Developing Project Management Competencies: An AI-Driven TPACK Training Program for the Construction Training Institute in Kuwait

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***Abstract*—This study addresses the skills gap in Kuwait's construction sector through the design and pilot implementation of an Artificial Intelligence (AI)-enhanced training program grounded in the Technological Pedagogical Content Knowledge (TPACK) framework. The program targets the development of Project Management (PM) competencies among trainees at Kuwait's Construction Training Institute (CTI), affiliated with the Public Authority for Applied Education and Training (PAAET), responding to Industry 4.0 demands for integrated digital, managerial, and analytical capabilities. Using a Design-Based Research (DBR) approach, the study proposes a conceptual training model that integrates adaptive AI tools, including intelligent simulations and guided automated feedback, to support experiential and context-specific learning. The training design aligns Kuwait-specific construction content with evidence-based adult learning strategies and advanced educational technology across the TPACK domains. The proposed design explicitly addresses technical, ethical, and implementation-related considerations associated with the use of AI in vocational training contexts. The pilot phase is intended to examine the program's potential impact on trainees' applied knowledge and integrated project management skills. The study is expected to contribute a scalable and contextually grounded training model that supports vocational project management education and workforce development within Kuwait's Vocational Education and Training (VET) sector.**

***Keywords*—Artificial Intelligence (AI), Technological Pedagogical Content Knowledge (TPACK) framework, project management competencies, Vocational Education and Training (VET), construction training, adaptive learning, simulation**

I. Introduction

Kuwait's Vision 2035 (New Kuwait) emphasizes large-scale infrastructure development as a key driver of economic diversification, placing increasing demands on a workforce capable of managing complex construction projects [1]. However, a persistent gap remains between vocational training outcomes and the contemporary Project Management (PM) competencies required in the construction sector, particularly in areas such as digital tool integration, risk analysis, sustainability, and stakeholder coordination [2].

As a key provider of Vocational Education and Training (VET), Kuwait's Construction Training Institute (CTI), affiliated with the Public Authority for Applied Education and Training (PAAET), is increasingly challenged to move beyond foundational trade skills toward the development of higher-order, integrative competencies. Traditional vocational training models often address content, pedagogy, and technology in isolation, which limits trainees' ability to transfer knowledge effectively to dynamic, real-world project environments [3].

The Technological Pedagogical Content Knowledge (TPACK) framework offers a structured approach to addressing this limitation by emphasizing the integrated design of Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK) [4]. Within the context of vocational PM training, TPACK supports the alignment of construction-specific content with adult learning strategies and appropriate digital tools. Recent advances in Artificial Intelligence (AI) further extend this potential by enabling adaptive learning environments, intelligent simulations, and guided automated feedback that support experiential and practice-based learning [3, 5].

Accordingly, this study proposes an AI-enhanced training program grounded in the TPACK framework to support the development of practical and integrative PM competencies among CTI trainees. By leveraging contextually relevant, AI-supported project simulations and adaptive learning support, the proposed program aims to bridge the gap between theory and practice and contribute to workforce development objectives aligned with Kuwait's Vision 2035 [1].

In designing the proposed AI-enhanced training program, this study explicitly considers key technical, ethical, and implementation-related factors associated with the use of AI in vocational education contexts. The program conceptualizes AI not as an autonomous instructional agent, but as a supportive technological layer that provides guided feedback, adaptive learning

Manuscript received April 16, 2026; accepted May 10, 2026; published June 17, 2026.

support, and scenario-based simulations under human supervision. In addition, potential implementation challenges related to technical readiness, trainee engagement, and institutional constraints are acknowledged and addressed through a phased pilot-oriented design. These considerations ensure that the proposed training model remains pedagogically grounded, ethically responsible, and contextually feasible within the operational environment of CTI [6, 7].

II. Literature Review

This study is grounded in three complementary strands of literature that inform the design of the proposed AI-enhanced training program: the TPACK framework, experiential and constructivist learning theories, and recent research on project management competencies and AI in vocational education.

The TPACK framework provides a widely adopted foundation for instructional design by emphasizing the integrated application of content knowledge, pedagogical strategies, and technological tools to support meaningful learning. Within the context of construction project management training, TPACK enables the alignment of domain-specific content with adult learning approaches and appropriate digital technologies to facilitate applied and authentic learning experiences [4].

Experiential and constructivist learning theories further inform vocational training design by highlighting learning through action, reflection, and guided support. Experiential learning emphasizes knowledge construction through active engagement with real-world tasks [3], while social constructivism underscores the role of scaffolding and feedback in supporting learner development [8]. Recent studies suggest that digital tools, including AI-supported simulations and feedback systems, can operationalize these principles by providing realistic learning environments and formative support [5, 9].

Recent literature also indicates that project management competencies in the construction sector have expanded beyond traditional cost, time, and quality constraints to include digital literacy, risk management, communication, and adaptive decision-making skills [10]. Studies within the Gulf region continue to highlight gaps between evolving industry requirements and the outcomes of traditional vocational training programs, underscoring the need for curriculum modernization [2]. While prior research has applied the TPACK framework primarily within teacher professional development contexts [4], limited attention has been given to student-facing, AI-enhanced instructional designs in construction-oriented vocational education.

The reviewed literature demonstrates a convergence between the increasing demand for advanced project management competencies in construction [2], the relevance of the TPACK framework for integrated instructional design [4], and the growing use of AI to support personalized and experiential learning [9, 11]. However, existing studies frequently address these elements in isolation. Research on TPACK has been predominantly situated within teacher professional development contexts rather than student-facing vocational training environments [4], while research on AI in education has largely focused on higher education contexts in general rather than construction-oriented vocational domains [9, 11].

Accordingly, limited empirical focus has been placed on integrative, AI-enhanced instructional models grounded in TPACK that specifically target project management competencies within construction-focused vocational education settings. In addition, mixed methods research design approaches provide valuable guidance for integrating qualitative and quantitative perspectives when developing and evaluating complex educational interventions in vocational contexts [12, 13].

This gap highlights the need for integrative design models that combine pedagogical grounding with technological innovation in authentic vocational contexts.

In addition to this conceptual gap, the literature identifies ongoing concerns related to technical feasibility, ethical implications, and implementation challenges associated with integrating AI into educational environments [6, 7]. Recent scholarship emphasizes the importance of maintaining human oversight, ensuring data privacy, and addressing institutional readiness when deploying AI-supported learning systems. These considerations reinforce the necessity of design-oriented research approaches that integrate AI within pedagogically grounded frameworks such as TPACK while explicitly addressing risk mitigation and responsible implementation. The present study responds to this need by adopting a Design-Based Research (DBR) methodology that prioritizes both instructional effectiveness and contextual feasibility [14].

III. Conceptual Frameworks

This study adopts an AI-enhanced TPACK conceptual framework to guide the design and evaluation of the proposed project management training program within a construction vocational education context. The framework builds on the integration of content knowledge, pedagogical strategies, and technological tools, with AI functioning as an enabling layer that supports experiential learning, adaptive feedback, and competency development. By positioning AI as a pedagogical partner rather than a delivery mechanism, the framework aligns instructional design decisions with targeted project management competencies relevant to contemporary construction practice [3, 4].

A. The Core TPACK Layer: Instructional Design Blueprint

The training program is grounded in the TPACK framework, which serves as the core instructional design foundation [4]. The framework ensures purposeful integration of construction project management content, adult learning strategies, and AI-enabled technologies to support applied and authentic learning. Content knowledge reflects both international project management standards and Kuwait-specific construction contexts, pedagogical knowledge emphasizes experiential

and problem-based learning approaches, and technological knowledge focuses on the effective use of AI-driven simulations and feedback tools. Learning activities are intentionally designed at the intersections of these domains to foster integrated project management competencies and enable trainees to apply knowledge flexibly in realistic project scenarios.

B. The AI Integration Layer: Enabling Infrastructure

The AI integration layer operationalizes the TPACK-based design by enabling personalization, experiential learning, and formative assessment. AI supports adaptive tutoring, dynamic scenario-based simulations, and automated feedback mechanisms that respond to trainee performance in real time. These functions allow learning activities to be tailored to individual needs, provide realistic project environments for decision-making practice, and generate actionable feedback aligned with targeted project management competencies [10].

C. The Competency Outcome Layer

The competency outcome layer defines the primary objective of the proposed model: developing measurable and industry-relevant project management competencies aligned with construction sector standards [10]. The program targets core competencies such as scheduling and resource management, risk mitigation, and stakeholder communication within realistic project contexts. AI-supported learning activities are designed to both develop and assess these competencies through embedded performance analytics and automated feedback, creating a closed-loop system that supports continuous personalization and program refinement.

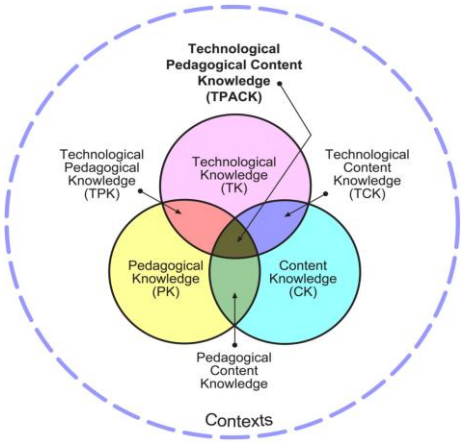

Fig. 1. The TPACK framework illustrating the integration of content knowledge, pedagogical knowledge, and technological knowledge within educational contexts [4].

From an implementation perspective, the proposed AI-enhanced TPACK framework explicitly incorporates technical, ethical, and contextual considerations to ensure responsible and feasible deployment within vocational training environments. AI is employed as a decision-support and feedback mechanism operating under continuous human oversight, rather than as an autonomous instructional agent. Ethical safeguards, including data privacy protection, transparency of AI-generated feedback, and learner agency, are embedded within the training design. In addition, potential implementation risks related to technical infrastructure, trainee readiness, and instructional adoption are addressed through a phased pilot-oriented approach, allowing iterative refinement prior to broader deployment [6, 7].

The foundational structure of the TPACK framework is illustrated in Fig. 1.

IV. Research Significance, Objectives, and Questions

This study responds to the increasing need for more effective project management training within construction-focused vocational education contexts. It focuses on the Project Management subject within the Quantity Surveying program at the CTI, Kuwait, affiliated with the PAAET. By integrating AI within a TPACK-based instructional design, the study seeks to support the development of applied, industry-relevant project management competencies through pedagogically grounded and technology-supported learning approaches.

The study aims to design and pilot an AI-enhanced project management training program and to examine its effectiveness in improving trainees' project management knowledge and practical skills, as well as to assess trainees' satisfaction with the program. In doing so, it seeks to identify priority project management competency gaps in relation to current construction industry requirements and to inform the design of more responsive vocational training models.

Accordingly, the study is guided by the following research questions:

(1) What project management competency gaps are identified during the needs analysis phase to inform the design of the AI-enhanced TPACK-based training program?
(2) What design principles characterise an effective AI-enhanced training program integrating the TPACK framework for construction project management?
(3) What implementation challenges and trainee engagement patterns emerge during the pilot application of the AI-driven TPACK program?
(4) What is the level of trainees' satisfaction with the AI-enhanced TPACK-based training program following its implementation?

V. Materials and Methods

This study adopts a DBR methodology supported by a mixed-methods approach [12, 13], combining quantitative pretest–post-test measures with qualitative feedback and instructor observations to guide the design and pilot implementation of the proposed AI-enhanced TPACK training program within the context of the CTI. DBR is appropriate for this study as it supports the systematic development and evaluation of educational

interventions in real-world settings while generating contextually grounded design insights [14].

A. Ethical Approval and Informed Consent

Ethical approval will be obtained from the Arabian Gulf University Research Ethics Committee prior to data collection. Participation in the pilot study will be voluntary, and written informed consent will be obtained from all participants. All collected data will be anonymised and used solely for research purposes.

B. Research Design and Procedures

The DBR process is organised into three main phases. The first phase involves a needs analysis conducted with relevant stakeholders, including construction industry practitioners, instructors, and trainees at the CTI. This phase aims to identify priority project management competency gaps and to inform the pedagogical and technological design requirements of the training program.

In the second phase, an AI-supported training prototype is designed based on the identified needs and structured around the TPACK framework. The program incorporates scenario-based learning activities, adaptive AI-supported guidance, and instructor-facilitated reflection aligned with targeted project management competencies. The prototype is then pilot-tested with a selected cohort of trainees using a one-group pretest–post-test design.

The final phase focuses on evaluation and iterative refinement. Data collection combines quantitative measures, including a project management knowledge test and a performance-based rubric for practical skills administered before and after the pilot implementation.

Quantitative data will be analysed using SPSS software to examine pre–post differences in project management knowledge and practical performance measures [15].

Qualitative feedback is gathered through trainee reflections and instructor observations to support interpretation of the findings and to guide program refinement.

Qualitative data will be analysed using thematic analysis to identify emerging patterns in trainee reflections and instructor feedback [16].

C. AI Integration and Technical Specifications

The proposed training program integrates AI as a supportive instructional component within the TPACK-based design, rather than as an autonomous decision-making or assessment tool. Specifically, Microsoft Copilot is utilized to provide AI-supported guidance, formative feedback, and scenario-based learning support aligned with defined pedagogical objectives.

Within the program, copilot functions as an assistive learning tool embedded in selected training activities, including project planning exercises, risk analysis scenarios, and reflective problem-solving tasks. Its role is limited to offering prompts, examples, and feedback that encourage trainee reflection and decision-making, while all instructional control, assessment, and final performance evaluation remain under instructor supervision. Copilot is not used for automated grading, summative assessment, or independent instructional delivery.

From a technical perspective, the AI integration operates within predefined usage boundaries to ensure reliability and consistency. Trainees interact with Copilot through guided prompts designed by the instructor, and AI outputs are reviewed and contextualized during facilitated learning sessions. This human-in-the-loop approach ensures that AI-generated responses support learning without replacing pedagogical judgement or learner agency [6, 7].

D. Risk Management and Ethical Considerations

The implementation of the proposed AI-enhanced TPACK training program may involve anticipated challenges related to technical reliability, human factors, and logistical constraints. These risks are addressed proactively through the study's DBR approach, which allows for iterative refinement during the pilot phase.

Potential technical risks, such as variability in AI-generated responses, are mitigated by restricting AI use to predefined instructional functions, employing guided prompts, and maintaining instructor oversight. Human-related risks, including uneven digital literacy levels or over-reliance on AI-supported guidance, are addressed through instructor-led facilitation and structured learning activities that emphasise critical reflection. Ethical considerations related to AI are addressed through transparency in AI use, informed consent, and data protection measures aligned with international AI ethics guidelines [6].

VI. Results and Discussion

As this study represents a work-in-progress, empirical results are not yet available. The following discussion outlines the anticipated outcomes of the pilot implementation based on the theoretical foundations of TPACK, experiential learning, and prior research on AI-supported training.

It is expected that participation in the AI-enhanced TPACK program will lead to measurable improvements in trainees' applied project management knowledge, particularly in scenario-based tasks requiring synthesis, decision-making, and non-linear problem-solving [10]. In addition, AI-generated performance analytics are anticipated to demonstrate enhanced integration of technological, pedagogical, and content knowledge, reflected in trainees' ability to apply digital tools strategically within realistic construction project scenarios [4]. The adaptive and experiential nature of the training is also expected to enhance trainees' applied performance in complex, real-world project environments through repeated engagement with AI-driven simulations [3].

Future empirical analysis will examine pre–post differences using quantitative statistical procedures and will explore qualitative patterns emerging from trainee reflections and instructor feedback.

These anticipated outcomes highlight the pedagogical value of embedding AI-supported learning within a TPACK-structured design, particularly for competency-based vocational education contexts.

A. Discussion, Limitations, and Future Research

The anticipated findings highlight the pedagogical potential of integrating AI-supported learning within a TPACK-structured design for vocational project management training. By enabling dynamic, scenario-based simulations, the proposed model supports what can be described as responsive authenticity, allowing trainees to engage with realistic project complexities in a low-risk environment. Such experiences are expected to foster adaptive expertise and support the application of knowledge in non-linear, real-world situations [3].

The use of TPACK as a guiding framework also serves as a conceptual guardrail, ensuring that AI technologies are selected and applied to support specific pedagogical objectives rather than functioning as isolated technical tools [4]. This intentional alignment differentiates the proposed model from technology-driven approaches that lack pedagogical coherence and reinforces its relevance for competency-based vocational education.

Despite its potential contributions, this study is limited by its pilot scope and single-institution context, which may constrain the generalizability of future findings. Further research is recommended through larger-scale and multi-institutional implementations, longitudinal studies examining workplace performance outcomes, and cost–benefit analyses of AI-enhanced vocational training models. Such investigations would strengthen the empirical evidence base and support broader adoption across VET contexts.

B. Implementation Overview

This overview is provided to contextualize the anticipated results and discussion within the broader DBR process, rather than to restate methodological procedures in detail. The study follows a DBR approach to guide the design, pilot implementation, and refinement of the proposed AI-enhanced TPACK training program. The process begins with a needs analysis involving construction industry stakeholders, instructors, and trainees to identify priority project management competency gaps. Based on these findings, an AI-supported training prototype is designed and pilot-tested with a cohort of CTI trainees using a one-group pretest–posttest design. Data collection combines quantitative measures of project management knowledge and practical performance analytics with qualitative feedback from trainee focus groups and instructor interviews. Findings from the pilot phase are used to iteratively refine the training model and inform design principles for broader vocational implementation.

VII. Conclusion and Implications

This work-in-progress study proposes an AI-enhanced TPACK training model aimed at addressing persistent gaps in project management competencies within Kuwait's construction vocational education sector. By integrating AI within a pedagogically grounded design framework, the proposed model moves beyond surface-level technology adoption toward meaningful, competency-based learning experiences. The study highlights the potential of AI-driven simulations, adaptive learning support, and performance analytics to enhance applied knowledge and integrative project management skills in complex construction environments.

From a practical perspective, the proposed model offers a scalable approach for vocational institutions seeking to modernise project management training in alignment with evolving construction industry requirements. From an academic perspective, the study extends the application of the TPACK framework to AI-supported, student-facing vocational training contexts, contributing a conceptual foundation for future empirical research.

Future empirical phases employing mixed-methods analysis are expected to provide quantitative evidence of competency development alongside qualitative insights into learner engagement and instructional effectiveness.

While the present work is limited by its pilot scope and single-institution context, future studies are encouraged to examine larger-scale implementations, longitudinal workplace performance outcomes, and cross-institutional replications to further validate and refine the proposed model.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Kawthar A. Jafar led the conceptualization, literature review, and development of the training framework. Dr. Sahar R. Hamzah contributed to methodological design and academic supervision. Prof. Alajab M.A. Ismail provided expert guidance on project management competency alignment and research validation. All authors reviewed and approved the final manuscript.

Acknowledgment

The authors thank the faculty of the College of Education, Administrative and Technological Sciences at Arabian Gulf University for their guidance and support throughout the development of this study.

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