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Digital Technologies in Construction Curriculum – Reshaping of Human Mindset and Professional Deliverance from Industry-Academia Collective Perspective

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With over 27 years of global experience, Dr. Farooqui has been recently conducting teaching and research in the domain of construction 4.0 technologies, particularly related to construction worker safety and mental health. Simultaneously, Dr. Farooqui has been actively working to improve construction engineering and management education with focus on inculcating leadership skills and critical thinking. This paper looks at the uncalculated cost of technology i.e. investigating as to how it is or can adversely impact human mindset, skillset and deliverance. It compares the industry and academic perspectives on this context.

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abstract

In recent years, advanced technologies such as BIM, VR, and AI have become increasingly common in construction engineering and management education, as well as in professional practice. While these technologies support project planning, visualization, management, collaboration, and decision making, concerns have emerged regarding how increasing reliance on digital systems may influence professional judgment. Construction remains a people-centered field, where situational awareness, responsibility, and judgment matter as much as technical skill. As a result, educators and industry professionals have begun questioning whether the convenience of digital technologies is shaping how construction professionals think and make decisions. To explore this issue, this study collected perspectives from both academia and industry. Students and faculty in construction engineering and management programs and related disciplines participated in surveys to examine how digital systems influence learning behavior, problem-solving approaches, and confidence in practical tasks. From an industry perspective, company leaders, project managers, and engineers were surveyed to understand how Construction 4.0 tools are perceived to affect professional behavior and decision-making among early-career practitioners. The investigation focused on reliance on automation, situational awareness, and accountability. Analysis revealed several consistent patterns. Students generally credited digital technologies with strengthening technical confidence and efficiency, while scenario-based decision tasks showed that most students favored verification-oriented actions when interacting with digital systems. However, this tendency weakened under contextual pressures such as time constraints or procedural hierarchy. Faculty and senior industry practitioners expressed concern that sustained dependence on automation may reduce situational awareness and blur responsibility when digital outputs are accepted without adequate scrutiny. Overall, the findings suggest that while digital technologies enhance efficiency and precision, their influence on professional judgment is context dependent. Construction programs and organizations must balance digital fluency with experiential and reflective learning so that technology supports professional judgment rather than replaces it.

Keywords: Construction 4.0 Technologies, Technology dependence, Situational Awareness, Critical Thinking and Accountability, Academic–Industry Perspectives

introduction

Digital technologies such as Building Information Modeling (BIM), immersive visualization, artificial intelligence (AI), and digital twins have become increasingly embedded in construction engineering and management education. These technologies are now commonly used to support visualization, planning, coordination, and safety-related learning activities, with the intention of better aligning academic training with evolving industry practices. Recent studies demonstrate that technology-enhanced learning environments can improve students' engagement with complex construction processes and support experiential understanding that is difficult to achieve through conventional instructional methods alone [1, 3, 4].

Despite these advancements, construction remains a fundamentally human-centered profession. Successful project delivery continues to rely on professional judgment, situational awareness, accountability, and adaptive problem-solving—particularly in dynamic site environments where conditions are uncertain and information is incomplete. While digital systems can improve efficiency and data accessibility, they do not eliminate the need for human interpretation, verification, and responsibility. As digital tools become more pervasive, questions have emerged regarding how sustained reliance on these systems may influence the professional mindset and decision-making orientation of future construction professionals.

Industry practitioners and educators have increasingly expressed concern that frequent dependence on digital output may reduce independent reasoning or verification behaviors among students and early-career professionals. Observations from practice suggest that some graduates demonstrate strong confidence in digital systems while exhibiting reduced attentiveness to contextual cues or physical conditions not represented in models. These concerns do not challenge the value of digital technologies themselves but rather emphasize the importance of understanding how technology usage shapes how professionals think, judge, and act, not only what they know.

Existing research has largely examined digital technologies in construction education through the lens of learning effectiveness, technology adoption, or technical skill development. Comparatively limited empirical attention has been given to their influence on professional mindset, situational awareness, and accountability, particularly from a perspective that integrates academia and industry. This study addresses that need by examining perceptions of digital technology impacts from students, faculty, and industry professionals that reflect realistic construction situations.

background and literature review

digital technologies in construction education

A growing body of recent literature highlights the educational benefits of integrating digital technologies into construction curricula. Empirical studies demonstrate that combining BIM with immersive technologies such as virtual reality (VR) can enhance students' understanding of construction sequencing, spatial relationships, and management tasks by enabling interaction with simulated project environments [1], [2]. These environments allow learners to engage with construction scenarios in ways that closely reflect professional workflows and site conditions.

Research also indicates that students' prior digital knowledge plays an important role in determining learning outcomes. Chen et al. showed that students with prior BIM experience performed more effectively in VR-based learning environments, suggesting that immersive technologies are most effective when embedded within broader digital competency development rather than introduced in isolation [3]. Systematic reviews further confirm that VR and AR generally improve engagement and comprehension in AEC education, while also noting variability in pedagogical integration and assessment rigor across studies [4].

Collectively, these studies establish the instructional value of digital technologies in construction education. However, their primary emphasis remains on learning performance, engagement, and adoption, with limited examination of how these tools influence deeper professional behaviors or decision orientations.

situational awareness, safety, and cognitive dimensions

Beyond instructional outcomes, recent research has begun to explore the situational and managerial implications of digital technology use. Lappalainen's work on digital situational awareness emphasizes that while digital systems can enhance information availability, effective situational understanding depends on how decision-makers interpret and act on that information within real project contexts [5]. This distinction is particularly relevant in construction, where conditions evolve rapidly and cannot be fully captured by digital representations.

Studies focused on construction safety further illustrate this point. Research examining digital technologies for safety management shows that tools such as VR, AI, and monitoring systems can support proactive hazard identification and training, but their effectiveness depends on users' engagement and interpretation rather than system capability alone [6], [7]. These findings suggest that the introduction of digital safety technologies may influence not only safety outcomes, but also how attention and responsibility are distributed within construction management processes.

Research on skills and training gaps reinforces this concern. Pittri highlights that successful technology adoption in construction requires more than tool availability; it depends on cognitive, behavioral, and experiential competencies that enable professionals to use digital systems critically and responsibly [8]. This perspective aligns with broader observations that digital tools can support decision-making, while also reshaping how attention and responsibility are managed in technology-enabled work environments.

industry-scale digital transformation and professional expectations

At the industry level, digital transformation is reshaping construction workflows across planning, execution, and asset management. Research on digital twin integration demonstrates how interconnected data environments can improve coordination and lifecycle decision-making across construction stages, while also raising questions about how professional judgment is exercised in increasingly data-driven environments [9]. Similarly, emerging research on AI in construction highlights expanding applications in analytics, automation, and decision support, suggesting that professional roles and workflows are evolving alongside these technologies [10].

Recent empirical work in construction project management further indicates that digital technologies influence not only efficiency but also coordination practices and information flows within project organizations [11]. However, while these studies document technological capabilities and adoption trends, they provide limited insight into how such transformations affect professional judgment, accountability, and adaptive thinking—attributes consistently emphasized by industry as critical for effective practice.

Taking together, the literature review shows the need to examine digital technologies not only as educational or operational tools, but also as influences on professional mindset and behavior.

research gap

Although recent studies demonstrate that digital technologies enhance learning experiences and support construction project processes, three key gaps remain.

First, there is limited empirical research examining how sustained exposure to digital systems influences professional mindset, situational awareness, and accountability, as opposed to technical competence alone. Second, most existing studies adopt a single stakeholder perspective, focusing on students, educators, or industry independently, despite the fact that concerns regarding professional readiness emerge most clearly at the intersection of academia and practice. Third, few studies employ scenario-based decision contexts that allow examination of how individuals may act when confronted with technology-mediated decisions rather than simply reporting attitudes.

These gaps highlight the need for a multi-perspective, behavior-informed investigation of digital technology impacts in construction education.

contribution of the study

This study addresses the identified gaps by making the following contributions:

1. It integrates student, faculty, and industry perspectives to examine perception gaps related to digital technology use and professional deliverance.
2. It adopts a human-centered framework focusing on professional mindset, cognition, and problem-solving.
3. It incorporates scenario-based decision situations to complement perceptual measures and explore tendencies toward digital reliance versus independent verification.

These contributions provide empirical insight to support balanced curriculum design and informed industry–academia collaboration in technology-rich construction environments.

research objectives and questions

The study examines how digital construction technologies are perceived to influence professional mindset and decision-making from an industry–academia perspective. Specifically, the study aims to: (1) assess student, faculty, and industry perceptions of digital technology impacts on mindset, judgment, and accountability; (2) identify areas of convergence and divergence across stakeholders; and (3) evaluate whether students' scenario-based decisions reflect digital reliance or independent verification.

Accordingly, the study addresses the following research questions: **(RQ1)** How do students perceive the impact of digital technologies on their professional and cognitive development? **(RQ2)** How do faculty perceive the influence of digital tools on students' professional readiness? **(RQ3)** How do industry professionals perceive the effects of digital technologies on judgment and accountability in early-career practitioners? **(RQ4)** Where do student, faculty, and industry perceptions align or diverge? and **(RQ5)** Do students' responses to scenario-based decisions indicate digital reliance or verification-oriented behavior?

methodology

research design

This study employs a cross-sectional, multi-stakeholder survey design to examine how the increasing integration of digital technologies in construction education and practice is associated with changes in professional mindset, cognitive engagement, emotional awareness, and problem-solving behavior. The design reflects an industry–academia perspective, integrating viewpoints from students, faculty, and industry professionals to capture both educational and practice-based implications of Construction 4.0 technologies. The study is exploratory in nature and focuses on identifying associations, patterns, and perception gaps rather than causal effects.

participant groups and sampling

Student respondents (n = 102) were enrolled in upper-division undergraduate and graduate construction courses at a single institution. Surveys were performed during regular class sessions, and participation was voluntary and anonymous. Faculty respondents (n = 23) were recruited through departmental circulation and academic networks in construction-related programs. Because the survey was distributed through open channels, the total number contacted could not be determined. Industry professionals (n = 34) were recruited through the department's Industry Advisory Board and professional networks and represented a mix of project managers, engineers, and senior practitioners with diverse experience levels.

survey instrument development

Survey instruments were developed by the research team drawing on prior literature in digital construction education, teaching experience in construction science, and observed industry concerns related to automation reliance, situational awareness, and accountability. Instrument content was reviewed by three faculty members with expertise in construction education for clarity, relevance, and construct alignment. This review served as an expert content validation process rather than a formal psychometric validation.

construct framework

Survey items were organized around four exploratory human-centered dimensions relevant to construction education and practice:

1. **Professional Mindset** – perceptions related to responsibility, reliance on digital systems, and professional judgment.
2. **Intellect (Critical Thinking)** – independent reasoning, questioning of digital outputs, and analytical engagement.
3. **Emotional Intelligence / Situational Awareness** – attentiveness to context, awareness of site conditions, and sensitivity to situational cues.
4. **Problem-Solving Capability –** ability to adapt to unexpected conditions and resolve problems beyond predefined digital solutions.

These dimensions align conceptually with prior research on digital situational awareness in construction [5], human competency gaps in emerging construction technologies [7], technology adoption and safety management [8] and the role of digital tools in project management [11]. In this study, they were adapted for educational contexts and treated as exploratory behavioral groupings rather than validated latent constructs.

question structure

Each survey contained three components: demographic and background items, Likert-scale construct items, and (for students only) scenario-based decision tasks. Demographic questions appeared first to contextualize responses. For students, these captured academic standing and prior exposure to construction practice and digital tools; for faculty, teaching role, experience, and familiarity with technology-enhanced instruction; and for industry professionals, role category, years of experience, and organizational context, including exposure to Construction 4.0 technologies.

Constructs were assessed using five-point Likert items ranging from strong disagreement to strong agreement, with a mix of positive and negatively worded statements. Negatively framed items were reverse coded during analysis for consistent scoring.

The student survey additionally included scenario-based decision questions simulating realistic construction contexts (e.g., reliance on BIM/AI outputs versus manual verification, safety-related judgments). Students selected the action they would most likely take, providing behavioral proxies rather than direct observations.

data collection procedure

All surveys were performed through Google Forms. Student surveys were completed during the Fall 2025 academic term, while faculty and industry surveys were distributed over a similar timeframe through academic and professional channels. Participation was voluntary, and no personally identifiable information was retained.

participant characteristics

Students (n = 102)
Student respondents were predominantly enrolled in construction science or closely related programs (97.1%). The sample was largely composed of upper-division undergraduates (65.7% juniors and 32.4% seniors), with a small number of graduate students (2.0%). Nearly all students (98.0%) were part of construction-focused curricula, indicating that the findings reflect perspectives of individuals nearing entry into professional practice and actively exposed to digital construction technologies.

Faculty (n = 23).
Faculty respondents primarily represented construction management or construction engineering disciplines (82.6%). Teaching experience was skewed toward senior educators, with over half (52.2%) reporting more than ten years of experience and an additional 30.4% reporting six to ten years. This experience distribution supports the credibility of faculty perspectives on student development, curriculum integration, and professional readiness.

Industry professionals (n = 34).
Industry respondents occupied a range of professional roles, including project and construction managers (35.3%), engineers (26.5%), and senior leadership positions (17.6%). The sample was experienced, with 85.3% reporting eight or more years in the industry. Most respondents were engaged in building (61.8%) or infrastructure/industrial projects (26.5%), representing digitally intensive construction environments where automation and decision support tools are increasingly used.

demographic implications for interpretation

Overall, the demographic profile reflects a balanced mix of perspectives across education and practice. Student participants largely represent individuals nearing entry into the construction workforce, with meaningful exposure to digital technologies during critical stages of their academic development. Faculty respondents contribute insights shaped by extensive teaching experience and involvement in curriculum delivery, while industry professionals offer observations drawn from long-term engagement with real-world project environments and workforce performance.

data preparation and analytical focus

Responses were screened for completeness and quality. In the industry dataset, one response with substantial missing data was removed (raw n = 35; final n = 34). No student or faculty responses were excluded. Duplicate entries were checked using timestamps and identical response patterns; none were found. Straight-lining (uniform responses across most Likert items) was also assessed, and no cases required removal. Negatively worded items were reverse-coded, and composite scores were calculated where appropriate. Final samples were students (n = 102), faculty (n = 23), and industry (n = 34). Inferential analyses focused on student data, with faculty and industry responses used for comparison.

student exposure to digital technologies

Students reported exposure to an average of 3.11 technology categories (SD=1.54), most commonly scheduling/visualization software (91%), 3D modeling (64%), BIM (63%), and AI tools (44%). Less common exposures included VR/AR (9%), digital twins (3%), and IoT systems (3%).

Perceived extent of digital integration in coursework was moderate to high (mode = 3 on a 5-point scale), indicating regular but not excessive reliance on digital systems.

reliability and measurement quality

Internal consistency was assessed using Cronbach's alpha prior to construct-level interpretation (Table 1). Given the exploratory nature of the study and the limited number of items within several scales, reliability values were interpreted cautiously.

Table 1: Reliability of Student Constructs

Construct	Items	Cronbach's α	Interpretation
Technology Perception / Use	2	0.63	Acceptable (exploratory)
Professional Mindset	5	0.35	Weak
Intellect / Critical Thinking	3	0.12	Very weak
Emotional Intelligence / Awareness	5	< 0	Not coherent
Hands-on Necessity (Problem Solving)	2	0.70	Acceptable
Digital Simulation Efficacy (Problem Solving)	2	0.73	Acceptable

Reliability varied across dimensions. Technology perception and the two problem-solving subscales demonstrated acceptable internal consistency for exploratory research. Professional mindset and critical thinking showed weaker internal coherence, while the emotional awareness items did not function as a unified scale. These results suggest that some dimensions reflect loosely related behavioral indicators rather than tightly unified latent constructs.

Accordingly, constructs with low reliability were interpreted as exploratory indices, and scenario-based behavioral outcomes were treated as primary evidence in subsequent analyses. This approach avoids overclaiming measurement precision while maintaining transparency regarding construct limitations.

descriptive results: student learning orientation

Students reported positive perceptions of digital systems (M=3.77) alongside strong endorsement of hands-on learning (M=4.21), suggesting complementarity rather than substitution.

scenario-based behavioral outcomes (students)

Scenario questions were treated as behavioral decision outcomes reflecting realistic professional contexts.

Table 2: Scenario-Based Student Decisions (n = 102)

Scenario	Decision Option	Count	Percentage
S1: VR Safety Check	Verify conditions	86	84.3%
	Trust teammate	12	11.8%
	Trust VR system	4	3.9%
S2: AI Scheduling	Verify output	52	51.0%
	Follow instructor	43	42.2%
	Accept AI	7	6.9%
S3: BIM Estimate	Verify results	64	62.7%
	Trust manual	25	24.5%
	Accept BIM	13	12.7%

Across all scenarios, verification dominated decision-making, though time pressure (Scenario 2) increased reliance on procedural compliance.

scenario–orientation relationships

Nonparametric tests (Kruskal–Wallis) were used due to unequal group sizes and non-normality.

Table 3: Scenario Differences by Learning Orientation

Scenario	Measure	H	p-value	Effect Size (ε²)	Interpretation
S1	Hands-on Necessity	3.30	0.192	0.013	Not significant
S2	Hands-on Necessity	11.23	0.0036	0.093	Small–moderate
S3	Intellect (explor.)	6.56	0.0376	0.046	Small (explor.)

No statistically significant differences were observed for Scenario 1, whereas Scenarios 2 and 3 showed small to moderate associations with selected learning-orientation measures.

Example Scenario (AI Scheduling Under Time Pressure):
Students were asked to evaluate an AI-generated project schedule that reduced project duration. However, the instructor cautioned that the AI sequence might increase rework risk and may not reflect real site constraints. With limited time remaining in the class exercise, students were required to choose among three options: (a) accept the AI recommendation, (b) follow instructor guidance without independent review, or (c) verify the schedule through additional analysis before deciding.

correlation patterns among student measures

Spearman correlations revealed stronger relationships among learning orientations than between exposure and mindset.

Table 4: Key Correlations (Spearman's ρ)

Variable Pair	ρ	p-value
Tech Perception ↔ Digital Simulation Efficacy	0.49	<0.001
Tech Perception ↔ Hands-on Necessity	0.26	0.008
Professional Mindset ↔ Hands-on Necessity	0.48	<0.001
Intellect ↔ Hands-on Necessity	0.37	<0.001

Technology exposure alone was not a strong predictor of mindset outcomes.

behavioral consistency and cross-group comparison

To examine whether verification behavior reflected isolated scenario responses or stable cross-context tendencies, a behavioral consistency analysis was conducted across the three student scenarios.

Table 5: Cross-Scenario Verification Consistency (Students, n = 102)

Consistency Measure	Percentage
Verified in S1 and S3	72.1%
Verified in all three scenarios	43.1%

Students who selected verification in Scenario 1 also selected verification in Scenario 3 at a rate of 72.1%, and 43.1% demonstrated verification behavior across all three scenarios. These findings indicate measurable cross-context stability, while also revealing that consistent verification across all contexts was not universal.

As automation reliance was the directly comparable construct measured across both student and industry surveys, a nonparametric comparison was conducted to examine alignment between groups.

Table 6: Student–Industry Comparison on Automation Reliance

Group	Mean	Mann–Whitney U	p-value
Students (Digital tools more accurate than humans)	3.36	1500.5	.647
Industry (Automation Reliance composite)	3.35		

Due to the ordinal scaling of Likert-type items and unequal group sizes across response categories, nonparametric methods (Kruskal–Wallis and Mann–Whitney U tests) were applied for inferential comparisons.

industry perspective

Industry scales showed strongest reliability for situational awareness ($\alpha = 0.81$).

Table 7: Industry Scale Descriptives

Construct	Mean	SD	α
Automation Reliance	3.39	0.63	0.68
Situational Awareness	2.84	0.69	0.81
Critical Thinking	2.92	0.61	0.60
Accountability	3.14	0.63	0.52

High agreement was observed for statements indicating reduced vigilance and blurred accountability under automation and time pressure.

faculty perspective

Faculty responses were analyzed descriptively.

Table 8: Faculty Agreement with Key Statements

Statement Theme	Agree / Strongly Agree
Students must verify digital outputs	95.7%
Hands-on experience is critical	87.0%
Over-reliance reduces responsibility	78.3%
Early tech exposure builds confidence	73.9%
Excessive reliance limits deep thinking	73.9%

Faculty perspectives reinforce the need for balanced integration rather than reduced digital exposure.

cross-stakeholder synthesis

Across students, faculty, and industry, results converge on a consistent theme: digital technologies enhance efficiency and confidence but introduce risks related to situational awareness, verification behavior, and accountability when over-relied upon. Scenario-based evidence shows that students generally favor verification, yet decision-making shifts under time pressure. Faculty and industry responses emphasize the importance of reinforcing judgment-centered, experiential learning alongside digital fluency.

discussion

behavioral patterns across contexts

Students generally selected verification-oriented responses rather than automatically accepting digital outputs. The cross-scenario analysis shows measurable stability: 72.1% of students who verified in Scenario 1 also verified in Scenario 3, and 43.1% verified across all three scenarios. This indicates that verification is not random. However, the reduced consistency under time pressure confirms that judgment is context-sensitive rather than automatic.

Industry participants described similar dynamics, noting that schedule pressure and workflow hierarchy can weaken verification behavior. Together, these findings suggest that digital tools do not eliminate professional judgment, but external project conditions influence whether it is exercised.

technology orientation and construct limitations

Digital exposure was not strongly associated with reported mindset or reasoning style. Students who viewed digital tools positively also valued hands-on learning, indicating that technology is seen as complementary rather than substitutive.

Several survey constructs showed weak internal consistency, suggesting that short perceptual scales may not reliably capture reasoning tendencies. In contrast, scenario-based tasks provided clearer behavioral insight, reinforcing their value for assessing decision-making under digital influence.

cross-group alignment on automation reliance

A nonparametric comparison found no significant difference between student and industry perceptions of automation reliance. This alignment indicates that both groups recognize the influence of digital systems in workflow decisions. At the same time, faculty and industry respondents expressed concern about reduced situational awareness and blurred accountability when system outputs are accepted without scrutiny.

implications for construction education

The findings support shifting from tool-centered instruction to judgment-centered digital fluency. Scenario-based exercises that simulate time pressure and hierarchical influence may better prepare students for real-world constraints. Behavioral assessment approaches may offer stronger evaluation of professional readiness than short perceptual surveys alone.

conclusion and future work

Students demonstrated consistent verification behavior across scenarios, indicating that professional judgment has not been replaced by automation. However, verification weakened under contextual pressures, confirming that digital decision-making is conditionally shaped by project environments.

Faculty and industry perspectives highlight the importance of reinforcing accountability and situational awareness alongside technical fluency. Given limitations in internal consistency across some survey measures, findings should be interpreted as exploratory behavioral patterns. Future research should refine measurement instruments and expand scenario-based evaluation of digital decision behavior.

limitations

This study is subject to several limitations. First, student data were collected from a single institutional context, which may limit generalizability across programs with different curricular structures or levels of digital maturity. Second, several student constructs exhibited weak internal consistency, constraining the strength of construct-level interpretations and necessitating an exploratory analytical approach. Third, faculty and industry samples were modest in size and relied on self-reported perceptions rather than direct observation. Finally, the cross-sectional design captures associations and decision tendencies at a single point in time and does not allow causal inference or assessment of longitudinal change. These limitations point to opportunities for future research using refined instruments, multi-institutional samples, and longitudinal or observational designs.

future work

Future research will refine the survey instruments to improve reliability and incorporate open-ended questions to examine whether students' stated verification intentions align with what they do in field settings. We will also pursue longitudinal studies tracking students into early professional practice to better understand how verification behaviors evolve under real project pressures. Expanding data collection across multiple institutions and industry sectors will improve generalizability. Experimental or simulation-based designs manipulating time pressure, automation transparency, and accountability cues will further clarify how digital systems influence professional decision-making.

references

[1] Narmin Abouelkhier, M. T. Shafiq, A. Rauf, and N. Alsheikh, "Enhancing Construction Management Education through 4D BIM and VR: Insights and Recommendations," *Buildings*, vol. 14, no. 10, pp. 3116–3116, Sep. 2024.

[2] M. Johansson and M. Roupé, "Real-world applications of BIM and immersive VR in construction," *Automation in Construction*, vol. 158, p. 105233, Feb. 2024.

[3] X. Chen *et al.*, "Effects of BIM prior knowledge on applying VR in construction education: Lessons from a comparison study," *Journal of Computational Design and Engineering*, Oct. 2023.

[4] M. R. Saiba, G. H. Berghorn, L. Nubani, K. Cetin, and M. G. M. Syal, "Transforming AEC Education: A Systematic Review of VR/AR in Mass Timber Curriculum," *Buildings*, vol. 15, no. 16, p. 2938, Aug. 2025.

[5] E. Lappalainen *et al.*, "Situational Management and Digital Situational Awareness Systems in Infrastructure Construction: Managerial Perspectives on Relevance, Challenges, and Adoption," *Buildings*, vol. 14, no. 7, p. 2035, Jul. 2024.

[6] E. I. Daniel, O. S. Oshodi, N. I. Nwankwo, F. A. Emuze, and E. Chinyio, "The Use of Digital Technologies in Construction Safety: A Systematic Review," *Buildings*, vol. 15, no. 8, pp. 1386–1386, Apr. 2025.

[7] J. Xu, J. Li, and X. Chen, "Assessment of technology adoption in construction safety management: Case study in China," *Science Progress*, vol. 107, no. 4, Oct. 2024.

[8] H. Pittri *et al.*, "Knowledge, Training, and Skills Gaps for Emerging Construction Technologies Adoption in the Construction Industry of a Developing Country," *International Journal of Construction Education and Research*, pp. 1–27, Nov. 2025.

[9] T. D. Moshood, J. OB. Rotimi, W. Shahzad, and J. A. Bamgbade, "Infrastructure digital twin technology: A new paradigm for future construction industry," *Technology in society (Print)*, vol. 77, pp. 102519–102519, Jun. 2024.

[10] V. S. Kalasapudi, A. Seelam, S. Ganupa, and C. Tofferi, "The overlooked frontier of AI in construction: conversational, document-native automation for administrative workflows," *Frontiers in Built Environment*, vol. 11, Jan. 2026.

[11] S. Qadir, Aawag Moshen Alawag, N. Zia, H. R. Almujibah, and Hashem Alyami, "The role of digital technologies in enhancing construction project management," *Scientific Reports*, Dec. 2025.