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The Future of Construction Education: Integrating Artificial Intelligence Tools in Cost Estimation Courses

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In the evolving landscape of construction management education, the integration of technology, especially Artificial Intelligence (AI), is reshaping traditional teaching methodologies. This study explores the effectiveness of AI-enabled and traditional digital construction cost estimation software in enhancing learning outcomes for 3rd-year undergraduate construction management students. We compare two software tools, Kreo, which utilizes AI for automated quantity takeoff, and On-Screen Takeoff (OST), a digital estimation software, to examine their impacts on students' learning efficiency and accuracy in cost estimation. Employing a mixed-method approach, the research involved practical assignments using both tools, followed by a survey to gather students' feedback on their experiences. Key metrics such as time taken to complete assignments and precision of estimations were analyzed. The results indicated a notable difference in time efficiency and user preference between the two software, with implications for integrating AI tools in construction management curricula. The study also highlights the challenges students face, primarily due to their unfamiliarity with the software and the limitations of AI in processing outdated drawings. These findings contribute to the broader discourse on the role of AI in educational settings, suggesting a need for curriculum adaptations to include such innovative technologies. The study's insights are vital for educators and curriculum developers aiming to equip future construction professionals with relevant technological competencies.

Key Words: Artificial Intelligence, Construction Management Education, Cost Estimation, AI-enabled learning, Construction Technology Integration, Educational Technology in Construction, Digital Transformation in Construction.

Introduction

Traditionally known for its cautious approach to technological adoption, the construction industry stands on the brink of a transformative era driven by Artificial Intelligence (AI). While AI has revolutionized various sectors, the construction industry still needs to embrace these advancements. The potential for AI in construction is vast, promising significant improvements in efficiency and decision-making. However, the industry's slow adoption rate can be attributed to the long duration of ongoing projects, the costs associated with training and software investment, and the inherent challenges of transitioning to new technology.

Despite AI's burgeoning development and bright future in construction, there remains to be a gap between current educational practices and the rapidly advancing technological landscape. Traditional construction management education primarily utilizes digital tools, creating a disconnect with the industry's evolving needs. This lag poses a critical challenge: preparing the next generation of construction professionals to navigate and leverage AI technologies effectively.

This study seeks to address this challenge by introducing AI-enabled and traditional construction cost estimation software into the educational sphere. By comparing Kreo, an AI-driven tool, with On-Screen Takeoff (OST), a conventional digital tool, the research aims to assess their respective impacts on student learning in terms of efficiency, accuracy, and user experience. This comparison intends to provide a learning platform that bridges the gap between traditional educational methods and the technological advancements in the construction industry.

Our study is pivotal in introducing these emerging technologies to the upcoming generation of construction professionals, thereby fostering a more seamless integration into the industry. The findings are expected to shed light on the benefits and challenges of incorporating AI tools into construction management curricula. By evaluating the practical implications of these tools in an educational setting, this research contributes significantly to the discourse on technology's role in enhancing construction education. The insights gained will be invaluable for educators, curriculum developers, and industry stakeholders, aiding in developing training programs that align with the industry's future direction and technological demands.

Literature Review

The advent of Artificial Intelligence (AI) has marked a transformative era across various industries, reshaping the way we approach problem-solving, decision-making, and operational efficiency. AI's increasing ubiquity is evident in its diverse applications, ranging from healthcare, where it assists in diagnostic procedures and patient care management (Jiang et al., 2017), to finance, where it revolutionizes trading and risk assessment (Dhar, 2016). In agriculture, AI contributes to crop yield prediction and pest control (Liakos et al., 2018), while in the realm of customer service, it enhances user experience through intelligent chatbots (Adamopoulou & Moussiades, 2020).

The purpose of this literature review is to delve into the multifaceted role of AI across these varied sectors, with a particular emphasis on its application in the Architecture, Engineering, and Construction (AEC) industry. This exploration is crucial in understanding AI's potential to revolutionize construction management education, a field that increasingly demands the integration of advanced technological competencies.

AI's integration into the AEC sector signifies a pivotal shift towards digitalization and automation. In construction management, AI applications range from predictive analytics for project timelines to automated design processes (El-Gohary & El-Diraby, 2010). The relevance of AI in construction management education is underscored by its potential to bridge the gap between theoretical knowledge and practical, technology-driven applications in the field (Wang et al., 2019).

This review aims to provide a comprehensive overview of AI's current and potential applications in various industries, focusing on the AEC sector. By doing so, it seeks to highlight the importance of incorporating AI into construction management education, preparing future professionals for an increasingly digitalized industry landscape.

Artificial intelligence across Industries

Artificial Intelligence (AI) has become a cornerstone in the transformation of multiple industries, each leveraging its capabilities to enhance efficiency and accuracy. AI plays a pivotal role in healthcare diagnostic processes, patient care management, and personalized medicine, significantly improving patient outcomes (Jiang et al., 2017). In the agricultural sector, AI technologies are employed for crop yield prediction, pest control, and precision farming, thereby optimizing resource use and increasing productivity (Liakos et al., 2018).

The finance and banking sectors have also embraced AI for its predictive capabilities in risk assessment, fraud detection, and algorithmic trading, leading to more secure and efficient financial services (Dhar, 2016). Similarly, in customer service, AI-powered chatbots and virtual assistants have revolutionized the way businesses interact with customers, offering personalized and efficient support (Adamopoulou & Moussiades, 2020).

AI's influence extends beyond industry-specific applications to become integral to daily life. Intelligent personal assistants like Siri and Google Assistant demonstrate the pervasive nature of AI, simplifying tasks such as setting reminders, searching for information, and navigating routes (Lopez et al., 2017). The use of smartphone AI for features like facial recognition, predictive text, and camera enhancements further illustrates its ubiquitous presence in our daily routines (Vincent, 2018). Search engines like Google employ AI algorithms to deliver relevant search results based on user behavior and preferences, showcasing AI's role in enhancing the online experience (Brin & Page, 1998). Additionally, platform recommendation systems like Amazon and Netflix utilize AI to analyze user preferences and suggest products or content, thereby personalizing the user experience (Gomez-Uribe & Hunt, 2016).

Artificial intelligence techniques in AEC

In the Architecture, Engineering, and Construction (AEC) sector, Artificial Intelligence (AI) techniques play a crucial role, particularly in enhancing cost estimation processes. These techniques are broadly categorized into decision-making algorithms and learning methods. Decision-making algorithms, such as linear programming and genetic algorithms, are employed for optimizing resource allocation and project scheduling, directly impacting cost efficiency (El-Gohary & El-Diraby, 2010).

Learning methods, including Bayesian learning and machine learning, adapt to the dynamic nature of construction projects. Bayesian learning is particularly effective in probabilistic risk assessment, influencing cost-related decisions by providing a framework for understanding uncertainty (Zhang &

Mahadevan, 2000). Machine learning techniques like neural networks are increasingly used for predictive cost modeling, enabling more accurate and timely cost estimations (Cheng & Teizer, 2013).

AI's impact on cost estimation in the AEC sector is profound. Machine learning algorithms can analyze historical data from past projects to predict costs accurately, considering factors like material prices, labor rates, and project duration (Wang et al., 2019). This predictive capability is crucial for budget planning and financial management in construction projects.

Neural networks, a subset of machine learning, have shown significant promise in cost estimation. They can process complex and non-linear relationships between various cost determinants, providing a more nuanced understanding of how different factors contribute to the overall project cost (El-Gohary & El-Diraby, 2010).

AI's ability to evaluate multiple design and delivery alternatives in project planning leads to more efficient and cost-effective outcomes. AI-driven tools assist in identifying the most sustainable and economical design options, thereby reducing waste and optimizing resource use (Cheng & Teizer, 2013). Furthermore, AI's predictive analytics aid in foreseeing potential project delays and cost overruns, which are critical for maintaining project schedules and budgets.

The transformative impact of AI across various sectors, as detailed in the literature review, sets a precedent for its integration into construction management education. The advancements in healthcare, agriculture, finance, and customer service through AI applications (Jiang et al., 2017; Liakos et al., 2018; Dhar, 2016; Adamopoulou & Moussiades, 2020) demonstrate the potential of AI to enhance accuracy and efficiency. These benefits are directly transferable to the AEC sector, where AI can revolutionize traditional practices, including cost estimation.

In educational settings, this translates to the need for integrating AI tools to prepare students for a data-driven, technologically advanced industry. The familiarity with AI in daily life, through tools like Siri and Google Assistant (Lopez et al., 2017), suggests that students are already acclimated to AI interfaces, which can facilitate the adoption of AI-based tools in their professional training.

Our research, which compares the AI-driven Kreo with the digital tool OST, indicates the broader industry trend toward embracing AI and data-centric processes. In line with AI's capabilities in project planning and cost estimation in the AEC sector (El-Gohary & El-Diraby, 2010; Cheng & Teizer, 2013), our study examines how these technologies can be effectively incorporated into construction management education. The use of AI for predictive cost modeling and risk assessment in the AEC industry (Wang et al., 2019; Zhang & Mahadevan, 2000) mirrors the objectives of our research in evaluating the efficiency and accuracy of AI tools in educational settings.

The findings of this research have significant implications for construction management education. They highlight the necessity of integrating. This integration is not just about familiarizing students with new tools but about equipping them with a mindset and skillset aligned with the future of construction management. The insights gained from this study can inform educators, curriculum developers, and industry professionals, aiding in the creation of a more dynamic, relevant, and technologically adept educational framework.

In conclusion, the literature review comprehensively understands AI's role across industries and its specific application in the AEC sector. Our research builds upon this foundation, exploring how AI can enhance construction management education, preparing future professionals for the challenges and opportunities of a digitally transformed industry.

Methodology

This study was primarily aimed at evaluating the effectiveness of AI-enabled versus traditional digital construction cost estimation software within a construction estimation course tailored for 3rd-year undergraduate students. A detailed comparison between Kreo, an AI-powered tool, and On-Screen Takeoff (OST), a digital estimation tool, was conducted to assess various critical dimensions including time efficiency, accuracy, and the challenges faced by students, as well as their previous industry experience and training, software features, and overall student preferences and experiences.

The research was conducted over the fall of 2023, involving one hundred and thirty-seven students enrolled in the course. A mixed-methods approach was adopted, integrating quantitative data from practical assignments with qualitative insights from follow-up student surveys. The students were divided into two groups for a balanced comparative analysis, with each group assigned to use either Kreo or OST for their assignments.

The assignments mirrored real-world tasks in construction estimation, providing practical experience with these tools. Students were required to perform quantity takeoff calculations for specific construction elements, including calculating linear feet of interior and exterior walls, areas and volumes of materials, and counting doors and windows, based on a standard wall height.

Upon completion of these assignments, comprehensive surveys were conducted to gather the students' perceptions, preferences, and experiences with each software tool. These surveys also collected information about the students' backgrounds in the industry, their roles at various companies, and any prior training with similar software. Of the hundred and thirty-seven students, eighty-seven completed the survey, providing a substantial data set for analysis. This methodological approach aimed to offer in-depth insights into the impact of different types of construction estimation software on learning and skill development in construction management education.

Quantitative Data Analysis

Our study's quantitative analysis critically evaluated the performance of two distinct construction estimation tools, OST (On-Screen Takeoff) and Kreo, within a construction management course. This evaluation primarily focused on two key performance metrics: time efficiency and measurement accuracy.

The analysis revealed that, on average, students were able to complete tasks more swiftly using Kreo, with an average time of approximately 131.33 minutes, as opposed to 144.78 minutes for OST. This suggests that Kreo's AI-driven approach might offer enhanced time efficiency in certain scenarios. However, the accuracy of measurements, a different picture emerged. For measurements such as 'Interior Wall Linear Foot' and 'Interior Wall Volume', OST users demonstrated greater accuracy compared to their counterparts using Kreo. This was particularly evident in the 'Interior Wall Linear Foot' measurement, where OST users achieved a mean accuracy of about 77.07%, in contrast to 45.06% for Kreo users.

The study encountered several limitations that are crucial to acknowledge. Firstly, the usage of outdated drawings in some assignments might have affected the performance of the AI-enabled tool, Kreo, which relies heavily on current and detailed inputs for optimal functioning. This factor could have skewed the accuracy results in favor of OST, which is less dependent on the currency of drawing details. Additionally, the version of OST utilized in the course was not the latest, which raises questions about the generalizability of our findings to the current version of OST in professional practice. The overestimations in measurements like 'Interior Wall Gross Area', where students using both tools significantly exceeded 100% accuracy, further indicate potential gaps in students' understanding or instructional methods.

The implications of these findings for construction management education are multifaceted. While Kreo shows promise in enhancing efficiency, the accuracy concerns, potentially exacerbated by the limitations of outdated drawings and an older version of OST, highlight the need for a balanced approach in tool instruction.

In conclusion, this quantitative analysis, despite its limitations, provides valuable insights into the comparative effectiveness of traditional and AI-enabled tools in a learning environment. It underscores the necessity of updating educational resources and methodologies to align with the evolving technological advancements in the construction industry.

Qualitative Data Analysis

Student Background and Experiences

The diversity of student backgrounds and levels of experience in the construction industry plays a pivotal role in shaping the learning dynamics within our course. Our analysis of the student data revealed a spectrum of experience, from complete novices with no exposure to the construction industry to those who have accrued several years of experience in various roles. Notably, a significant portion of the class reported having less than one year of experience, which underscores the presence of newcomers to the field. Concurrently, there were students with 1-3 years and even 4-6 years of experience, indicating a more seasoned understanding of industry nuances.

This diversity is further enriched by the variety of roles held by the students. For instance, the presence of Project Engineers and Architects in the class brings a depth of practical insights and perspectives. These roles, coupled with experiences as Field Engineers, Assistant Project Managers, and others, contribute to a multifaceted learning environment. This diversity not only enriches peer-to-peer interactions but also challenges instructors to address a wide range of learning needs and expectations.

The analysis of students' roles and prior experiences suggests that their adaptability to new tools like Kreo and OST could vary significantly. Students with more experience or those who have held specific roles might find certain aspects of these tools more intuitive or relevant. Conversely, students with less experience might require a more foundational approach to these tools, emphasizing basic concepts and applications.

The implication of such diversity in backgrounds and experiences is clear: there is a pressing need for a curriculum that is not one-size-fits-all but rather one that is flexible and responsive to a wide array of student needs. Tailoring the curriculum to accommodate this diversity is essential. This could involve offering more personalized learning paths, where students have the opportunity to engage with content that aligns closely with their experience level and career aspirations. Additionally, providing additional support mechanisms, such as supplementary tutorials or mentorship programs, could help bridge the gap for those who are newer to the field.

In conclusion, recognizing and effectively responding to the diverse backgrounds and experiences of students is crucial in fostering an inclusive and effective learning environment. This approach not only enhances the educational experience for all students but also prepares them more effectively for the diverse and evolving landscape of the construction industry.

Feedback and Perceptions of Estimation Tools

This section explores students' experiences with OST (On-Screen Takeoff) and Kreo, focusing on their feedback, perceived challenges, and views on the accuracy and applicability of these tools in real-world projects. A notable aspect of the feedback was the call for improvements in OST's user interface, with students expressing a desire for a more intuitive and modern experience akin to newer software. This feedback is crucial for understanding where OST might evolve to better align with current user expectations and technological advancements.

In addition to interface concerns, students encountered technical difficulties with Kreo and OST. Issues ranged from problems in uploading drawings to compatibility challenges with specific devices. These practical challenges not only hinder the learning process but also mirror real-world scenarios that students might face professionally. The need for increased familiarity and hands-on practice with the tools was also a recurrent theme, suggesting a gap in current exposure levels within the course.

Interestingly, while students showed a general preference for the AI capabilities of Kreo, their opinions shifted when considering the tools for real-world projects and accuracy. Despite recognizing Kreo's potential, many students preferred OST in scenarios demanding high accuracy and reliability. This preference stems from a belief that Kreo, while innovative, requires further validation and testing on previous projects to establish its reliability fully. This cautious approach reflects a nuanced understanding of the tools, where the allure of AI's potential is balanced against the proven track record of traditional digital estimation methods.

The synthesis of this feedback and these perceptions calls for a more tailored approach to integrating construction estimation tools into educational curricula. First, enhancing OST to meet modern user expectations is essential, especially in its interface design. Addressing technical issues in Kreo and OST should be prioritized to facilitate smoother learning experiences.

Moreover, the curriculum should provide in-depth, practical training sessions for both tools, emphasizing how to use them and when and why one might be preferable over the other in professional contexts. This deeper engagement will prepare students for tool selection and application complexities in real-world scenarios.

In summary, students' feedback on Kreo and OST highlights the need for educational curricula that teach tool usage and foster critical thinking about tool selection based on project requirements and accuracy needs. Such an approach will ensure that students are technically proficient and strategically adept in choosing the right tools for their future roles in the construction industry.

Implications for Construction Management Education

The insights gleaned from our analysis of student feedback, preferences, and challenges provide a rich foundation for refining construction management education. These findings underscore the necessity of a curriculum that adeptly balances traditional tools like OST with AI-enabled tools like Kreo, catering to the diverse technological familiarity and preferences of students.

A key recommendation is the adoption of a dual-tool approach in the curriculum. This approach would integrate the hands-on, detail-oriented training offered by traditional tools with the innovative, efficiency-driven capabilities of AI-enabled tools. Such a curriculum would not only provide students with a broad skill set but also instill an understanding of the strategic application of different tools based on project needs and accuracy requirements.

The student feedback highlighted specific areas for improvement in both Kreo and OST, particularly regarding usability and technical challenges. Future iterations of the course should incorporate these insights, perhaps through enhanced tutorial sessions, user interface improvements in the software, or additional support for technical troubleshooting. Addressing these areas directly will not only improve the student learning experience but also mirror the adaptive nature of the construction industry.

The overwhelmingly positive outlook on AI's role in construction, as reflected in student responses, indicates a growing trend that cannot be overlooked. The curriculum should, therefore, place a strong emphasis on preparing students for a technologically advanced industry. This preparation involves not just training in AI-enabled tools but also fostering an understanding of the broader implications of AI in construction, such as data-driven decision making, predictive analytics, and automation.

To enhance learning outcomes, the curriculum should incorporate a mix of theoretical knowledge and practical applications. This blend will ensure that students are not only proficient in using various tools but also understand the underlying principles and rationales. Furthermore, incorporating case studies, real-world project simulations, and industry partnerships can provide students with contextual applications of these tools, enhancing their readiness for professional challenges.

Conclusion

This study's exploration of AI-enabled and traditional digital construction cost estimation tools in an educational setting marks a significant step towards aligning construction management education with the rapidly advancing technological landscape. By comparing the AI-driven Kreo with the traditional On-Screen Takeoff (OST), our research offers insightful revelations about the current state and future direction of construction education.

The findings highlight a nuanced interplay between technological proficiency and the adaptability of students to diverse tools. While Kreo showcased advantages in terms of efficiency, OST was often preferred for its accuracy, indicating the importance of a balanced approach in tool selection. This balance is crucial in preparing students for the real-world scenarios where decision-making extends beyond mere familiarity with a tool to strategic considerations of its appropriateness for specific tasks.

The diverse backgrounds of students underscore the need for adaptable educational strategies. A one-size-fits-all approach is no longer viable in an environment where student experiences range widely. Tailoring the curriculum to these varied backgrounds, with an emphasis on bridging the gap between traditional practices and emerging technologies, is imperative.

Future research avenues include a longitudinal study to assess the long-term impact of AI tool integration, like Kreo, on construction management students' career progress. Exploring the effectiveness of the latest versions of these tools with current construction data could overcome limitations related to outdated materials used in our study. A detailed analysis of specific features of Kreo and OST and their influence on learning outcomes could inform targeted improvements in tool functionality and teaching methods. Additionally, broadening the scope to compare a variety of AI tools across different educational contexts would deepen our understanding of AI's role in construction education worldwide.

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