Each class has specific accuracy ranges and methodologies appropriate for different project stages (AACE International, 2005).

Ahn et al. (2012) examined the alignment between CM education and industry practice through a comprehensive survey of industry recruiters. Their research identified critical competencies needed for CM graduates, with problem-solving ranking as the second most important competency (mean score 4.46 out of 5). The researchers grouped problem-solving skills together with adaptability and interdisciplinary application into a broader "cognitive competency" category (Ahn et al., 2012). This categorization reflects the complex nature of CM, where professionals must analyze data, adapt to project uncertainties, and apply critical thinking to develop solutions with limited information (Ahn et al., 2012).

Class 4 estimates (1-15% project definition) were used in this analysis as they correspond to conceptual estimating requirements. These estimates, according to AACE standards, have an expected accuracy range of -15% to -30% on the low side and +20% to +50% on the high side, establishing evaluation criteria for student performance (Bates et al, 2005).

The value of experiential learning in CM education is well-documented and aligns with Kolb's (2014) experiential learning model, which emphasizes a cycle of Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. Kolb (2014) described learning as a dynamic process where knowledge emerges through both outward engagement with the external world and inward contemplation of these experiences. This dual process of action and reflection is particularly relevant in CM education, where theoretical knowledge must be actively tested and applied in practical situations.

Collins and Redden (2021) conducted a study with 102 CM students that validated the effectiveness of experiential learning in estimating education. Through pre- and post-exercise surveys, their research demonstrated statistically significant improvements in students' ability to understand estimating roles, collect and organize quantity takeoff information, and identify errors. Their results showed that hands-on field exercises provide students with valuable learning opportunities that align with course objectives and enhance their understanding of the connection between estimating and field operations (Collins & Redden, 2021).

The gap between academic preparation and industry needs represents a key challenge in CM education. Ahmed et al.'s (2014) survey of industry stakeholders captured this challenge through an observation from a CM program head that "no university education can prepare a graduate for all aspects of the industry. However, the base skill set that allows for entry level employment is being delivered" (p. 242). Their research identified specific skills demanded by industry, including health and safety knowledge, contract document interpretation, and building code knowledge, suggesting that CM programs must evolve beyond basic skill delivery to meet modern industry demands. This evolution requires innovative teaching approaches that can better prepare students for the complex realities of CM.

While researchers like Kantianis (2022) validate the use of historical data from completed projects for professional conceptual estimating, there remains a need to develop effective methods for teaching these essential skills to CM students. The challenge of making accurate cost predictions with limited information that Kantianis (2022) described makes it crucial to provide students with hands-on experience in analyzing and applying historical project data.

Methodology

This study used AACE International's Recommended Practice No. 18R-97 Cost Estimate Classification System as its analytical framework, specifically focusing on Class 4 estimates which have an expected accuracy range of -15% to -30% on the low side and +20% to +50% on the high side. The research employed problem-based learning through interdisciplinary application, building on Zolin et al.'s (2003) study, which demonstrated the effectiveness of real-world industry settings in educational contexts. Using the Florence Roache Elementary School Project, a Construction Manager at Risk (CM@R) delivery method project as a case study, CIS students developed an estimation database using historical data which CM students later applied in their conceptual estimating exercises. This approach created a realistic simulation of industry practices while exploring the impact of experiential learning on CM skill development.

The methodology draws upon Kolb's (2014) experiential learning model through a phased interdisciplinary approach. CIS students began by developing a real-world database tool, while CM

students engaged in active experimentation by applying this database to their cost-estimating tasks. This project learning model provided a rich, hands-on learning environment that closely mirrored industry challenges.

Estimation Methods: Students employed three distinct estimation approaches to develop cost projections:

1. **MSBA Bid Results Data Estimate:** Students utilized bid result data from similar CM@R projects provided by the Massachusetts School Building Authority (MSBA). This method involved analyzing past bid results and adjusting them for current conditions. Students applied the ENR Building Cost Index for time-based cost changes and the RS Means City Cost Index for location-specific adjustments.
2. **RS Means Square Foot Estimator**: Students developed a second estimate using the RS Means Square Foot Estimator. They customized the model by modifying at least five critical assemblies to match the project's specific requirements and then generated a comprehensive report.
3. **MIS Student Estimator**: The final method leveraged a custom database created by CIS students. This tool incorporated advanced features for analyzing historical data and followed the same adjustment process as the MSBA Bid Result Data Estimate. Students applied the ENR Building Cost Index for time-based cost changes and the RS Means City Cost Index for location-specific adjustments.

Project Implementation: The project was structured in two distinct phases. In Spring 2024, CIS students developed the MIS Student Estimator database using historical data from three Massachusetts elementary schools. While students initially faced challenges in understanding construction concepts, these obstacles provided valuable learning opportunities. In Summer 2024, CM students applied this peer-developed tool alongside MSBA Bid Results Data and RS Means Square Foot Estimator. Each CM student ($N = 20$) produced independent estimates using all three methods, generating 60 total estimates for analysis against AACE International Class 4 accuracy standards (-15% to +30%).

Data Collection and Analysis: Data for the analysis was collected from student submissions, including MSBA Bid Results Data calculations, RS Means reports, and Microsoft Excel spreadsheets downloaded from the MIS Student Estimator. Results were evaluated against AACE International's accuracy standards for Class 4 estimates to assess both accuracy and consistency (Bates et al., 2005). The comparative analysis of these different estimating methods revealed a surprising discrepancy in results across the three methods. The MSBA Bid Results Data Estimate and MIS Student Estimator estimates aligned closely, indicating consistency and reliability in using these methods. However, the RS Means Square Foot Estimator was significantly lower, suggesting potential challenges in adapting standardized estimating guides to specific project conditions.

Results

This study was designed as a phased, sequential project where CIS students first developed an estimation tool that was later used by CM students. In Spring 2024, CIS students created the MIS Student Estimator database in Microsoft Access as part of their Management Information Systems (MIS) course, gaining practical software development experience with real construction data. In Summer 2024, CM students in the Advanced Estimation course then applied this tool alongside

industry-standard methods, with several noting increased engagement when using peer-developed software. This sequential approach provided both student groups with valuable real-world experience while maintaining clear educational objectives for their respective disciplines.

How did the MIS Student Estimator work? The CIS students used costs from three separate Massachusetts elementary schools. The database adjusted the historical data for both year and location built and created a per-square-foot average. The MIS Student Estimator prompted CM students to input information about the proposed new school: the size in square feet and the location (in Massachusetts). Once input was provided, the database returned the overall estimate for the proposed school.

This study employed a within-subjects design where each of the 20 students in the Advanced Estimation course ($N = 20$) worked independently to complete all three estimation methods. Each student produced their own individual estimates using each method, creating a total of 60 separate estimates (20 students × 3 methods) to compare against the Florence Roache School PSR Cost Estimate (Groton-Dunstable Regional School Building Committee, 2020c). The PSR Cost Estimate was calculated as the mean ($60,081,335) of two professional estimates (Leftfield: $61,157,633 and PM&C: $59,679,893) for the 109,885-square-foot facility ($546.77 per square foot).

The overarching research question for this study was whether the MIS Student Estimator could provide realistic conceptual estimates for CM students.

The PSR Cost Estimate was compared to student work using three separate estimation tools: the MIS Student Estimator, the MSBA Bid Result Data Estimate, and the RS Means Square Foot Estimator (RS Means). As such, there were three dependent variables (MIS Student Estimator, MSBA Bid Results Data Estimate, RS Means Square Foot Estimator) compared to one independent variable (PSR Cost Estimate).

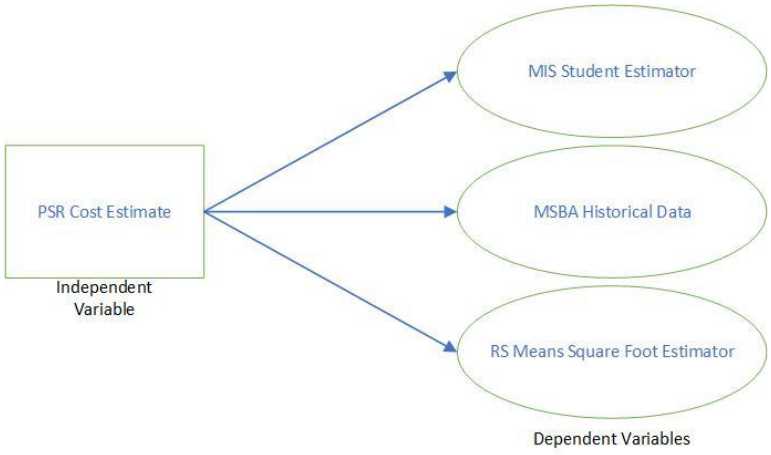

Figure 1. Independent and Dependent Variables

Three single sample *t*-tests were used to compare the single estimate (PSR Cost Estimate) to each of the three available tools.

RQ1: Regarding the use of MIS Student Estimator, how accurate is the estimate given compared with the PSR Cost Estimate?

RQ2: Regarding the use of MSBA Bid Results Data Estimate, how accurate is the estimate given compared with the PSR Cost Estimate?

RQ3: Regarding the use of the RS Means Square Foot Estimator, how accurate is the estimate given compared with the PSR Cost Estimate?

Below were the hypotheses used:

H1: Regarding the use of the MIS Student Estimator, there will be no significant difference in the estimate given compared with the PSR Cost Estimate.

H2: Regarding the use of the MSBA Bid Results Data, there will be no significant difference in the estimate given compared with the PSR Cost Estimate.

H3: Regarding the use of the RS Means Square Foot Estimator, there will be no significant difference in the estimate given compared with the PSR Cost Estimate.

Focusing on H1, a single sample *t*-test was performed in IBM SPSS to evaluate whether there was a difference between the estimates of the treatment (MIS Student Estimator) and the control (PSR Cost Estimate**)** (see Table 1). The results indicated that there was a significant difference, $t(19) = -3.499$, $p = .001$, in estimates between the treatment group ($M = 51693812.900$, $SD = 10720439.86$) and the PSR Cost Estimate($M = 60081335$). The effect size, as measured by Cohen's *d*, was $d = -.728$, indicating a medium effect (Cohen, 2013). As such, H1 was rejected; there was a significant difference in the estimates between the MIS Student Estimator and the PSR Cost Estimate.

Table 1. Estimate Comparison for the MIS Student Estimator and PSR Cost Feasibility Estimate

	PSR Cost Estimate	**MIS Student Estimator**				
	M	**M**	**SD**	***t*(19)**	***p***	**Cohen's *d***
Estimates	60081335.0	51693812.900	10720439.860	-3.499	.001	-.782

When comparing the means of the PSR Cost estimate (60,081,335) and the MIS Student Estimator (51,693,812.90), the MIS Student Estimator calculated 8,387,522.10 or -13.96% lower than the PSR Cost Estimate mean. According to Bates et al. (2005), feasibility construction estimates are off by -15% to +30%. If the low side and high side of the normal range are considered, feasibility estimates range from -30% to +50% (Bates et al., 2005). Using these acceptability ranges, the MIS Student Estimator estimates fall easily into the acceptable feasibility estimate ranges.

Regarding H2, a single sample *t*-test was performed to evaluate whether there was a difference between the estimates of the treatment (MSBA Bid Results Data Estimate) and the control (PSR Cost Estimate) (see Table 2). The results indicated that there was no significant difference, $t(19) = -6.831$, *p*

< .001, in estimates between the treatment group (M = 44207175.200, SD = 10393225.642) and the PSR Cost Estimate(M =60081335.0). The effect size, as measured by Cohen's d, was d = -1.527, indicating a very large effect (Cohen, 2013). As such, H2 was rejected; there was a significant difference in the estimates between the MSBA Bid Results Data Estimate and the PSR Cost Estimate.

Table 2. Estimate Comparison for the MSBA Bid Results Data and the PSR Cost Estimate

	PSR Cost Estimate	**MSBA Bid Results Data Estimate**				
	M	**M**	**SD**	***t*(19)**	***p***	**Cohen's *d***
Estimates	60081335.0	44207175.200	10393225.642	-6.831	<.001	-1.527

Looking deeper, the means of the PSR Cost Estimate (60,081,335) and the MSBA estimates (44,207,175.20) were compared. The MSBA Bid Results Data estimate was 15,874,159.90 lower than the PSR mean estimate. As such, the MSBA estimate was -26.42% lower, falling on the low side of acceptability for the MSBA feasibility estimate (Bates et al., 2005).

Analyzing H3, a single sample t-test was performed to evaluate whether there was a difference between the estimates of the treatment (RS Means Square Foot Estimator) and the (PSR Costs' Estimate) (see Table 3). Like H1 and H2, the results indicated that there was a significant difference, $t(19)$ =-58.929, p < .001, in estimates between the treatment group (M = 19434382.650, SD = 3084703.8057) and PSR Cost Estimate(M =60081335.0). The effect size, as measured by Cohen's d, was d = -13.177, indicating a very large effect (Cohen, 2013). Consequently, H3 was rejected as there was a significant in the estimates between the RS Means Square Foot Estimator and the PSR Cost Estimate.

Table 3. Estimate Comparison for the RS Means Square Foot Estimator and PSR Cost Estimate

	PSR Cost Estimate	**RS Means Square Foot Estimator**				
	M	**M**	**SD**	***t*(19)**	***p***	**Cohen's *d***
Estimates	60081335.0	19434382.650	3084703.806	-58.929	<.001	-13.177

The RS Means Square Foot Estimator had the largest estimation variance of the three tools used; the estimates were 40,646,952.35 on average lower than the PSR mean estimate. As this estimate was off by -67.65%, the RS Means fell outside of the range of acceptable feasibility estimates (Bates et al., 2005).

While the statistical analysis demonstrates the technical effectiveness of the tools, anecdotal feedback revealed additional educational value. CIS students reported that developing industry-focused software enhanced their professional prospects, with several securing co-op positions based on this project experience. Students noted increased engagement when creating software for peer use. CM students similarly reported higher engagement when using tools developed by fellow WIT students, suggesting the sequential project structure successfully provided real-world experience while maintaining clear educational objectives.

Student mastery of estimation concepts showed substantial improvement in final exam performance. When tested on conceptual estimating questions requiring historical data adjustment for time and location factors, students achieved an average score of 97.7%, compared to a three-year historical average of 75.16% (84.62% in 2021, 63.16% in 2022, and 77.7% in 2023), representing a significant improvement in learning outcomes.

Discussion

The results of this study demonstrate how Kolb's (2014) framework emphasizes experiential learning through concrete experience, reflective observation, abstract conceptualization, and active experimentation. The statistical findings provide measurable evidence of effective learning outcomes through these dimensions.

The variance between different estimation methodologies when comparing to AACE International Class 4 standards (-15% to +30% of PSR Cost Estimate), particularly the performance of the MIS Student Estimator (-13.96%) versus the significant deviation in RS Means Square Foot Estimator (-67.65%), demonstrates how students progressed through Kolb's (2014) learning cycle. Starting with concrete experience using the estimation tools, students engaged in reflective observation of results, developed abstract conceptualizations of cost factors, and actively experimented with different approaches. The high standard deviations across methods indicate varying levels of student mastery in this cycle, suggesting areas for additional guidance in future iterations. Additionally, the interdisciplinary project between CM and CIS programs exemplified another crucial aspect of Kolb's (2014) experiential learning theory. CIS students moved from abstract database concepts to concrete implementation, while CM students progressed from theoretical estimation principles to practical application. This mutual exchange fostered a dynamic learning environment, as described by Kolb (2014), where diverse ideas and skills contributed to both creativity and engagement.

Beyond quantitative measures, anecdotal feedback highlighted broader educational impacts. CIS students reported enhanced professional opportunities, including co-op positions, while both CIS and CM students noted increased engagement through the peer-developed tool connection. These outcomes suggest the sequential structure successfully bridged academic learning with industry-relevant experience.

The success of this educational approach was evident in several measurable outcomes:

- Exam performance improved from a three-year historical average of 75.16% to 97.7%
- Analysis of estimate variances revealed patterns in how students applied different estimation tools
- Students gained practical experience with multiple estimation approaches

These results suggest that structured experiential learning, following Kolb's (2014) cycle, can effectively develop both technical competency and practical application skills in construction education. The different results between locally-informed and standardized tools provided students exposure to how regional factors can influence estimation approaches.

Conclusion

This study examined three estimation methods in an experiential learning context. This study found that the MIS Student Estimator and MSBA showed comparable variances in student applications, while RS Means produced more tightly clustered but consistently lower estimates. Also, student understanding of estimation concepts improved, as demonstrated by exam performance increased from a three-year average of 75.16% to 97.7%.

The analysis revealed that locally-informed methods (MIS Student Estimator and MSBA) produced different results than standardized tools (RS Means), highlighting the importance of exposing students to multiple estimation approaches. The comparable variances between MIS Estimator and MSBA results suggest consistent tool application, though the high standard deviations across all methods indicate opportunities for additional pedagogical support. These results suggest several implications for CM education and future research:

- Cross-disciplinary projects enhance both technical competency and professional development opportunities
- Multiple estimation approaches better prepare students for industry challenges
- Educational tools can effectively integrate technology with practical application
- High estimation deviations suggest the need for additional student support mechanisms

This study had limitations. The participants were selected by enrollment in both Management Information Systems course (Spring 2024) and the Advanced Estimation course (Summer 2024) at Wentworth Institute of Technology. The selection of the participants may have been influenced by selection bias effects (Sekaran & Bougie, 2016). Additionally, the sample size was small, as data was collected from only the Advanced Estimation students ($N = 20$). As such, the results of this study cannot be generalized.

The results demonstrate the value of experiential learning in CM education, supporting Kolb's (2014) framework of concrete experience leading to practical application. The project builds upon Ahmed et al. (2014) and Ahn et al. (2012) studies regarding problem-based learning in construction education, while highlighting opportunities for continued refinement of teaching methodologies.

References

Ahn, Y. H., Annie, R. P., & Kwon, H. (2012). Key competencies for US construction graduates: Industry perspective. *Journal of Professional Issues in Engineering Education and Practice*, *138*(2), 123-130.

Ahmed, S. M., Yaris, C., Farooqui, R. U., & Saqib, M. (2014). Key attributes and skills for curriculum improvement for undergraduate construction management programs. *International Journal of Construction Education and Research*, *10*(4), 240-254.

Bates, J., Burton, C. D. J., Creese, R. C., Hollmann, J. K., Humphreys, K. K., McDonald Jr, D. F., & Miller, C. A. (2005). Cost estimate classification system–as applied in engineering, procurement, and construction for the process industries. *AACE International Recommended Practice*, *18*.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Academic Press.

Collins, W., & Redden, L. (2021). Improving student's estimating abilities through experiential learning. *International Journal of Construction Education and Research*, *17*(2), 117-132.

Groton-Dunstable Regional School Building Committee. (2020a, December 1). *Florence Roche Elementary School Building schematic design set project.* https://www.florencerocheproject.org/3_2020-12-17_fres_sd-drawings_final.pdf

Groton-Dunstable Regional School Building Committee. (2020b, December 17). *Groton-Dunstable Regional School District schematic design project manual outline specifications.* https://www.florencerocheproject.org/2_2020-12-17_fres_sd-project-manual_final.pdf

Groton-Dunstable Regional School Building Committee. (2020c, May 5). *Florence Roche Elementary School Building feasibility study estimate.* https://www.florencerocheproject.org/floro-psr-06-4-6-project-estimate.pdf

Kantianis, D. D. (2022). Design morphology complexity and conceptual building project cost forecasting. *Journal of Financial Management of Property and Construction*, *27*(3), 387-414.

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.

Gordian. (n.d.) *RSMeans Data*. https://www.rsmeansonline.com/SquareFootEstimate/Index/RefreshPage

Sekaran, U., & Bougie, R. (2016). *Research Methods for Business* (7th ed.). John Wiley and Sons, Ltd.

Zolin, R., Fruchter, R., & Levitt, R. (2003). Realism and control: Problem-based learning programs as a data source for work-related research. *International Journal of Engineering Education*, *19*(6), 788-798.