EPiC Series in Built Environment
Volume 5, 2024, Pages 93–101
Proceedings of 60th Annual Associated Schools of Construction International Conference

Integrating a Module on Artificial Intelligence Literacy in an Undergraduate Construction Management Course

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The rapid advancements in Artificial Intelligence (AI) hold the promise of transformative benefits across industries, including construction. To navigate this changing landscape, construction students must not only harness AI's potential but also grasp its ethical considerations and potential challenges. As such, there is a growing imperative within construction education to foster AI literacy among prospective professionals. This study developed and integrated an "AI in Construction" course module into an undergraduate construction management course. The primary goal is to equip students with AI literacy, achieved through a comprehensive approach that encompasses both theoretical knowledge, covering essential AI concepts and their applications in construction, and practical hands-on experiences, exemplified by a project focused on computer vision for personal protective equipment (PPE) inspection. Results from the course module implementation show that students gained a basic understanding of AI fundamentals after the module, such as dataset annotation, model development, deployment, and evaluation. Qualitative feedback indicates students were motivated to explore further AI-related topics in construction, and several topics that are of their interest were identified. These findings affirm the effectiveness of the proposed module and offer valuable insights for further development and enhancement of AI-related modules in construction education.

Key Words: Artificial Intelligence, AI literacy, Construction Education

Introduction

The rapid development of Artificial Intelligence (AI) is reshaping industries worldwide, including construction. Projections suggest that the integration of AI could potentially add $0.5 trillion to the gross value of the construction industry by 2035, ranking it 8th among all industries (Purdy and Daugherty 2017). Furthermore, a recent survey indicates that 37% of professionals in the Architecture, Engineering, and Construction (AEC) industry are actively utilizing AI, placing it 13th among industries (Salesforce Research 2022). As AI advances, developing "AI literacy" among the future construction professionals grows increasingly vital. AI literacy encompasses "*a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace*" (Long and Magerko 2020). These competencies

T. Leathem, W. Collins and A. Perrenoud (eds.), ASC 2024 (EPiC Series in Built Environment, vol. 5), pp. 93–101

are increasingly recognized as essential knowledge for future workforce, even for students who are not majoring in computer science. As such, fostering AI literacy among construction students extends beyond their ability to effectively use AI in their professional roles, but also to understand potential concerns related to AI, such as privacy, security, data bias, trust, transparency, and ethical concerns (Akinosho et al. 2020). Moreover, inadequate AI literacy within the construction workforce not only hinders them to effectively use AI to assist their jobs but also raise misunderstandings and misconceptions, which can further drive resistance to its integration (Maitz et al. 2022). As the demand for students with AI competencies continues to grow, educational programs in construction must adapt to teach students about AI and its applications in the industry.

However, existing literature reveals that while AI has been introduced into AEC courses through case studies, the focus has predominantly been on research-centric AI tools addressing civil engineering challenges (Chiang 2021; Wanyan et al. 2017). Such courses with complex programming requirements can intimidate students, leading to unfavorable views on AI (Sulmont et al. 2019). Additionally, current literature tends to prioritize research-centric problems over the application of AI to practical construction challenges. This approach inadequately addresses the integration of essential AI skills required by construction professionals into educational content. To address this educational need, there is a pressing need to develop a curriculum based on the AI literacy framework to educate construction students about AI knowledge, providing them with essential AI literacy to navigate the growing applications of AI in the construction industry. In response, this study focuses on creating an AI in Construction course module designed to provide students with a foundational understanding of AI to prepare them for future industry demands. The module specifically aims to equip undergraduate construction students with AI literacy, ensuring they comprehend what AI is, what AI can accomplish, how AI functions, how AI should be used, and how people should perceive AI.

Applications of Artificial Intelligence in Construction

The construction industry, with its unique set of challenges, such as safety concerns, labor shortages, and low-profit margins, has been progressively exploring the capabilities of AI to improve site safety and enhance project efficiency (Fang et al. 2020a). AI applications have been explored throughout the construction lifecycle, from the planning, design, construction phases, to operation and maintenance phases (Regona et al. 2022; Xu et al. 2019). In pre-construction, AI has been applied to project planning and scheduling, and cost estimation (Amer and Golparvar-Fard 2019; Matel et al. 2022). During the construction phase, AI has been utilized to assist in progress monitoring, quality control, and operational productivity analysis (Regona et al. 2022). Computer vision-based AI techniques, for example, have been used to automate critical tasks, such as object recognition, identification, and monitoring (Paneru and Jeelani 2021). In the maintenance phase, AI-based techniques have been used in building management systems to optimize energy usage and reduce costs (Ngarambe et al. 2020).

The integration of AI promises to mitigate many industry challenges, including safety concerns, labor shortages and low-profit margins. Nevertheless, the integration of AI is not without its challenges. The integration of AI brings technological challenges, such as the "black-box" nature of AI systems, which underscores the importance of transparency, and trust, leading to concerns such as privacy, security, data bias, and ethical considerations (Akinosho et al. 2020). Finally, another challenge is also the current lack of AI-literate construction workforce and the shortage of construction professionals with sufficient understanding and awareness of AI (Maitz et al. 2022) and the skill gaps for employing AI tools in construction tasks (Abioye et al. 2021). Addressing these issues requires not only technological solutions but also educational initiatives to cultivate AI literacy among construction students, setting the stage for the subsequent section on AI literacy in construction education.

AI Literacy in Construction Education

The potential of AI to significantly transform the construction industry is clear, with prospects to significantly enhance safety, efficiency, and sustainability. Despite this, the industry faces hurdles in AI adoption, one of the reason is the existing gap in AI understanding and skills among construction professionals (Abioye et al. 2021). To mitigate this, there have been growing calls to integrate AI into construction education, aiming to overcome obstacles associated with its slow adoption in the sector (Naser 2022). However, the prevalent focus on research-driven AI applications (Chiang 2021), risks indimidating students with its demanding programming components and potentially cultivating aversion to AI (Sulmont et al. 2019). Therefore, there is a need for educational programs to teach AI applications pertinent to construction and address the gaps identified in the literature that often prioritizes research-centric AI tools over practical construction applications.

Consequently, educational programs must develop curricula that extend beyond technical AI training to include these essential AI literacy. AI literacy, as defined by Long and Magerko (2020), provides such comprehensive framework that is crucial for non-computer science majors and includes the ability to understand, utilize, and critically assess AI within the construction context. Moreover, research has also emphasize on the importance of contextualizing AI literacy into the real-world settings while teaching AI (Allen and Kendeou 2023). This approach ensures that AI knowledge is contextualized and accessible, enabling students to effectively and responsibly leverage AI tools in construction practices. For example, the University of Florida has developed a course that imparts AI fundamentals, models, and methods for the built environment to both undergraduate and graduate AEC students, part of the broader AI Fundamentals and Applications certificate (Saldana Ochoa and Wang 2022). However, the imperative now is not not only for the effective use of AI in their future roles but also for understanding its broader implications, including ethical concerns (Southworth et al. 2023). In response to educational need, this study has developed an "AI in Construction" module to provide students with a foundational understanding of AI within the construction safety context. The following section depicts how the module was developed and the assessment process of this study.

Research Methodology

As this study aims to integrate novel content into the curriculum and explore students' understanding and perceptions of the content, action research is considered an appropriate approach to conduct this investigation (Laudonia et al. 2018). This research encompassed two key phases: initially, the development of the AI in Construction Module, followed by its assessment within an undergraduate construction course. In the initial phase, we identified and categorized learning objectives, encompassing both theoretical understanding and hands-on practical knowledge. Subsequently, these objectives were integrated into two separate sessions. Following the module implementation, we conducted an assessment, evaluating students' performance through a project interpretation assignment and gathering qualitative feedback on the module. The subsequent sections will provide a detailed explanation of each step in this process.

AI in Construction Module Development

The AI in Construction Module was integrated into two sessions, spanning a total of three hours, within the *BCN4252: Introduction to Building Information Modeling* course offered as an undergraduate course at University of Florida. This course is designed to acquaint construction management students with BIM-based workflows and advanced technologies such as clash detection, quantity takeoffs, virtual/augmented reality, laser scanning, and robotics. Each module in the course consists of two sessions: a 2-hour theoretical knowledge session on Tuesday and a 1-hour hands-on training session on Thursday. This section outlines both the theoretical knowledge and hands-on training aspects of the AI in Construction Module, detailing the students' learning objectives and expected outcomes for this three-hour module.

Theoretical Knowledge: AI Literacy Education within Construction Context

For the AI in Construction module, the theoretical knowledge component focused on introducing fundamental AI concepts and its applications in the construction context, following the AI literacy framework by Long and Magerko (2020). This framework offers a structured approach for designing AI curricula suitable for non-computer science students through 17 competencies across 5 themes: (1) *What is AI?* (2) *What can AI do?* (3) *How does AI work?* (4) *What should AI do?* and (5) *How do people perceive AI*? Following this framework, five learning objectives for theoretical knowledge were identified:

- T1: Define AI and provide examples of AI in everyday life;
- T2: Explain the core concept of AI and how it learns and makes predictions;
- T3: Understand the capabilities of AI, such as natural language processing, image classification, and audio recognition;
- T4: Exemplify AI applications in construction, including how it can be integrated into the BIM-based workflow;
- T5: Discuss ethical concerns in AI applications in the construction industry, including issues like data bias, explainability, and privacy.

To achieve these learning objectives, the theoretical knowledge contents were divided into three parts: (1) Understand AI and its Basics; (2) Explore AI Applications; and (3) Discuss Ethical Issues. To streamline the flow of the module, learning objectives T1 and T2 were combined to constitute the first part of the contents. These objectives focus on delivering introductory and fundamental concepts of AI. Similarly, learning objectives T3 and T4 were combined to shape the second part of the contents, as they are more closely associated with the application of AI in the construction industry. The specifics of each content section are elaborated below: Firstly, the “Understand AI and its Basics” commenced the module by acquainting students with real-world examples of AI applications, providing context and meaning to the definition of AI (Theoretical Learning Objective T1). Subsequently, the core concepts of AI were systematically explained, delving into its fundamental aspects such as inputs, outputs, and model types (Theoretical Learning Objective #T2). Specifically, machine learning models were employed as illustrative examples, offering insights into AI's diverse learning styles and prediction methods. Secondly, the “Explore AI Applications” part built upon the foundational knowledge and ventured into the vast capabilities of AI. This part encompassed areas like natural language processing, computer vision, and audio recognition (Theoretical Learning Objective T3). Practical examples from the construction industry illustrated AI's potential applications in this context, emphasizing its seamless integration into the BIM-based workflow (Theoretical Learning Objective T4). The last part, “Discuss Ethical Issues,” covered Theoretical Learning Objective T5 and concluded this session with a comprehensive discussion of ethical concerns associated with AI applications in construction (Theoretical Learning Objective T5). Topics such as data bias, explainability, and privacy were critically examined. After the theoretical knowledge session, a straightforward hands-on project was introduced to students, aimed at reinforcing the concepts covered in the preceding session.

Hands-on Practical Knowledge: PPE Inspection using Computer Vision

As only one hour was allocated for the hands-on project, the course module selected computer vision as the focal point for enabling students to gain a more comprehensive understanding of the workflow involved in building an AI model. Computer vision models incorporate numerous visual elements, offering students a clearer perspective on the process of constructing an AI model. Additionally, the hands-on project was designed with a construction-specific context, specifically PPE inspection. This focus was chosen in light of the growing adoption of AI technologies in enhancing construction safety (Chen and Ying 2022). Furthermore, computer vision techniques have been extensively employed for PPE inspection (Fang et al. 2020b), making the PPE inspection a reasonable and practical context. The primary objective of the hands-on project was to provide students with a practical experience, and the learning objectives were identified as follows:

- H1: Understand the workflow of creating an AI model;
- H2: Produce a dataset by annotating, preprocessing, and augmenting to train a computer vision model;
- H3: Create a computer vision model;
- H4: Evaluate the computer vision model's performance;
- H5: Justify the performance of the model, and suggest potential improvements or applications based on the results.

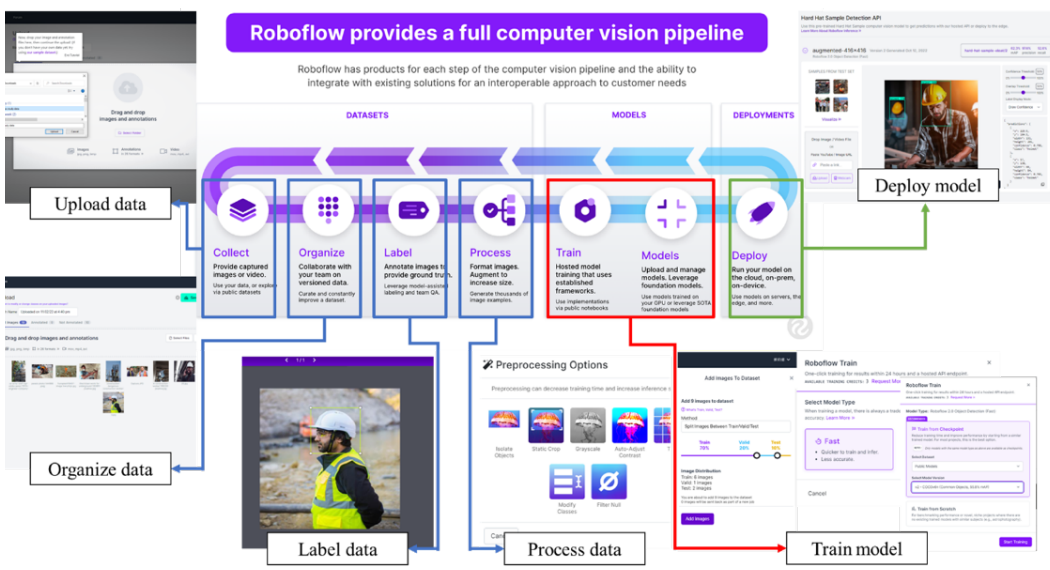

Figure 1 Hands-on practical knowledge contents (Roboflow 2023)

To achieve these objectives, the Roboflow® platform (Roboflow 2023) was employed to provide students with a set of tools for dataset preparation and computer vision model training. This platform is readily accessible and provided free of charge, allowing developers to effectively manage, annotate, and process computer vision data. Furthermore, it enables developers to train and deploy computer vision models without necessitating any programming skills. The platform streamlines the computer vision model development process into three parts: dataset, model, and deployment, and seven steps: collect, organize, label, process, train, models, and deploy (see Figure 1). This simplified approach empowers students to gain a comprehensive grasp of the workflow involved in building an AI model

(Hands-on Learning Objective H1). The rest of the learning objectives were achieved with the following parts: (1) Datasets; (2) Models, and (3) Deployments.

Initially, the "datasets" part covered Hands-on Learning Objective H2, and steps were included as follows: upload, organize, and process data. In this part, students received a small dataset comprising 16 images of construction workers wearing and not wearing PPEs. Their task was to upload these images to Roboflow® and annotate them with the user-friendly interface offered on the platform, labeling whether workers were wearing PPEs or not. Within this step, students also became acquainted with the "dataset health check tool" on the platform, which could serve as an educational tool, shedding light on factors that may impact data quality, including the number of images and class balance of data. Subsequently, knowledge and instructions regarding data processing, dataset division into training, validation, and testing subsets, and model training were introduced. The data processing step entailed several crucial elements, including preprocessing techniques (such as object isolation and static cropping) and augmentation options (e.g., flipping and rotation). The rationale behind employing these techniques was explained to the students. Then, the "models" part covered Hands-on Learning Objective H3. In this part, the concept of dividing the dataset into training, validation, and testing sets was elucidated prior to model training. Within the Roboflow® platform, students were presented with a choice of computer vision models. To prevent overwhelming students with complicated model details, the default option, which allows for one-click model training, was selected. However, students were encouraged to explore the differences of each model through the resources available in the Roboflow® documentation. In a few minutes, the model was constructed with a single click, and several performance indicators were provided. The final part "Deployments" covered Hands-on Learning Objectives H4 and H5. This part not only demonstrated how the created model could be deployed on image or video resources, but also discussed how AI model could be evaluated. Roboflow® offered a user-friendly deployment interface, which could serve as an exemplar for students to grasp how their models could be implemented. In this step, students were also asked to evaluate the performance of their models on images not initially included in the dataset (Hands-on Learning Objective H4). During this stage, students were educated on how to evaluate the results, and the potential reasons for the outcomes and possible strategies for enhancing model performance were discussed (Hands-on Learning Objective H5).

Module Assessment

The students' knowledge and comprehension of course material were assessed through a project interpretation assignment. In this assignment, students were required to individually evaluate and discuss the outcomes of the computer vision model they had constructed. Specifically, each student was asked to: (1) Perform annotation task on "hardhat" and "safety vest," and build the computer vision model; (2) Deploy the model on a random image not included in the provided training dataset for PPE inspection and submit the model deployment screenshot; (3) evaluate the model training results generated by Roboflow® and provide justifications for its performance; (4) evaluate the deployment outcomes and provide justifications for the observed performance; and (5) suggest potential improvements for the trained model. These assessment questions were designed to help students gain a deeper understanding of how to effectively evaluate the performance of AI models, recognize the factors that can influence AI performance, and propose solutions for model improvement. In addition, students were requested to offer qualitative feedback on whether this module had motivated them to explore AI knowledge within the construction context and to express their interest in other AI-related topics in construction, if any. This qualitative feedback served the purpose of assessing how well this module was motivating construction students to engage with AI in a construction context and identifying potential areas for AI integration in construction education.

Results

In this study, a total of 15 students were enrolled in the construction management course, all of them are senior level students, most of them are male (73%), and 2 of them choosing not to participate in the AI module. Overall, most students who actively engaged in the class demonstrated a basic understanding the following key concepts: (1) dataset creation and annotation for model training, (2) development and deployment of computer vision models, (3) critical evaluation of model outcomes, and (4) the ability to offer constructive suggestions for model enhancement. These knowledge acquisitions are evidenced by several indications. For instance, all participating students successfully constructed their own computer vision models and deployed them for PPE inspection. This practical application demonstrated their preliminary knowledge on the AI model development workflow within the construction context. Moreover, most students effectively evaluated the model's performance, with one student noting, "*My* (model's) *mAP is 37.4% which is bad.*" Additionally, students demonstrated the capacity to rationalize the results, such as one student's remark, "*The bad result might be due to a bad dataset with not enough images,*" and to propose reasonable suggestions for improvement (e.g., "*I think this could be improved by having more pictures to go off of*"). However, some students did not fully understand what level of mAP could be considered as an acceptable performance. For example, one student stated that "*44% mAP, 60% precision, and 49% recall are good for a data set of only 16 pictures*." Therefore, additional explanations about to how an AI model could be considered as an acceptable model was provided in the beginning of next class to avoid confusion. It is also suggested to consider enhancing the content related to model evaluation in future improvement of the module.

In terms of qualitative feedback, most students expressed an increased interest in delving further into AI in construction after their exposure to this module (e.g., "*I would like to learn more about AI in construction. This module was able to directly link construction safety to AI and I thought that was pretty neat*"). Some students even expressed interest in potential career paths involving AI within the construction context, as evidenced by the comment, "*It would be interesting to see what career path in construction with AI is possible without completely switching into a coding related job.*" Furthermore, when asked about their interests in other AI-related topics in construction, several common themes emerged. These included AI-powered floor plan design (e.g., "*The potential of using auto-generated models & plans as a baseline for actual construction documents*"), AI-assisted construction contract and documentation review (e.g., "*I would be interested in how AI can help with reviewing submittals information*"), and ethical concerns surrounding AI in construction (e.g., "*Discussing how AI can be monitored and prevented from removing labor positions from people who need work*"). Some students also mentioned topics like cost management, estimating, structural safety, and surveying, albeit with less frequency. Interestingly, those students who harbored reservations about the increased adoption of AI in construction exhibited a particular interest in the ethical dimensions of AI within this context. These findings provide valuable insights and guidance for the ongoing development and enhancement of AI-related modules in construction curricula.

Conclusion and Future Work

The increase of AI is transforming the construction industry as more and more professionals in the AEC industry are using AI-based applications in their job. Construction students must understand AI's potential as well as its ethical implications and possible drawbacks in order to successfully navigate this rapidly evolving field. Therefore, this research aims to equip students with AI literacy through an "AI in Construction" module. The module's structure, which combined theoretical teachings with practical, hands-on exercises using the Roboflow® platform, facilitated a comprehensive learning process. It began with a theoretical grounding in AI fundamentals, guiding students through the core concepts and applications within the construction context. This framework set the stage for the subsequent practical hands-on tasks, where students engaged in data annotation, model creation, and computer vision exercises - components that reinforced their theoretical understanding and honed their AI skills. The effectiveness of the module was substantiated by the students' qualitative feedback, which reflected a growing interest in AI's potential within the construction industry. Comments indicated an appreciation for the module's ability to connect AI to construction safety outcomes and an eagerness to explore AI's role in broader construction scenarios. Beyond basic AI knowledge, students showed a keen interest in its real-world applications for things like floor plan creation, contract oversight, and addressing AI's ethical implications in the workplace. This interest points to the opportunity for creating a more varied curriculum and the importance of integrating AI into more aspects of construction education. A notable limitation of this study is the small sample size. Consequently, the focus of this study primarily centers on extracting intriguing findings from students' qualitative feedback. It is suggested that future studies should evaluate the effectiveness of integration of AI into construction courses with larger and more diverse samples. Moreover, this study only included several specific AI applications, and the scope is limited to safety topics. Looking forward, future research efforts on developing similar AI literacy educational interventions in construction could aim to diversify the scope beyond computer vision and safety applications to explore a variety of construction contexts such as planning, control, estimating, and construction documentation management. The other limitation of this study was that only the short-term impact of the intervention was explored. Further research could examine the longitudinal influence of AI literacy education on construction students to ascertain the lasting impact of such academic initiatives.

Acknowledgments

This material was produced under the National Science Foundation under Grant No. 2024656.

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