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AI in Construction Education: A Case Study on Introducing No-Code Computer Vision Modeling Through Project-Based Learning

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The construction industry is increasingly embracing Artificial Intelligence (AI). This uptick in AI adoption has been met by a talent shortage, stemming from a lack of broader integration of AI in construction education. Existing research has looked at the introduction of AI through short modules with specific applications, along with calls for more research into challenges and learning opportunities incidental to this development. This study carried out a case study on an early attempt at AI education in construction, examining the impact of its content and project-based learning approach on the development of AI literacy. The study employed a qualitative approach, utilizing a focus group to gather in-depth insights from five students enrolled in the course. The study found a positive relationship between the project-based approach, course content, and the increased AI literacy of the participants. Cross-domain learning and industry-academia collaborations were identified as significant opportunities for AI education.

Keywords: Artificial Intelligence (AI), Construction Education, Construction Safety, Project-Based Learning.

Introduction

The construction industry is increasingly embracing Artificial Intelligence (AI). Recent research shows that AI is driving transformation in project management, scheduling and resource allocation, risk mitigation, design and planning, estimations, quality control, and safety (Egwim et al., 2023). However, the industry is still viewed as conventional. Despite undergoing digital transformation, the construction industry still lags behind other sectors in adopting Artificial Intelligence (AI) -based solutions (McKinsey Global Institute, 2015). While AI is recognized as a transformative technology capable of bringing unprecedented changes to our work and lives, its application in the built environment industry remains in its nascent stage due to the industry's unique, labor-intensive, dynamic, complex, and uncertain nature (Abioye at al., 2021). With the construction industry facing productivity issues and numerous other challenges such as cost and time overruns, AI could potentially help address these shortcomings (Ivanova et al., 2023). Arumugam & Ravichandran. (2024) have expressed the difficulty in finding AI-literate construction professionals to meet industry demands. This has contributed to the slow pace of AI adoption in the industry. Abioye et al. (2021) have also identified that despite the growing adoption of AI in the construction industry, there is a shortage of suitable talents to meet the demands of the industry. The problem of talent shortage can be connected to a lack of AI integration in the construction curriculum of many higher education institutions. Researchers have begun to explore how this gap can be addressed. For example, Cheng et al. (2024) explored the incorporation of AI into construction safety education. In their conclusion, they recommended that studies be carried out to extract deeper feedback from students, emphasizing the challenges and learning opportunities associated with integrating AI into the construction curriculum. This study explores their proposed future research agenda by undertaking a case study of a similar intervention in a construction science course. The study pays particular attention to how the use of no-code tools impacts AI education, considering the lack of prior computational skills among construction students as reported by Akanmu et al. (2022).

Literature Review

Applications of AI in Construction

The incorporation of AI tools and techniques has aided in improving automation and providing enhanced competitive merits in comparison to traditional means (Chien et al., 2020). The future of AI in the construction sector, and the industry at large, looks promising. As technologies and computing power continue to advance, it is clear that AI is poised to become an essential component of the construction process in the future (Soori & Arezoo, 2022). Applying AI tools and concepts in construction encapsulates the adoption of computer systems and algorithms to execute intricate construction and construction management practices (Bang & Olsson, 2022). AI has been adopted in construction project cost and time planning, project management, risk management, and workforce and safety (Egwim et al., 2023).AI algorithms improve project planning by examining historical data to analyze delays and streamline schedules. For example, machine learning models have been used to predict project timelines and pinpoint critical path activities (Chen et al., 2024). Accurate construction cost estimation is one of the determining factors of project success (Lanley, 2018). This has put construction companies on the path to seek ways to improve cost estimation constantly (Tayefeh Hashemi et al., 2020a). Therefore, to improve the accuracy of cost estimations, AI techniques such as Artificial Neural Networks (ANN) (an AI technique that trains computers to process data similar to the human brain). and Regression Analysis (RA) (a statistical technique used to predict continuous values based on the relationship between dependent and independent variables) are being implemented (Tayefeh Hashemi et al., 2020).

The management and control of project schedules are of utmost importance to the construction industry considering client satisfaction and the presence of liquidated damages clauses in contracts. In their study, Lin et al (2021) introduced an image analytics method designed for site managers to monitor irregular activities that could delay the schedule. Their framework included object detection, object tracking, action recognition, and operational analysis.

Risk management is crucial in construction projects due to inherent uncertainty, complexity, and interdependencies among stakeholders (Aung et al., 2023). Lee et al (2019) applied AI techniques for proactive contract-risk assessment, providing stakeholders with insights into their contractual positions and rights based on contract details. This approach aids in minimizing the number of claims and disputes among parties involved in construction projects. The construction industry records a significantly higher rate of occupational injuries and deaths than other industries. Advanced data analytics techniques are used to predict and prevent workplace accidents (Winge et al., 2019). A study carried out by Bang & Olsson (2022) reported that the leading areas of AI application in construction were estimating and cost control (22%), logistics planning and scheduling (19%), strategy (12%), and health and safety (10%). Considering the vast current and projected application of AI in construction, it is expedient to provide relevant and suitable training to future construction professionals on AI tools (Rivera et al., 2024).

An Overview of AI in Construction Education

According to Kong et al (2021), AI education has been primarily offered at the tertiary level, targeted at students in Computing and Information & Communication Technology-related fields. However, in recent years, AI education has become significant in university programs across many disciplines (Kong et al., 2021). Long and Magerko (2020) described it as encompassing a range of skills that allow individuals to critically assess AI technologies, interact and collaborate efficiently with AI systems, and utilize AI tools in various settings, including online environments, at home, and in the workplace.

The integration of AI in construction education is gaining momentum as the industry seeks to address challenges related to efficiency, safety, and productivity (Onatayo et al., 2024). Educators are making strides toward equipping future construction professionals with basic knowledge of AI techniques. For instance, Cheng et al (2024) designed a 2-hour course aimed at teaching construction students AI literacy skills, specifically within the context of construction safety, and assessed the curriculum's impact on improving their AI literacy. Despite this increasing awareness, there is a dearth of evidence to learn from to facilitate broader integration in construction education in the United States. This study, therefore, investigates how AI education has been instantiated through a project-based learning approach to help bridge this evidence gap.

Project-Based Learning

Higher education plays a vital role in developing a skilled and prosperous economy by preparing graduates for the future workforce (Ramírez De Dampierre et al., 2024). Given the significant shift to technology-supported workplaces, higher education providers ought to consider effective teaching and learning processes such as Project-Based Learning to meet the demands of the industry (Zhang et al., 2024). Project- Based Learning (PBL) focuses on engaging students in practical, hands-on activities that lead to the creation of a final project (Becerra-Posada et al., 2022). PBL involves students creating, developing, and building practical solutions to address a problem (Almulla, 2020). Students engaged in PBL typically collaborate to address a particular issue, create a product tailored for a specific audience, and subsequently assess both the project and the development process (Kokotsaki et al., 2016).From a study by Almulla (2020), the benefits of the PBL approach to the student include: building personal connections with others, encouraging authentic student engagement, learning to follow directions, developing the ability to ask questions, and increasing interaction with teachers. Becerra-Posada et al (2020) also reported that students experience an enhancement of communication skills and the building of self-confidence when PBL approaches are incorporated. PBL does not only develop the students but enhances the professional expertise of teachers as well. It has been revealed that PBL approaches equip unseasoned teachers with different and beneficial learning experiences that boost their professional and personal development (Tsybulsky & Muchnik-Rozanov, 2019).
On the other hand, it is also expedient to note that, as students and tutors are used to working independently, working together in a collaborative environment may pose some uneasiness for both students and teachers (Bashan & Holsblat, 2012). Moreover, Bashan & Holsblat (2012) suggest that there is a tendency for uncongenial environments within student groups which can lead to unpleasant experiences for the people involved. This could impede the benefits of using a PBL approach to introducing construction students to AI. The use of AI in construction necessitates the blending of knowledge from computer systems and construction practices in real-world contexts. Therefore, implementing a learning approach like PBL that fosters interdisciplinary learning and the application

of theoretical knowledge in practical scenarios, would aid in preparing construction students for professional roles in the industry (Ramírez De Dampierre et al., 2024).

Methodology

Students were assigned a group project as part of an AI in construction module in a course covering innovation and data analytics in construction. Upon completion of the module and project assignment, a qualitative method was used, and data was obtained from five graduate students in a virtual focus group discussion setting. The objective of the discussion was to capture the students' before and after opinions and perceptions on (1). Awareness of AI, (2) Evaluation of Instructional Approach, (3) Connection of domain knowledge to the AI education received, and (4) Challenges and Practical Readiness. Two researchers developed a discussion guide with open-ended questions based on the theoretical framework (Table 1) that aligned with the research objective. During the focus group discussion, the facilitator ensured that all participants had opportunities to speak and asked follow-up questions to clarify and deepen the understanding of participants' responses. The research design is illustrated in Figure 1.

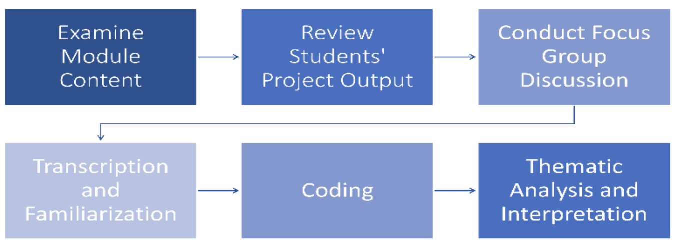

Figure 1. Research Design

Table 1. Focus Group Discussion Guide Questions

Area of Assessment	Pre-module & Project Assessment	Post-module & Project Assessment
Awareness of AI	Did you have any AI knowledge before the module and the project?	Do you feel more knowledgeable about AI after the project? (Explain)
Evaluation of Instructional Approach	How did you relate to the instructional content before taking on the project?	How did you connect the instructional content with your approach to completing the project?
Connection of domain knowledge to the AI education received	What was your knowledge and experience of construction job site safety before starting the project? How did your knowledge and experience or the lack of it influence your approach to the project?	How did you utilize your knowledge of construction site safety in this project? If you did not have this knowledge, how did it affect your ability to complete the project?
Challenges and Practical Readiness	Did you have any inherent challenges that made you apprehensive about the project?	In what other ways do you think you could be provided with more AI education in construction? Do you feel well educated about AI to be able to apply it in the industry?

Study participants

All five participants are graduate students enrolled in the course with the AI in Construction module and project assignment. The participants, at the time of the study, were pursuing either a master's or Ph.D. degree in a construction-related field.

Module and Project Description

The AI module of the course involved a three-week curriculum. Students were given a basic introduction to the fundamentals of AI, including foundational AI concepts such as Machine Learning, Deep Learning, Natural Language Processing, and Computer Vision. The module was divided into five units. Unit 1 covered a historical and theoretical definition of AI, Unit 2 explored how to understand AI/ML models, Unit 3 exposed students to the AI application development workflow, Unit 4 examined the current applications of AI in construction and related fields, and Unit 5 focused on the ethical considerations and the future of AI in construction. To give the students a sense of practical application, a guest speaker session was organized to demonstrate how a Top 50 Engineering News-Record (ENR) general contractor was using AI in their operations. The guest speaker, the Vice President of Advanced Technologies and Innovation, presented their company's in-house AI agents for operations and technical support. The session covered the process for developing custom tools, with emphasis on data preparation, organizational workflow integration, and a live demonstration of the platforms.

According to Abioye et al (2021) , Computer Vision (CV) is an interdisciplinary field focused on replicating the human visual system through artificial means; its ultimate aim is to enable machines to emulate human intelligence. This involves capturing images with suitable devices, processing them with advanced algorithms, and analyzing these images to support decision-making processes. CV represents one of the most germane applications of AI in construction and has been investigated by several researchers (Xu et al., 2021). To test the students' understanding of the content and the effectiveness of the module design, they were assigned a project that required them to apply CV to a real-world problem in construction safety management. The assignment brief was designed to be broad to stimulate students' creativity, critical thinking skills, and higher-order application of the learned concepts. The brief given was:

"*Identify a safety management activity that you can apply AI to. In this project, you are limited to applications that utilize classifiers. For example, the in-class demonstration covered how to detect if a worker is wearing a helmet or not. Your chosen use case may address similar PPE-related safety issues or posture-related issues. You may also choose to create a model that recognizes safety signs at a construction site."*

As part of their submission, students were to demonstrate their AI literacy by justifying their assignment of training classes, the number of training samples, the hyperparameters (configuration variables for machine learning) used in training, real-time demonstration, and a statement of translation of their solution from design to practice. Since students were not trained to code in the course, they were introduced to Google Teachable Machine Version 2 (TM), and Microsoft Lobe as no-code tools to implement their solutions. Google TM was used in the project due to its lower impact on the students' computers.

Results and Discussion

Participants are referred to as Participants A, B, C, D, and E. Two researchers independently familiarized and thoroughly read the transcripts and captured words and phrases that encapsulated the essence of the data as codes. The themes were then formed from the closely related codes that reflect the overall dataset. The results of both researchers from this exercise were contrasted and compared to ensure consistency. Internal reliability was established by both researchers reaching intercoder agreements on the final output of the analysis. The responses and the themes are discussed below:

Awareness of AI

Students indicated that they had limited knowledge of AI before completing the module and assigned project. With respect to AI in construction, none of the students had any prior exposure to AI tools and techniques. Their understanding was limited to random articles on AI and discussions with colleagues. For example, Participant A noted, *"My knowledge of AI before the course was very basic. I knew nothing specific about AI in construction".* Participant B indicated that before the module and the project, they could not appreciate any correlation between construction safety and AI. Upon completing the module and project assignment, there was a consensus among participants that they had become knowledgeable about the application of AI in real-world contexts as well as in the construction industry. Other participants noted they now have direction on self-education in AI techniques and tools. Not only could Participant B appreciate the application of AI in construction safety but also said "*...AI can be useful in other subjects like Precon...*". In light of the above, it can be deduced that the module and PBL approach to reinforcing AI education had a positive impact on increasing students' awareness of AI. The context-specific manner in which AI literacy was pedagogically framed offered a well-defined scope of knowledge, which formed a good basis for learners to build upon and appreciate AI applications in practical situations. The PBL approach further ensured that learners were allowed to demonstrate their higher-order understanding of the knowledge acquired.

Evaluation of Instructional Approach

Before taking the module, the students felt a mix of curiosity and anxiety. This is consistent with the notion that construction students are apprehensive of courses that involve coding and computational thinking (Akanmu et al., 2022). However, participants reported that the module tutorials alleviated their anxiety and instilled confidence and direction for tackling the assigned project. There was a keen interest in assessing the value and efficiency of the application of AI in construction. It is worth pointing out that upon completion of the project assignment, the students expressed a preference for teaching to include more emphasis on the theoretical foundations of AI before commencing the project. The consensus was that the module should have included a more extensive theoretical background of AI/ML concepts rather than a brief introduction to these theories. Participant E stated, "*...I think the introduction to foundational theories was a bit fast...*". Participants generally expressed that the project would have been less challenging if they had tutorials that specifically addressed construction job site safety before taking on the project.

Juxtaposing the above feedback to the average grade on the project, which was 86%, the PBL approach appears to have played a vital role in helping students improve their understanding of the subject through self-driven research versus being given all the information by the instructor. Before beginning the project, participants' shared perspective was that the module was highly sufficient, efficient, and comprehensively covered all aspects of AI. However, after engaging in the project assignment, learners believe that an extensive but simplified theoretical background will help alleviate student anxiety and further enhance the PBL experience.

Connection of Domain Knowledge to AI Literacy

The participants have diverse levels of knowledge and experience in construction job site safety. Participant A One participant admitted to having very little knowledge of construction job site safety stating they relied on "*...common sense...*" and knowledge of their project group mates. Participants C, B & E had already completed the Occupational Safety and Health Administration (OSHA)'s 30-hour Outreach Training Program and had some onsite field experience before enrolling into the module. Whilst Participant D had already completed the OSHA's 10-hour Outreach Training Program. Participants heavily depended on their OSHA training and job site experience to identify and determine aspects of construction safety where AI could be applied. Participant E noted, "*...carpenters don't like wearing gloves...*". This participant's group developed a project titled "Construction PPE Detection by Teachable Machine". An example of the group's output is shown in Figure 2. The responses from the participants suggest that the ability to understand and apply AI tools and techniques in construction is highly dependent on the level of domain knowledge. This is noteworthy for instructors looking at incorporating AI in their curriculum to ensure that there is a sufficient level of understanding of the domain knowledge to which AI is being applied. Furthermore, using project group work allows for diverse levels of knowledge to be incorporated into the respective endeavor. This can compensate for weaknesses and knowledge gaps among group members, fostering peer learning. Moreover, learners can assess their level of knowledge and expertise when they undertake project-based learning endeavors.

Challenges and Practical Readiness

Upon completing the project assignment, the participants had differing views on the value of working in a group. Participants A, C & B expressed satisfaction with the group format, appreciating the opportunity to compensate for their weaknesses and knowledge gaps. Participants D & E felt the project assignments should have been completed individually, citing difficulties in suitably allocating tasks within the project teams. Upon completing the module and project, participants believe they will be able to identify and suggest areas of probable AI applications during their professional careers. However, they admitted to lacking confidence to fully lead the implementation of AI in a real-world setting. Concern was also raised about the industry's openness to accepting AI recommendations from entry-level construction graduates. Participant B, after taking the course, indicated that they pitched AI applications to their employer but encountered reluctance. Participant D, having engaged with a construction company president, strongly believes employers in the industry are only willing to allocate roles involving AI applications to graduates with academic degrees in computer science–related programs. The latter reinforces the need for integrating AI into construction curricula to a level that inspires industry confidence.

Concerning pedagogy, the foregoing suggests that some students may strive in project group assignments whilst others do not. It is expedient for teachers to consider this when giving assignments related to AI education. Furthermore, to motivate construction science students to continually expand their AI literacy, there needs to be some form of assurance and belief that their efforts would be appreciated and valued in the industry. Partnering with industry partners in the delivery of AI education in construction could potentially address this present challenge.

Figure 2. Samples of Participant E Group's Project Output

Other Learning Opportunities and Recommendations.

Participants suggested that the module be offered in the first semester of the graduate program. This approach will help guide graduate students in choosing final semester research topics, selecting companies for internships, and motivating them to delve deeper into AI applications in construction while pursuing academic degrees. They also emphasized the essence of forging a strong connection between industry and academia to better understand their expectations regarding the level of AI literacy they require of graduates. Again, participants also suggested that educational bridges should be established between the Construction Science/Management and Computer Science departments to support students who desire to further their knowledge beyond the module. It must be noted that these responses are from graduate students and that the perspectives of undergraduate students may differ. Nonetheless, the foregoing suggests that exposing students to AI education early in their programs may be beneficial. Early exposure can help forge an interest in AI-related skill/knowledge development, shape research interest, and help define career choices. Educators should also work on creating pathways for construction students who want to pursue more in-depth studies in AI, by partnering with Computer Science departments.

Conclusions

The study carried out a reflective case study on an effort to integrate AI education into a slash-listed course for construction science upper division and graduate students. There is an evidence gap within the incorporation of AI into construction curricula in higher education, which is concerning as the industry is increasingly embracing AI. To help bridge this gap, this study built upon the recommendation of existing research to carry out a qualitative investigation of an AI module and its pedagogical approach i.e., PBL, from students' perspective. The study found that the design of the AI in Construction module coupled with the PBL approach had a positive influence on the students' awareness and understanding of AI in construction. Using a PBL approach also allows the students to demonstrate higher-order application of the material through self-driven knowledge acquisition inspired by the introductory material from the instructor. The study further found that students believe that cross-learning between their home departments and Computer Science departments will take AI education in construction to the next level. Close collaboration between industry and academia on the development of curriculum to respond to industry needs is also essential. The present study is limited in terms of sample size and diversity, having only graduate students as participants. As such, the results cannot be readily generalized but provide anecdotal evidence that may be useful to instructors looking at incorporating AI into their construction curriculum. Further research should be conducted with a more diverse and larger sample to afford generalization to other contexts. Future work should also examine the best ways industry practitioners and educators can collaborate to enhance AI in construction education.

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