

Use of AI in a Graduate Construction Estimating Course

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Abstract

The construction industry faces ongoing challenges such as low productivity, cost overruns, and labor shortages, prompting increased interest in digital and AI solutions to enhance efficiency. This study explores the integration of Togonal.AI, an artificial intelligence tool, and other Generative AI tools into a graduate-level construction estimating course and examines its implications for construction education. The research involved nine graduate students primarily utilizing Togonal.AI to estimate tasks and document their experiences to answer the question, “What are student experiences related to the use of AI in a construction estimating course?” A qualitative content analysis of student feedback revealed several key themes: learning curve with AI tools, estimating accuracy using AI, comparison with traditional methods, challenges, and potential for future adoption. Integrating AI tools in coursework appeared to have enhanced students' skills in quantity take-off and cost estimation, preparing them for the evolving technological demands of the industry. Togonal.AI provided hands-on experiences that aligned academic learning with industry practices, effectively bridging the gap between theory and application. Despite initial challenges, such as a learning curve, students expressed increased confidence and familiarity with the tools, indicating that sufficient training and support can help overcome these barriers and enhance digital literacy. Additionally, AI tools fostered critical thinking, as students had to validate AI outputs and understand estimation principles, emphasizing the importance of a balanced approach that combines AI with traditional techniques. The findings suggest that construction education should integrate AI-focused modules alongside traditional estimating methods to ensure students are equipped with foundational and advanced technological skills. These insights seek to guide educators looking to modernize construction curricula to align with industry needs and technological advancements.

Introduction

The construction industry continues to grapple with challenges such as low productivity, cost and time overruns, and safety concerns, mainly due to its reliance on manual processes and low levels of digitization [1]. These issues have hampered the industry's ability to meet increasing demand for efficiency [2] [3].

Artificial Intelligence (AI) has emerged as a transformative technology capable of addressing these challenges by introducing automation and improved decision-making capabilities [4] [5]. Machine learning, a prominent subfield of AI, is being applied in areas such as risk management, resource allocation, and cost prediction. Robotics facilitate precision and efficiency in repetitive tasks like site monitoring [2], while AI integrations can also enhance surveying processes and quality control [5]. Furthermore, the integration of AI with Building Information Modeling (BIM) has enhanced real-time monitoring and design optimization, streamlining collaboration among stakeholders [1] [6].

Despite these advancements, significant barriers to the adoption of AI remain. These include data fragmentation and the risk factors associated with an algorithm's prediction, which hinder the

broader application of AI across the construction lifecycle [4]. Overcoming these challenges requires concerted efforts tailored to construction-specific needs.

Literature Review

AI in Construction Estimating

Artificial intelligence (AI) in construction estimating can provide innovative ways to improve accuracy, reduce manual workload, and enhance project planning and cost management decision-making processes.

Pan and Zhang [7] critically reviewed AI applications in construction, noting the significant role of computer vision, natural language processing, and information fusion in automating construction engineering and management (CEM) tasks, with cost estimating as one of those tasks. In another study, García De Soto and Adey [8] demonstrated how combining AI approaches such as neural networks and case-based reasoning with traditional regression analysis could improve preliminary resource estimates in construction projects. Using hybrid AI and traditional techniques led to more reliable construction materials such as concrete and reinforcement estimates, highlighting the advantages of using AI to refine early-stage project cost estimates [8].

Elmousalami [9] also explored AI in construction cost modeling, focusing on parametric estimation techniques. The study reviewed different computational intelligence methods like artificial neural networks, fuzzy logic, and ensemble models. The study's findings highlighted the effectiveness of AI techniques for cost estimation during the conceptual stage of projects, where uncertainty and limited data often hinder traditional estimating methods [9].

Additionally, Ghasemi and Dai [10] investigated the use of GPT-4 in construction estimating, mainly for cost analysis and bid pricing in a bridge rehabilitation project. The study found that GPT-4 "holds the potential for construction estimating with reasonable accuracy." Despite showing potential, the authors noted that issues related to consistency and reliability could limit GPT-4's use in complex or novel estimating scenarios [10].

AI in Engineering Education

Artificial intelligence (AI) is increasingly integrated into engineering education, reshaping how students learn and educators teach. ChatGPT and other generative AI tools are also gaining attention in engineering education. Qadir [11] discussed the potential of generative AI to provide personalized learning experiences through adaptive feedback and real-time simulations. However, challenges such as bias, ethical considerations, and the potential for misuse are key concerns that educators must address. Similarly, Fatahi et al. [12] illustrated using AI in the Geotechnical Engineering discipline. They found that AI integration in education may improve student engagement and learning outcomes while still recognizing the limitations of quality and completeness.

AI has been shown to have a transformative impact on higher education by enabling new learning methodologies. Walter [13] highlighted how AI literacy, prompt engineering, and critical thinking skills can be integrated into engineering curricula to make learning more interactive and student-centered.

The role of ethics in AI learning has also been explored by Shih et al. [14], who emphasized the importance of situated learning in teaching non-engineering students about AI concepts and ethics. This is relevant to engineering education, as it underscores the necessity of understanding ethical implications when applying AI technologies to real-world engineering problems. Furthermore, Neumann et al. [15] addressed the growing relevance of ChatGPT in engineering education, highlighting its potential applications in scientific writing, code creation, and assessment preparation. They proposed structured approaches for integrating generative AI into higher education while mitigating challenges such as plagiarism and misuse.

Pillay et al. [16] described how AI is integrated into engineering courses in South Africa, aiming to equip students with skills necessary for solving complex problems. Intelligent tutoring systems provide personalized learning paths for students, which is crucial for various competency acquisitions.

In general, as provided in a U.S. Department of Education report authored by Cardona, Rodriguez, and Ishmael [17], there is a rising interest in AI in education as educators see opportunities to help learners who can benefit from greater “adaptivity and personalization in digital tools for learning” with the provision of intelligent tutoring systems as highlighted previously. Additionally, this report highlights how educators are aware of new risks associated with using AI in data privacy and security. One key insight from this report concerning this study is “Using AI to Improve Teaching Jobs” and enhancing productivity.

With the positives of any innovation, there will always rightfully be negatives or concerns related to its adoption. As mentioned by research, there is a concern for privacy and security. In academia, there is a concern that AI language models may make mistakes and that their use raises ethical concerns, such as the potential for dishonest use by students or even the unemployment of humans who may be redundant with the advent of new AI technology [11]. Even with these negatives, it is still important that educators explore the adoption of AI innovation in the classroom.

Purpose & Question

This study aims to explore the integration of AI tools, such as Tocal.AI [18] and other Large Language Models (LLMs), into a graduate-level construction estimating course, focusing on the feedback provided by students regarding its application in an attempt to answer the broad question, “what are student experiences related to the use of AI in a construction estimating course?”

By documenting the students’ experiences and analyzing their feedback, this study provides insights into the educational benefits and challenges of integrating AI into a construction

estimating course, contributing to the broader discourse on AI adoption in construction and engineering education.

Approach

The research utilizes a case study approach, where the context is a graduate Foundations I - Estimating, and the case involves the use of Tocal.AI, ChatGPT, and MS Copilot for construction estimating solutions. This approach is suitable because it allows for in-depth exploration of students' perceptions, challenges, and the impact of AI tools on learning outcomes. An IRB approval was obtained for the study.

Participants

The participants in this study are students enrolled in a graduate course ($n=9$). These students were assigned a semester project to explore and utilize various AI tools to complete construction estimating tasks. Students provided individual submissions detailing their experiences, preliminary research, and reflections on using AI tools during the semester. Their varied backgrounds, ranging from minimal experience with AI to extensive interaction with AI technologies, offer a diverse perspective on the applicability of AI tools in construction education.

Data Collection

Qualitative data collection involved gathering students' final project submissions. This consisted of preliminary research and experience reports where students researched AI applications in construction estimating and documented their experiences using AI tools for their coursework (Tocal.AI, ChatGPT, Copilot, etc.). Tocal.AI has machine learning (ML) features for quantity takeoff (QTO) purposes (*see Figure 1*), but it also incorporated an AI chatbot to query the uploaded project documents. These submissions provided insights into how students interacted with AI tools, the challenges they faced, and the perceived benefits. They also had to answer preliminary questions. The project included structured questions to gauge students' familiarity with AI and large language models (LLMs), their experience in estimating before the course, and their perceived future role of AI in their careers. Students were also required to provide chat logs (as an appendix to the assignment) detailing their interactions with AI tools, which provided a dataset of the types of prompts used, responses received, and the workflows followed during estimating tasks. Examples of chat logs are provided in Figures 2-3.

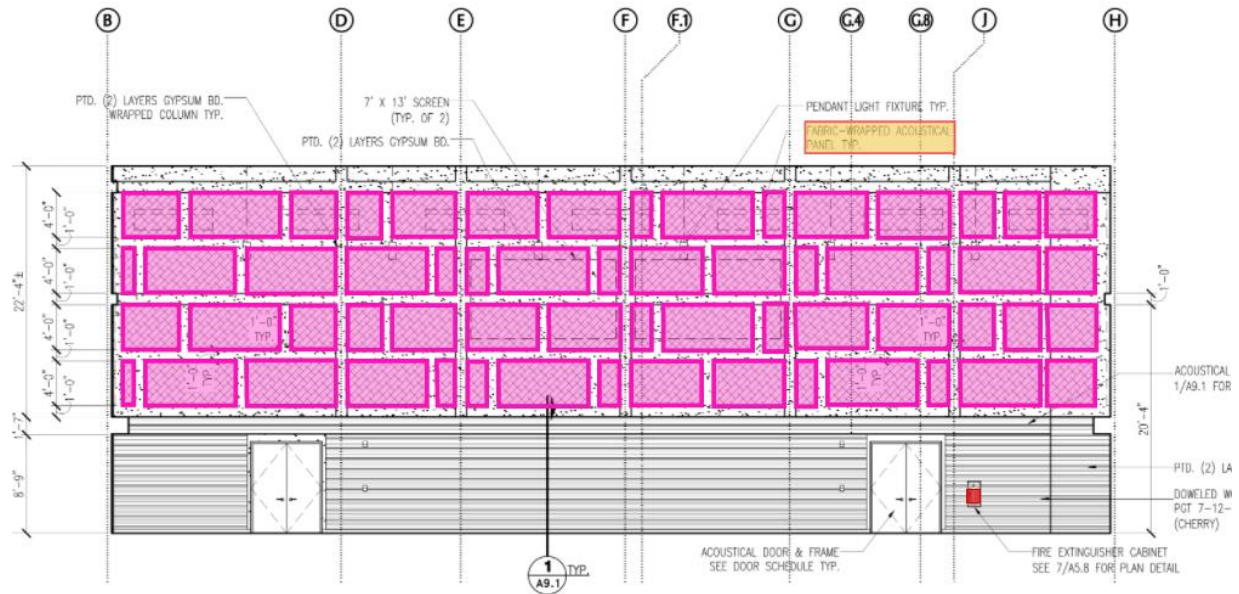


Figure 1. Togonal.AI's pattern recognition feature for automated QTO (student example submitted)

what are the types of windows in this project

The project includes several types of windows, as outlined in the provided document. Here are the details:

Window Glass & Glazing Types:

- Type A:**
 - Count: 2
 - Glass: GL1
 - Typical Dimensions: 5.44 sf and 4.67 sf
- Type B:**
 - Count: 9
 - Glass: GL3
 - Typical Dimension: 13.6 sf
- Type C:**
 - Count: 5
 - Glass: GL2
 - Typical Dimension: 13.6 sf

count each type of window

The counts for each type of window in the project are as follows:

- Type A: 2 windows
- Type B: 9 windows
- Type C: 5 windows [-]

show me where the windows are

To determine the locations of the windows in the project, you should refer to the architectural floor plans and elevation drawings. Based on the document index, these sections will provide detailed illustrations and positions of the windows:

- Floor Plans:**
 - A1.0 - Basement Floor Plan
 - A1.1 - First Floor Plan
 - A1.2 - Clerestory Plan
 - A1.3 - Clerestory Plan (Alternate)
- Elevations:**
 - A2.0 - Composite Elevations
 - A2.1 - West & South Elevations
 - A2.2 - North Elevation
 - A2.3 - East Elevation (Alternate)
- Window Details:**
 - A8.1 - Door & Window Schedules
 - A8.2 - Door Details
 - A8.3 - Door Details
 - A8.4 - Door Details
 - A8.5 - Window Details
 - A8.6 - Window Details

what is the acronym SCW stand for when referring to a type of door in construction documents

In construction documents, when referring to a type of door, the acronym SCW typically stands for **Steel-Clad Wood**. This type of door has a core made of wood with a steel exterior cladding, providing the benefits of both materials: the strength and durability of steel with the aesthetic and insulation properties of wood.

Figure 2. Examples of student prompts and answers from ChatGPT

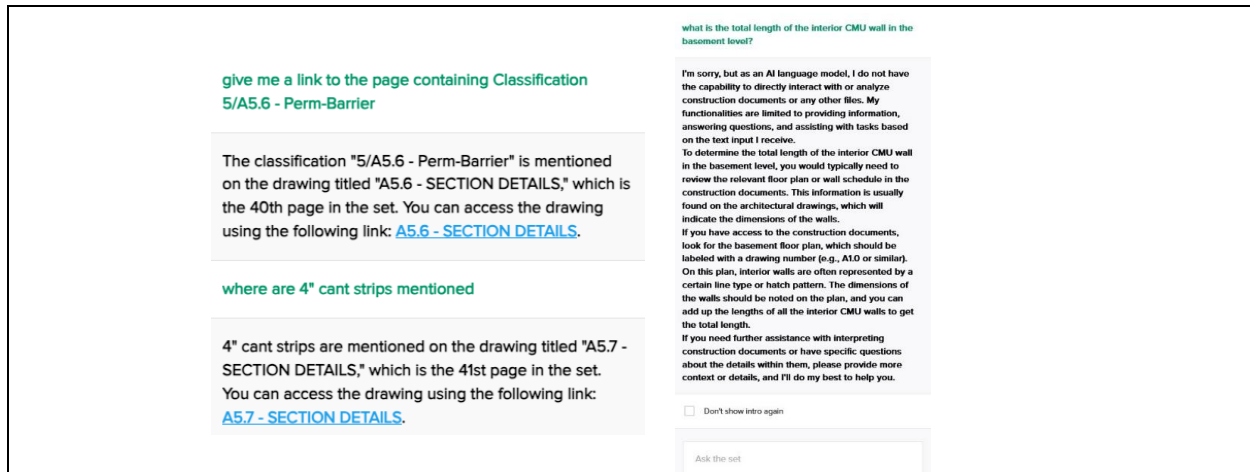


Figure 3. Examples of student prompts and answers from Tocal.AI

Data Analysis

The analysis followed a qualitative content analysis approach, which was used to identify recurring themes and patterns in the students' responses. The first step involved reading each student's submission, which was read multiple times to understand their experiences, challenges, and insights. Secondly, an open coding method was employed to categorize the data into themes. Common themes included the perceived efficiency of AI tools, ease of use, challenges in understanding the software, and differences between AI-assisted and traditional estimating methods. Codes were then grouped into broader themes, such as "Learning Curve with AI Tools," "AI in Estimation Accuracy," "Comparison with Traditional Methods," "Challenges and Limitations," and "Potential for Future Adoption." The thematic analysis allowed for identifying key insights into how AI tools affected the students' construction estimating process.

Tools and Software

Students used various AI-based tools during their coursework. Tocal.AI was utilized to automate quantity take-offs. ChatGPT, Copilot, and Gemini were used to estimate tasks, such as generating cost breakdowns, clarifying abbreviations, and assisting in report writing. These tools were examined for their impact on improving the efficiency and accuracy of estimating tasks as part of the student learning experience.

Procedure

The study followed a structured learning process throughout the semester. Students began with a more manual approach to estimating using Bluebeam Revu®, followed by hands-on sessions with Tocal.AI for estimating specific construction divisions (Divisions 4, 9, and 10) from digital plans. Students documented their use of AI for coursework throughout the semester and reflected on their experiences in final project submissions. The final project required students to include an analysis of AI tools, reflecting on how these tools compare to traditional estimating methods and discussing potential improvements. As qualitative research, it is essential to address the quality metrics for the study. A means toward validity was ensured through detailed descriptions by students, and the qualitative responses and coding processes ensured a comprehensive

understanding of student perspectives; it allowed for a credibility measure. Regarding reliability, the structured approach (i.e., via an assignment with specific details required) to collect student experiences ensured uniformity across participants; also, as an assignment, a proper audit trail was maintained. The authors recognized the potential for researcher bias, but this was limited due to the nature of the analysis approach, which only focused on student responses in the results. Additionally, there was a diversity in student responses, particularly with varying experience with AI, ensuring a broader range of insight. Also, counterexamples were considered to ensure balance and avoid confirmation bias.

Results

Learning Curve with AI Tools

The student submissions revealed many experiences learning to use AI tools for construction estimating tasks. Several students initially struggled with understanding the functionalities of Togonal.AI, mainly due to a lack of familiarity with AI tools. For example, one student noted that their limited knowledge of AI initially made them "not a fan of it" and that transitioning from using Bluebeam to Togonal.AI required time and adaptation. Another student mentioned their unfamiliarity with prompt engineering but highlighted that they had begun to grasp its value after interacting with ChatGPT and other AI tools.

Other students discussed positive learning experiences, indicating that once they overcame the initial learning curve, they found the tools to be highly beneficial for improving efficiency in estimating. Students found features such as automatic page labeling and pattern recognition in Togonal.AI to significantly simplify tasks. Despite the challenges, most students could adapt to the AI tools, reporting increased confidence in using AI for estimating tasks.

AI and Estimating Accuracy

A significant theme that emerged was enhancing estimation accuracy through AI tools. Many students pointed out the role of Togonal.AI in automating quantity take-offs with high precision, which reduced errors typically associated with manual take-offs. For example, Togonal.AI's automatic recognition of patterns allowed students to quantify materials quickly and accurately, like bricks and acoustic ceiling tiles. This automation minimized manual oversight and significantly improved the accuracy of their estimates.

Comparison with Traditional Methods

Students frequently compared their experiences with AI-based estimating to traditional methods. Many highlighted that Togonal.AI saved time compared to traditional manual methods. For instance, some students noted that Togonal.AI's automated processes allowed them to complete take-offs much faster than manually measuring and counting elements, which can be labor-intensive and error-prone. Using ChatGPT for tasks such as defining abbreviations and generating summaries was beneficial for quickly acquiring the information they needed to complete assignments.

However, some students also appreciated the depth of understanding gained from traditional methods. One student commented that manual take-offs helped them understand construction plans and the overall estimating process better than relying on AI tools, which may complete the task without requiring the user to understand every detail. This indicates that while AI tools offer significant efficiency gains, the educational value of traditional methods remains important for developing foundational skills in construction estimating.

Challenges and Limitations

Despite the clear advantages, students also reported several challenges and limitations associated with using AI tools. A significant issue highlighted was the difficulty of using Togonal.AI initially, especially for students with little to no prior experience with estimating software or AI in general. One student noted that they struggled to use Togonal.AI effectively due to its learning curve and because they were more accustomed to Bluebeam, a more traditional takeoff software.

Additionally, limitations of the AI software itself were noted. Students reported instances where Togonal.AI could not provide accurate take-offs due to multiple scales on a single drawing or when the software experienced outages. There was also feedback on the limited capabilities of Togonal.AI's AI component compared to other tools like ChatGPT, particularly in providing detailed guidance for non-standard tasks.

Another challenge that emerged was the potential for over-reliance on AI tools. Some students expressed concerns that relying on automation might reduce their ability to manually estimate in a practical setting, potentially leading to skill gaps.

Potential for Future Adoption

Students expressed optimism about the future adoption of AI in construction estimating. Many believed that AI tools, such as Togonal.AI, would become indispensable for the construction industry due to their ability to streamline workflows and improve accuracy. For instance, students saw great potential in AI's ability to conduct automated quantity take-offs and real-time cost estimation, which could transform traditional estimating practices. Moreover, several students emphasized the need to develop AI tools further to enhance their capabilities. They pointed out that integrating additional features, such as more advanced pattern recognition and seamless integration with BIM software, would further improve the functionality of these AI tools. Students also highlighted the potential for AI tools to become more user-friendly, thus reducing the learning curve and enabling broader adoption across the construction industry.

Discussion

The findings from this study reveal several important insights into integrating AI tools such as Togonal.AI into construction estimating coursework, and they align well with the existing literature on AI in construction and engineering education. The qualitative analysis of student feedback highlighted AI's transformative potential and the challenges accompanying its implementation. The learning curve associated with AI tools like Togonal.AI was one of the significant themes that emerged. Integrating AI tools requires learning new skills to use AI for decision-making

processes. These findings highlight the importance of support and training when implementing AI in educational settings.

The theme of AI in estimation accuracy underscored the potential for AI tools to improve cost estimation workflows by automating repetitive and error-prone tasks, consistent with the literature on AI's impact on construction accuracy. García De Soto and Adey [8] demonstrated that hybrid AI-traditional techniques can lead to more reliable estimates, and students in this study echoed this sentiment, noting that TogaI.AI can reduce errors typically seen with manual quantity take-offs. This aligns with Elmousalami's [9] findings, which emphasized the precision of AI-driven cost estimation during the conceptual stage of projects.

The comparison between AI-assisted and traditional methods illustrated the dual value of both approaches. Many students appreciated the time savings provided by AI, as noted by Ghasemi and Dai [10], who highlighted the efficiency of using AI tools for tasks such as bid pricing. However, the students also recognized the importance of traditional methods for building foundational knowledge, suggesting that AI tools should supplement, rather than replace entirely, traditional estimating practices.

Challenges and limitations of AI tools were highlighted, including software limitations, the learning curve for those unfamiliar with AI, and the risk of over-reliance on automation. These challenges reflect the barriers to AI adoption in construction discussed. Students noted that issues like multiple drawing scales and software outages hindered their efficiency, highlighting the need for further development to address these limitations and ensure reliable AI solutions in practical applications.

The potential for future adoption of AI in construction estimating was evident, with many students expressing optimism about AI's role in transforming the construction industry. This aligns with the literature on AI adoption in construction, where advancements in machine learning, automation, and predictive analytics are expected to enhance project efficiency and accuracy. Students identified areas for further enhancement, such as better integration with BIM, more advanced pattern recognition, and improved user interfaces, which could facilitate broader AI adoption across the industry.

Overall, the findings from this study align with existing research on AI in construction and engineering education when referring to key themes. Integrating AI into construction estimating presents opportunities to enhance accuracy, efficiency, and learning outcomes, but it also necessitates careful consideration of challenges related to usability, training, and maintaining foundational skills.

Implications for Construction Education

The findings from this study have implications for construction education, particularly in how artificial intelligence (AI) tools like TogaI.AI can be integrated to enhance the learning experience and better prepare students for the evolving demands of the construction industry.

Integrating AI tools such as Togonal.AI into construction estimating coursework can enhance students' skill sets by familiarizing them with technologies that are becoming increasingly common in the industry. As the construction sector continues to adopt digital tools to address challenges like cost overruns, inefficiencies, and labor shortages, exposing students to AI technologies during their education can ensure they are well-prepared to use these tools effectively in their careers. This study's findings suggest that AI tools can significantly improve estimation accuracy and efficiency, thus equipping students with advanced skills in high demand.

Using AI tools in the classroom can bridge the gap between academic learning and real-world industry practices. AI adoption in construction is still emerging, and many professionals are unfamiliar with implementing these technologies effectively. By integrating tools like Togonal.AI into coursework, educational institutions can better align their programs with the industry's technological advancements, providing graduates with practical experience that enhances their employability and readiness for the workplace. The ability to conduct automated quantity take-offs, utilize predictive analytics, and perform cost estimations using AI tools provides students with hands-on experience relevant to modern construction workflows.

Introducing AI tools in construction education can help develop students' critical thinking skills and adaptability. Although AI tools offer automation and efficiency, students must learn to understand the underlying principles of estimating and how to validate AI outputs. As indicated by the findings, some students appreciated the value of traditional methods for building foundational knowledge, which suggests that integrating AI should complement, rather than replace, manual estimating techniques. This approach will allow students to develop a balanced skill set, using AI efficiently while retaining the critical thinking required to assess AI-generated estimates, manage data quality, and make informed decisions.

The study also highlighted the importance of addressing the learning curve associated with AI tools. As some students experienced initial challenges with adapting to Togonal.AI, construction education must incorporate sufficient training and support to help students overcome these obstacles and build digital literacy. Providing structured tutorials, peer mentoring, and real-world scenarios can ease the transition into using AI tools and ensure that students are confident and competent in their application. Developing digital literacy is crucial as construction relies on data-driven decision-making and automation.

The optimism expressed by students regarding the potential for future AI adoption indicates that exposure to AI tools in the classroom encourages exploration and openness to new technologies. This is critical for fostering a culture of innovation within construction education. By challenging students to use innovative tools, educators can promote a mindset that embraces technological advancement and encourages continuous learning. This quality is essential for navigating the rapid changes characteristic of the construction industry today.

The findings align with the literature on the broader adoption of AI in engineering education, suggesting that integrating AI into construction programs will be essential for preparing students for new competencies. As Pillay et al. [16] discussed, AI skills are increasingly required across engineering disciplines to solve complex, interdisciplinary problems. By including AI-based construction estimating in curricula, educators can ensure that students are equipped with

competencies that are not only relevant to the construction sector but also applicable across a wide range of industries facing similar technological transformations.

The insights gained from this study underscore the need for construction education programs to rethink their curriculum design. Programs should focus on balancing traditional estimation techniques with the incorporation of AI tools, ensuring that students develop a comprehensive understanding of both methods. Additionally, construction education should include modules on digital tools, data analytics, and AI literacy, providing students with the foundational knowledge required to utilize emerging technologies in their future careers effectively.

Limitations & Future Work

This study has several limitations that should be acknowledged to provide a clear understanding of the scope and context of the findings. First, the sample size was small: only nine graduate students enrolled in the course. The small number of participants and case study approach limits the generalizability of the results. The experiences documented here are particular to the educational setting at a single university and the integration of Togonal.AI and other AI tools within a specific course structure. As such, the findings may vary in different educational or industry contexts where other tools or teaching methodologies are employed. Focusing on a primary AI tool (Togonal.AI) also presents a limitation. While other tools like ChatGPT and Copilot were explored, the primary emphasis on Togonal.AI may have restricted the scope of insights. Additionally, the timing and duration of the study were confined to a single semester, which limited the ability to observe the longer-term effects of AI integration on student learning outcomes and proficiency. A longitudinal study would be beneficial to evaluate how familiarity with AI tools develops over time and how these tools impact students' skills beyond the initial learning phase. Lastly, technical limitations related to the software included occasional system outages and difficulties handling complex drawings with multiple scales. These issues may have influenced students' overall experience and perceptions of AI tools' utility for construction estimating. Future studies could benefit from including improved versions of AI tools or testing in environments with more robust technical support. Additionally, future research could focus on understanding how human factors can increase the overall utility of AI for students and using a different methodology that can allow for more generalization, such as a more quantitatively based study. Despite these limitations, the findings provide valuable insights into the integration of AI in construction estimating education and offer a foundation for further research in this emerging area.

Conclusion

This study explored integrating AI tools like Togonal.AI into a graduate construction estimating course, documenting student experiences, and analyzing feedback regarding the educational benefits and challenges. The findings indicate that while AI tools offer substantial benefits in terms of time savings and enhanced accuracy, there are also notable challenges associated with their implementation. Students faced a learning curve in adapting to new technologies, encountered limitations in the software, and emphasized the need to retain traditional estimating skills.

The use of AI in construction estimating, as discussed in the literature review, can address some of the industry's long-standing challenges, such as cost overruns, low productivity, and inefficiencies. The findings from this study support these claims, demonstrating how tools like TotalAI can improve estimation accuracy and streamline workflows. However, it is also evident that successful integration requires adequate training, the development of intuitive user interfaces, and a balanced approach that incorporates both AI and traditional methods.

The results also suggest that for AI tools to be more broadly adopted, construction education must focus on preparing students to use these tools and understand their limitations. The insights gained from this study contribute to the broader discourse on the role of AI in construction education, emphasizing the need for strategic integration that enhances both efficiency and foundational skills.

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