Exploration of Transformation Pathways for Technical Quality Management Experience at Engineering Sites within the Teaching of Construction Engineering Project Management Courses

Hongtao Wang*

Hainan Vocational University of Science and Technology, Haikou, 571126, China
**Corresponding author: victory0311@163.com*

Abstract: *The teaching of Construction Engineering Project Management courses has long been plagued by a disconnect between theoretical instruction and the demands of engineering practice. In particular, the technical quality management experience embedded in complex on-site contexts is difficult to effectively transform into teaching resources. This exploration aims to establish a systematic transformation pathway to bridge this gap. The pathway begins with the theoretical deconstruction of on-site experience and the extraction of its pedagogical essence. It involves identifying and structuring core elements such as technical planning, process control, and outcome evaluation, while also analyzing the obstacles and mechanisms involved in making tacit knowledge explicit. Subsequently, it reconstructs the teaching objective system centered on core competencies including technical cognition, managerial execution, and professional literacy. Building upon this foundation, the pathway designs modular teaching content and integration strategies based on experience transformation. It comprehensively employs problem-oriented and scenario-simulation teaching methods, and establishes a teaching feedback mechanism focused on formative assessment and competency achievement evaluation. To ensure the sustainability of transformation effectiveness, it further proposes the establishment of a dynamic teaching resource repository, the creation of a feedback-driven teaching iteration cycle, and the reinforcement of guarantee mechanisms aimed at enhancing the transferability of skills to professional contexts. This research provides a theoretical framework and practical guidance for transforming individualized, context-specific engineering site experience into teachable and assessable systematic course content.*

Keywords: *On-site engineering experience; Technical quality management; Pedagogical transformation; Competency; Scenario simulation*

Introduction

The Construction Engineering Project Management course serves as a crucial link between professional theory and industry practice. The effectiveness of its teaching directly impacts the competency of future engineering technicians in solving complex on-site problems. However, traditional course instruction often overemphasizes the teaching of regulatory provisions and generic management processes. It lacks an effective mechanism for transforming and integrating the highly contextualized and comprehensive technical quality management experience gained at engineering sites. Consequently, students may acquire knowledge yet struggle to develop the comprehensive abilities needed to address real-world challenges. This disconnect highlights the necessity and urgency of exploring systematic transformation pathways.

The significance of this research lies in moving beyond the simple use of on-site experience as case studies. It is committed to exploring, across the complete chain from theoretical deconstruction and curriculum reconstruction to mechanism building, how discrete, tacit practical experience can be refined, codified, and transformed into structured, transferable teaching content and competency development models. The core objective is to address the questions of "what to teach," "how to teach," and "how to sustain effective teaching." It aims to promote a fundamental shift in course teaching from knowledge transmission to competency cultivation and mindset development, thereby providing a concrete pedagogical reform plan for training high-quality engineering technical management personnel who meet the evolving demands of the industry.

1. Theoretical Deconstruction of On-site Experience and Extraction of Its Pedagogical Essence

1.1 Identification and Structuring of Technical Quality Management Elements in Engineering Projects

The core elements of technical quality management in engineering projects can be identified as three interrelated dimensions: technical planning, process control, and outcome evaluation. The technical planning element encompasses construction organization design, the compilation and review of specialized plans, drawing review and detailing, and the technical disclosure system. Its structure is manifested through vertical integration from overall deployment to operational levels and horizontal coordination among various specialized plans. The process control element includes the management of materials and equipment, process acceptance inspections, physical measurements and inspections, quality patrols, and the closed-loop rectification process. Its structuring relies on standardized workflows, a clear responsibility matrix, and timely information feedback mechanisms. The outcome evaluation element relates to subsequent stages such as the acceptance of divisional and subsection works, final project acceptance, and the pursuit of excellence awards. Its structure is characterized by target-oriented upfront planning and traceability management throughout the entire process.

To pedagogically structure these identified elements, it is necessary to construct a multi-tiered framework. At the macro level, this involves mapping the relationship between the quality management system and the project's overall objectives. At the meso level, it requires modularizing the key points and methods of technical quality control for each phase, such as foundation work, main structure, and finishing work. At the micro level, it entails detailing the standards, common issues, and preventive measures for specific process nodes. For example, drawing on practices from projects awarded the Gold Medal for Steel Structures and concrete structure engineering, knowledge points such as construction techniques for complex joints, the layout of measurement control networks, and the prevention of common defects in welding or concrete quality can be systematically integrated into different teaching modules, forming a complete knowledge chain that progresses from concepts to methods and then to specifics[1].

1.2 Analysis of Barriers and Mechanisms in the Pedagogical Transformation of Tacit Knowledge Explicitation

A significant amount of tacit knowledge in engineering sites exists within the trade-off process of technical decision-making, the emergency response to unforeseen problems, the strategies for multi-party communication and coordination, and the intuitive judgments based on experience. This type of knowledge is characterized by high context-dependency and individualization, posing significant barriers to its pedagogical transformation. The primary barrier is the lack of embodied cognition. Students cannot personally experience the sense of pressure and the integrated information input within complex construction site environments, making it difficult for them to appreciate the multi-dimensional constraints-safety, quality, cost, and schedule-involved in selecting technical solutions. Secondly, tacit knowledge often exists in a non-codified, "tacit" form. The holders of such experience may themselves find it difficult to clearly articulate their thought processes and decision-making rationale, leading to challenges in extraction.

The key mechanism for explicating tacit knowledge lies in designing effective "scenario simulation" and "cognitive externalization" components. Scenario simulation aims to construct decision-making environments that closely approximate reality through methods such as case-based teaching, virtual simulation, and project-based learning. This guides students to experience and construct their own cognitive models while solving simulated problems. Cognitive externalization, on the other hand, requires instructors to conduct deep analysis and present their experiential decision-making logic, error reviews, and communication strategies in a step-by-step manner through structured reflection. For example, the complex process of addressing sudden leakage in a deep foundation pit or coordinating technical conflicts between general and specialized contractors can be transformed into a clear thinking pathway map. This map would include stages such as problem identification, information gathering, solution comparison and selection, risk assessment, decision implementation, and feedback adjustment. Consequently, students can "glimpse" and learn the originally ineffable thinking processes.

1.3 Restructuring the Teaching Objective System Oriented Towards Core Competencies

The teaching objectives of traditional Construction Engineering Project Management courses often overemphasize the memorization of theoretical knowledge and regulatory provisions, creating a gap with the comprehensive competencies required on-site. Restructuring needs to be oriented towards core competencies. This competency model should integrate technical cognitive ability, managerial execution ability, and professional literacy. Technical cognitive ability includes not only understanding codes and standards but, more importantly, emphasizes innovative thinking and computational analysis skills for solving non-standard technical problems within the regulatory framework. Managerial execution ability encompasses planning, resource coordination, process control, and risk management. Professional literacy involves professional ethics, communication and collaboration, and lifelong learning[2].

Based on this model, the teaching objective system must shift from "knowing what" to "doing what" and "thinking how." Specifically, teaching objectives should be tiered. At the foundational level, the objective is to master the basic concepts, processes, and tools of technical quality management. At the application level, the objective is to be able to develop feasible technical solutions and quality plans for given project scenarios and to identify potential risks. At the comprehensive innovation level, the objective is to possess the ability to conduct integrated analysis, make decisions, and justify their rationale within complex simulated situations characterized by incomplete information and conflicting constraints. For example, a teaching objective could be set as "students should be able to collaboratively plan the critical path, control points, and core deliverable documents for the lifecycle technical quality management of a specific project type, such as a super high-rise steel structure or a large-scale residential block with full decoration." This objective drives students to integrate and apply multidisciplinary knowledge, simulating the complete process from technical planning to project delivery.

2. Design of Course Content and Pedagogical Models Based on Experience Transformation

2.1 Construction and Integration Strategy for a Modular Teaching Content System

The construction of a modular teaching content system should be designed along dual axes: the full-cycle processes of technical quality management and the requirements of core competencies. The vertical axis, based on the project management lifecycle, can be divided into three major phase modules: "Technical Planning and Preliminary Work," "Construction Process Control," and "Project Completion Acceptance, Delivery, and Maintenance." The horizontal axis integrates core competency threads that run through all phases, such as "Proficiency in Drawing and Code Application," "Ability to Formulate and Compare Technical Solutions," "Ability to Identify and Mitigate Quality Risks," and "Ability to Communicate and Coordinate with Multiple Stakeholders." Each module is no longer an isolated unit of knowledge but rather a competency development package containing key theoretical points, typical cases, tools and methods, and simulation tasks.

The key to the integration strategy lies in academically refining and pedagogically encoding personalized on-site experience, and then organically embedding it into the aforementioned modules. For example, the experience of participating in the technical proposal preparation for the terminal building of Beijing Daxing Airport can be transformed into a case study on "Key Points of Technical Planning for Large-Scale Complex Public Buildings" and integrated into the "Technical Planning and Preliminary Work" module. Similarly, the experience gained from managing the full-decoration delivery and coordinating large-scale maintenance for the Haikou residential relocation project can be systematically developed into a specialized topic on "Delivery Management and Client Relationship Maintenance for Residential Projects," which is then incorporated into the "Project Completion Acceptance, Delivery, and Maintenance" module. This type of integration is not merely a simple accumulation of cases. Rather, it involves converting the implicit decision-making logic, standards, and deviations embedded within the experience into teaching materials suitable for analysis, discussion, and simulation exercises, thereby achieving a structural alignment between experiential knowledge and disciplinary theory.

2.2 Comprehensive Application of Problem-Oriented and Scenario-Simulation Teaching Methods

Problem-oriented teaching uses authentic, complex, and ill-structured problems originating from real-world sites as the starting point for learning. These problems typically do not have a single standard answer. Examples include: "During deep foundation pit construction, how should the dewatering and support plans be adjusted when encountering an unexpected high groundwater level and the presence of important historical buildings nearby?" or "Under general contracting management, how can the cross-construction interfaces among curtain wall, mechanical/electrical, and interior finishing contractors be effectively coordinated to prevent quality defects and schedule delays?" These questions are directly linked to the core challenges of technical quality management, driving students to actively search for knowledge, analyze constraints, weigh multiple factors, and propose solutions[3].

Scenario simulation teaching, in turn, provides a realistic implementation field for problem-solving. It can design serialized role-playing simulation tasks based on real project backgrounds, such as a super high-rise building in the Beijing CBD commercial district or an intelligent office building project in the Jiangdong New District of Haikou. Students are divided into groups to assume different roles, such as the project owner, designer, general contractor, specialized subcontractor, and supervision engineer. They engage in simulated negotiations, decision-making, and document preparation surrounding specific technical quality issues, such as disputes during drawing reviews, mock-up section acceptance, handling quality incidents, and handover of completion documentation. This method transforms static knowledge transmission into dynamic competency practice. It enables students, through role immersion, to profoundly appreciate the management logic, communication strategies, and boundaries of responsibility underlying technical problems, effectively facilitating the transfer and internalization of tacit knowledge.

2.3 Design of Formative Assessment and Competency Achievement Evaluation Mechanisms

Traditional summative assessment, primarily based on final examinations, is insufficient for effectively measuring students' comprehensive competency achievement in technical quality management. The design of a formative assessment mechanism should be integrated throughout the entire teaching activity cycle, with its core being the collection of key evidence that reflects the process of students' competency development. Assessment tasks must be highly aligned with modular teaching content and scenario simulation activities. For example, to evaluate students' learning outcomes in the "Technical Planning" module, a comprehensive judgment can be made based on the quality of a simulated technical plan they submit for a specific divisional work, the depth of questions they raise during simulated drawing review sessions, or the logical rigor of their arguments in solution comparison discussions.

The evaluation of competency achievement requires the establishment of a multi-dimensional indicator system. This system may include: a knowledge application dimension (e.g., the standardization and completeness of plans and technical disclosure documents), a problem-solving dimension (e.g., the depth of analysis and feasibility of measures regarding complex issues in simulated cases), a teamwork and communication dimension (e.g., contribution level, clarity of expression, and negotiation skills demonstrated during role-playing), and a professional literacy dimension (e.g., the rigor of technical documentation and the understanding of quality and safety baselines). The evaluation subjects should also be diversified, incorporating teacher assessment, peer review, and self-assessment. Ultimately, through methods such as portfolio assessment, the process-oriented outputs generated by students across various modules and scenario tasks-such as reports, plans, meeting minutes, and reflection journals-are integrated. This allows for a comprehensive and developmental evaluation, thereby more accurately mapping the growth trajectory and actual level of students' core competencies.

3. Construction of Sustainable Safeguard Mechanisms for Transformation Effectiveness

3.1 Establishment of a Dynamic Teaching Resource Repository and Knowledge Management Platform

The establishment of a dynamic teaching resource repository serves as the foundation for capitalizing and managing experiential knowledge. This repository should not be a static collection of cases or documents but rather a knowledge system structured with multiple tags according to project lifecycle phases, specialized domains, problem types, and competency dimensions[4]. Its content sources must be diversified, including but not limited to: forward-looking engineering project technical documents from instructors (such as construction organization plans, specialized plans, drawing review records, and quality inspection reports); the latest technical standards and construction methods from industry developments; in-depth analysis reports of typical quality incidents; and excellent solutions as well as analyses of common pitfalls generated by previous students during scenario simulations. For example, materials such as the analysis of key technical challenges in the tender for the Beijing Daxing Airport terminal building and the implementation pathway for the Three-Star Green Building standard in the Jiangdong New District intelligent office building project in Haikou can be anonymized, pedagogically encoded, and incorporated into the repository.

The function of the knowledge management platform lies in supporting intelligent retrieval, associative analysis, and collaborative development of resources. The platform should be equipped with version control functionality to document the evolutionary history of solutions for the same category of technical problems. It should also possess associative push capabilities, automatically linking relevant regulatory provisions, positive/negative case studies, and virtual simulation resources when a specific knowledge point is being explained. Furthermore, the platform serves as a collaborative workspace, enabling the teaching team to jointly annotate, revise, supplement existing resources, or develop new teaching modules based on newly acquired industry information or teaching feedback. Through this platform, individual experience is consolidated into collective wisdom, forming standardized "knowledge components" that can be flexibly utilized across different teaching stages.

3.2 Feedback-Driven Teaching Iteration and Content Update Cycle

The continuous optimization of teaching effectiveness relies on a rigorous, feedback-driven iteration cycle. The input to this cycle consists of a multi-source, high-frequency stream of feedback data. This primarily includes student learning process data (such as performance in simulation tasks, depth of online discussions, and iterative versions of solutions), summative competency evaluation data, post-graduation career development tracking information, and macro-level signals indicating shifts in industry technology and management paradigms. The systematic collection and analysis of this data serve as the crucial basis for diagnosing the effectiveness of teaching content and methods.

Based on the conclusions drawn from data analysis, teaching iteration must follow a clear logic and established procedures. When feedback data indicate a widespread misunderstanding among students regarding a particular complex technical management aspect, such as the review process for ultra-hazardous major engineering schemes, it triggers an immediate review of the corresponding teaching content. This iteration may manifest as updating case studies, refining the rules of scenario simulation tasks, or adding targeted micro-lectures. The content update cycle must be closely linked to industry trends, establishing a "monitoring-integration" mechanism. For instance, when prefabricated construction, intelligent building, or new digital tools for quality management become mainstream in the industry, it is essential to promptly transform the latest relevant technical specifications, application scenarios, and potential challenges into teaching modules. These should replace or update outdated content to ensure the course remains both cutting-edge and practical[5].

3.3 Cultivation Pathways for Transfer to Professional Contexts and Higher-Order Thinking Skills

The long-term goal of the safeguard mechanisms is to promote the effective transfer of students' acquired competencies to future diverse and uncertain professional contexts. This requires teaching to go beyond solving known problems and to consciously design cognitive bridges to uncharted territories. The cultivation pathway must deliberately transcend the specific details of individual projects and technologies, guiding students to focus on the fundamental principles, universal models, and adaptive strategies underlying technical decision-making and managerial actions. For example, through comparative analysis of the commonalities and specificities in technical quality management across different project types-such as commercial complexes, super high-rise residential buildings, and large transportation hubs-students can develop their abilities in abstract generalization and differentiated management.

The cultivation of higher-order thinking skills focuses on shaping systems thinking, critical thinking, and innovative problem-solving abilities. During the teaching process, it is necessary to design some unstructured challenges. For example, providing a flawed technical plan and requiring students to conduct an independent review and risk assessment; or setting up a virtual scenario with severely compressed resources and deadlines, requiring students to replan the technical approach and refocus quality control priorities. Such tasks aim to train students' abilities to make trade-off judgments, construct logical arguments, and propose creative solutions under conditions of incomplete information and conflicting objectives. The ability to transfer learning to professional contexts is precisely cultivated through confronting these complex challenges. This process enables students not only to handle simulated problems within their current studies but also to develop a mindset and methodological toolkit capable of addressing novel challenges in their future careers.

Conclusion

This study focuses on the effective transformation of technical quality management experience from engineering sites into course teaching, systematically exploring and constructing an integrated pathway encompassing theoretical deconstruction, model design, and safeguard mechanisms. This pathway first achieves the preliminary transformation of experiential knowledge from tacit to explicit and from fragmented to systematic through the identification, structuring, and extraction of the pedagogical essence of on-site experience. Subsequently, guided by core competencies, it designs a modular teaching content system, a teaching model that combines problem-oriented and scenario-simulation methods, and a supporting formative competency evaluation mechanism. This completes the organic integration and competency transformation of experiential knowledge within the "teaching-learning-assessment" cycle. Finally, by proposing sustainable safeguard mechanisms such as the establishment of a dynamic resource repository, a feedback-driven iteration cycle, and the cultivation of higher-order thinking skills, it ensures the transformation pathway can adapt to the long-term demands of industry evolution and pedagogical development. The construction of this pathway provides a systematic logical framework and practical reference for deepening the teaching reform of Construction Engineering Project Management courses. Future work should focus on conducting empirical application research on the constructed pathway, using teaching experiments and long-term tracking to quantitatively evaluate its actual effectiveness in enhancing specific student competency dimensions. Simultaneously, continuous attention must be paid to emerging trends such as intelligent construction and sustainable development, to continuously iterate and enrich the pathway's content, thereby maintaining its vitality and foresight.

References

[1] Sun Ying. "Research on the Teaching Reform of 'Engineering Project Management' Course under the Transformation and Development of the Construction Industry." Modern Vocational Education .27(2025):145-148.

[2] Cheng Jiajia, et al. "Digital-Intelligent Reform of Engineering Project Management Oriented towards Engineering Management Majors." Journal of Luoyang Normal University 44.08(2025):77-80.

[3] Liang Shaofang. "Research on the Teaching Practice of Construction Engineering Project Management Course Based on the 'Learning-Training-Competition-Research-Innovation' Model." Journal of Changchun University 35.06(2025):80-83.

[4] Jiang Xue, Zhou Qingxia, and Tan Siyuan. "Exploration on Teaching Reform of Higher Vocational Construction Engineering Technology Courses-Taking 'Construction Engineering Project Management' as an Example." Brick and Tile .04(2024):168-170+173.

[5] Peng Cong, Liu Zhengquan, and Huang Yijian. "Application of 'Internet+' Platform Real-Time Interactive Information Technology in Engineering Project Management Course Teaching." Housing and Real Estate .36(2020):253+260.