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Strategic Pathways for Developing TPACK in Vocational College Teachers from the Perspective of Generative AI

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Abstract

As a core technology driving the new wave of industrial revolution, Generative Artificial Intelligence (GenAI) is profoundly reshaping the ecosystem and substance of vocational education, imposing unprecedented demands on the professional competencies of its educators. The Technological Pedagogical Content Knowledge (TPACK) framework, a critical measure of a teacher's ability to integrate technology, requires urgent re-examination of its connotations and developmental pathways from the perspective of GenAI. Employing methods of literature review and qualitative analysis, this study first deconstructs the systemic challenges that GenAI poses to the TPACK framework for vocational college teachers across technological, content, pedagogical, and ethical dimensions. Subsequently, through an analysis of existing research on frontline educators, it reveals the developmental predicaments they face in terms of cognitive attitudes, knowledge and skills, practical application, and environmental support. Based on these findings, this study constructs a three-tiered strategic framework for competency development—encompassing foundational, integrative, and comprehensive levels—and proposes corresponding implementation guarantees at the institutional, organizational, and cultural levels. The research posits that, guided by systematic strategies, vocational college teachers must transition from mere technology users to designers of human-AI collaborative instruction, thereby adapting to the urgent need for cultivating high-caliber, skilled talent in the intelligent era.

Keywords

Generative AI, TPACK, Vocational College Teachers, Competency Development, Strategic Pathways

1. Introduction

1.1. Research Background

Artificial intelligence is rapidly reshaping the educational systems of nations worldwide [1]. Generative Artificial Intelligence (GenAI), with large language models at its core, is transforming societal modes of production and professional skill sets with unprecedented depth and breadth. Liu *et al.* (2025) contend that GenAI is bringing about a disruptive transformation in the field of education [2]. As the educational sector is most intrinsically linked to industrial development, vocational education experiences a synergistic evolution between its reforms and technological progress. The rise of GenAI presents not only historic opportunities for the pedagogical models, curriculum content, and evaluation methods within vocational education but also poses systemic challenges to its most crucial element: the professional competence of its teachers. As the primary force in cultivating high-quality skilled and technical talent, the ability of vocational college teachers to proactively adapt to and effectively harness GenAI directly impacts our nation's industrial competitiveness and the quality of autonomous talent development in the intelligent age.

1.2. Problem Statement

Distinct from general education, vocational education is characterized by its pronounced integration of industry and education and its skills-oriented nature. The impact of GenAI is particularly acute in this context, creating a tripartite crisis of adaptation for vocational teachers across the dimensions of knowledge, competence, and 观念 (concepts/beliefs). Firstly, at the level of Technological Knowledge (TK), the rapid iteration of GenAI has induced widespread technological anxiety among educators, as rudimentary tool operation is no longer sufficient to meet instructional demands. Secondly, concerning Content Knowledge (CK), AI is accelerating the renewal cycle of industry knowledge, causing traditional textbook content to become rapidly dislocated from frontline industry practices and challenging the knowledge authority of teachers. Lastly, in terms of Pedagogical Knowledge (PK), traditional teacher-centered paradigms are ill-suited to the personalized and inquiry-based learning needs driven by AI, making pedagogical reform an urgent imperative. In this context, conventional models of professional development, which rely on short-term training or individual exploration, have proven inadequate for systemically addressing these challenges. It is therefore essential to construct a new paradigm for teacher competency development that is adapted to the characteristics of the GenAI era and aligned with the principles of vocational education.

1.3. Significance of the Study

The theoretical significance of this study lies in situating the established TPACK framework within the intersecting perspectives of GenAI and vocational education for a contextualized re-examination. It explores the evolution and expansion of the framework's theoretical connotations, with a particular focus on the ethical dimension, aiming to enrich the theoretical discourse on teacher professional development. The practical significance is even more pronounced. Through systematic analysis, this study seeks to construct a concrete and actionable strategic framework for developing TPACK competencies among vocational college teachers. This framework is intended not only to provide a clear "roadmap" for the self-improvement of frontline educators but also to offer valuable decisional references for institutional teacher training programs, resource development, and the policy-making of relevant educational administrative bodies, ultimately serving the national strategies of digital transformation in education and the cultivation of innovative talent.

1.4. Definition of Core Concepts

- Generative Artificial Intelligence (GenAI): Refers to AI technology based on large-scale models that, through learning from vast datasets, can autonomously generate multimodal content such as text, images, and code. Within the educational sphere, it functions not merely as an auxiliary teaching tool but as a cognitive partner capable of deep interaction and co-creation with both teachers and students. As Ke (2024) notes, GenAI empowers the entire educational process, even suggesting that "the machine, teacher, and student engage in mutual, bidirectional learning and construction, forming a tripartite community with a shared educational destiny." [3]
- TPACK Competency: An acronym for Technological Pedagogical Content Knowledge, this seven-dimensional framework comprises three core elements—Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK)—and their intersections (PCK, TCK, TPK), culminating in their holistic integration as TPACK [4]. It serves as a core construct for analyzing and measuring a teacher's proficiency in effectively integrating information technology into instruction within a specific subject context.

2. Challenges and New Requirements for the TPACK Framework from the Perspective of Generative AI

As Li (2025) points out, "the development of AI technology brings multiple challenges and impacts to teaching philosophies, content, resources, and models." [5] GenAI fundamentally challenges every dimension of the TPACK framework, imposing new demands for our time.

2.1. The Impact of GenAI on the Core Knowledge Elements of TPACK

GenAI has catalyzed profound changes within the core knowledge elements of TPACK. Firstly, it has enriched the substance of Technological Knowledge (TK). Whereas traditional TK focused on hardware and software operational skills, in the GenAI era, its core has shifted to the cognitive and practical abilities required for human-AI collaboration. Teachers must not only know how to use these tools but also understand their generative logic, master effective Prompt Engineering techniques, and possess the capacity for critical evaluation of AI-generated content. Secondly, Content Knowledge (CK) has become increasingly dynamic. The CK of vocational education is intimately tied to industry practice, and GenAI can capture and generate the latest industry trends and technological applications in real-time. This renders static, fixed textbook knowledge rapidly obsolete. A teacher's CK is no longer measured by the volume of knowledge possessed, but by the ability to dynamically acquire, verify, integrate, and transmit fluid, cutting-edge disciplinary knowledge using AI. Finally, Pedagogical Knowledge (PK) is witnessing the emergence of new paradigms with the aid of GenAI. The powerful capacity of GenAI for personalized support is driving a shift from "standardized instruction" to "customized education." This demands that teachers' PK evolves from traditional methods like lecturing and demonstration to more complex, modern paradigms such as designing and guiding personalized learning, data-driven instruction, project-based inquiry, and virtual simulation training.

2.2. The Challenge of GenAI to the Integration of Intersecting Knowledge in TPACK

GenAI impacts not only the individual knowledge elements of TPACK but also profoundly challenges their integration. Firstly, it presents a challenge to Technological Pedagogical Knowledge (TPK): How to design effective human-AI collaborative learning activities that leverage the advantages of AI while preventing student dependency and fostering higher-order thinking has become a central dilemma for TPK. Secondly, it challenges Technological Content Knowledge (TCK): How to utilize AI to transform abstract industrial principles and complex processes into vivid, intuitive, and interactive instructional content, while ensuring its accuracy and currency, poses a direct test to the TCK of vocational teachers. Finally, it challenges Technological Pedagogical Content Knowledge (TPACK): The highest-level challenge lies in seamlessly integrating GenAI, advanced pedagogies, and dynamic subject matter content within authentic industry-integrated projects or practical training scenarios to create novel, high-value learning experiences. This requires teachers to possess an exceptional degree of integrated design and innovative capabilities.

2.3. A New Requirement: The Prominence of the Ethical Dimension (GenAI-TEAK)

The traditional TPACK framework addresses ethical issues in a relatively implicit manner. However, GenAI introduces a series of acute ethical risks, including data privacy, algorithmic bias, ideological influence [2], academic integrity, and intellectual property rights. As Liu *et al.* (2025) state, "the powerful capabilities emerging from large models are commensurate with the ethical challenges they bring." [2] It is therefore imperative to supplement the TPACK framework with Techno-

Ethical Assessment Knowledge (TEAK) for the GenAI era. Rather than being a standalone eighth component, TEAK should be conceptualized as an essential ethical layer that permeates and informs every other domain within the framework. It represents the wisdom to critically evaluate and responsibly apply GenAI, ensuring that its use aligns with pedagogical goals and societal values. GenAI-TEAK requires teachers to possess the ability to make ethical judgments and risk assessments when using AI technologies, ensuring that their application aligns with educational ethics and pedagogical goals, thereby realizing "AI for good."

3. Predicaments in the Development of TPACK Competency for Vocational College Teachers from the Perspective of Generative AI

In the burgeoning wave of GenAI, vocational teachers face challenges both internally, in terms of cognition and skills, and externally, regarding the application environment and policy.

- At the Cognitive and Attitudinal Level: A widespread sense of "technological anxiety" and "role ambiguity" prevails. On one hand, teachers feel overwhelmed by the rapid advancement of AI and its integration into new teaching paradigms [2]. On the other hand, the shift from "knowledge authority" to "learning facilitator" causes discomfort and confusion, with some teachers harboring misconceptions about AI technology [2] and maintaining a conservative or resistant stance toward its educational application.
- At the Knowledge and Skills Level: A lack of systematic knowledge is a core impediment. The GenAI-TK of most teachers is limited to a superficial use of common chatbots, lacking a deep understanding of their underlying principles and advanced application skills. A survey of over 250 teachers from 12 universities at different levels in Jilin Province showed that "fewer than 20% of teachers are proficient in using AI for teaching innovation, such as developing personalized courseware or using intelligent algorithms for student performance analysis" [6]. At the level of integrated knowledge, effectively translating cutting-edge industry information generated by AI into instructional content (GenAI-TCK) and designing learning activities that truly embody the advantages of human-AI collaboration (GenAI-TPK) also present significant difficulties.
- At the Practical and Application Level: Application scenarios are often monolithic and lack depth. The use of AI is frequently confined to preparatory and supplementary tasks such as lesson planning and information gathering, corresponding to the "Substitution" level of the SAMR model. In core areas like practical training and project development, the integration of AI is exceedingly limited. Moreover, teachers generally lack the methods and tools to effectively assess students' higher-order thinking and innovative abilities in an AI-enhanced environment.
- At the Environmental and Support Level: There is a deficiency of systemic sup-

port. Teachers report that institutional training is often perfunctory, focusing on basic tool introductions rather than providing systematic, sustained professional development. Furthermore, there is a scarcity of high-quality case studies of AI-enhanced teaching practices, interdisciplinary communication platforms, and institutional cultures that encourage innovation, leaving most teachers to navigate this new terrain in isolation.

4. Strategic Framework for Developing TPACK Competency in Vocational College Teachers from the Perspective of Generative AI

Based on the analysis of the aforementioned predicaments, this study, adhering to the principles of systematicity, practice-orientation, tiered progression, and ethical precedence, proposes a "three-stage progression" strategic framework for competency development.

4.1. Foundational Competency Development Strategies (TK & TEAK)

This stage aims to eliminate teachers' cognitive barriers regarding technology and ethics.

- Technology Empowerment Strategy: Implement "tiered and modularized" specialized training in GenAI tailored to specific vocational fields. The introductory module should focus on the fundamental principles, dialogue strategies, and operational skills of common large models to help teachers overcome technological apprehension. The intermediate module should cater to different professional needs, explaining how to use AI for industry-relevant instructional design, resource generation, and student learning analysis. The advanced module should concentrate on higher-level applications such as building custom AI teaching assistants for specific technical skills and model fine-tuning to cultivate a cohort of master teachers.
- Ethical Cognition Strategy: Establish a regular mechanism for deliberating on AI in education ethics. Through case studies, scenario simulations, and other methods, organize teachers to deeply explore issues of data privacy, algorithmic fairness, and academic integrity. This will allow them to anticipate potential ethical dilemmas in teaching, develop response plans, and thereby strengthen their cognitive and judgmental abilities in GenAI-TEAK.

4.2. Integrative Competency Development Strategies (TCK & TPK)

This stage is designed to foster the deep integration of technology with subject matter and pedagogy.

- Content Knowledge Reconstruction Strategy (TCK): Forge a new paradigm of "human-AI collaborative knowledge production" to bridge the gap between classroom content and rapidly evolving industry practice. Encourage teachers to form "AI + Industry" tracking groups to periodically scan and analyze industry reports, technical standards, and market trends using AI tools. This will enable them to dynamically update course content and case libraries, ensuring that teaching remains synchronized with industry demands.

For instance, an automotive engineering instructor might use a large language model to analyze and summarize the latest research on EV battery technology to update their curriculum, while a hospitality management teacher could use AI to analyze real-time guest review data from global hotel chains to identify emerging service standards and incorporate them into skills training.

- Promote AI-enhanced teaching models that simulate real-world work environments. The focus should be on advancing AI-based Project-Based Learning (PBL), virtual simulation training, and formative assessment.

This is particularly critical in vocational education, where learning must mirror authentic workplace challenges. For example, use AI to generate complex, interdisciplinary, real-world problems to drive projects; create high-fidelity virtual training environments for students to practice complex technical procedures safely and repetitively; and leverage AI to analyze student learning process data in real-time, providing personalized feedback and guidance. **To make this actionable, a teacher could use the following prompt sequence to generate a PBL scenario: "Act as a senior project manager in a logistics company. Create a detailed project brief for a team of student trainees. The task is to design a more efficient last-mile delivery solution for a dense urban area, considering cost, environmental impact, and customer satisfaction. The brief must include realistic constraints, key performance indicators (KPIs), and potential challenges they will face.".

4.3. Comprehensive Competency Development Strategies (TPACK)

This stage aims to achieve a holistic leap in TPACK competency.

- Community of Practice Construction Strategy: Form interdisciplinary "AI + Major" teaching innovation communities. These communities, oriented toward solving real workplace-integrated teaching problems, will explore deeply integrated AI teaching models through collective lesson planning, comparative teaching ("tong ke yi gou"), and action research. Such social interaction is a key mechanism for the "emergence" of complex knowledge like TPACK.

A guiding question for a community in a culinary arts program might be: "How can we use AI-powered recipe generation and analysis tools to teach students about flavor profiling and menu costing, while still ensuring they master foundational cooking techniques?"

- "Competition for Training" Driving Strategy: Regularly hold institutional or regional AI-empowered teaching innovation competitions. These competitions require teachers (or teams) to submit complete instructional design plans, lesson videos, and reflective reports that demonstrate comprehensive TPACK competency in a simulated or real-world industrial training context. The pull and incentive of competition can effectively stimulate teachers' intrinsic motivation for deep study and proactive practice, achieving a virtuous cycle of "learning through application and research through competition."

5. Guarantee System for Strategy Implementation

The effective implementation of the above strategies depends on a multi-layered, systematic support system.

5.1. Institutional Level

As General Secretary Xi Jinping has emphasized, "it is necessary to integrate multidisciplinary forces, strengthen research on AI-related legal, ethical, and social issues, and establish and improve the legal regulations, institutional systems, and ethical morals that ensure the healthy development of artificial intelligence" [7]. Given the ethical issues of GenAI, relevant departments should expedite the formulation of ethical norms and guiding principles for the application of AI in education, drawing clear "red lines" for its use. Concurrently, professional development standards and criteria for faculty evaluation and promotion should be optimized to include GenAI-TPACK competency as a key indicator of assessment and motivation.

5.2. Organizational Level

Institutions must provide organizational support, such as establishing specialized bodies like a "Center for Intelligent Teaching Development" to coordinate training, research, and technical support. They must also provide necessary resources, including AI software licenses, computing power, localized technological adaptation [6], and high-quality databases, to lower the barriers for teachers' application of these tools.

5.3. Cultural Level

An innovative culture is the fertile ground for growth. Institutions should actively foster an academic atmosphere that encourages exploration and tolerates failure, recognizing teachers' efforts in AI-driven teaching innovation. At the same time, it is essential to advocate for a new knowledge perspective that is open, shared, and autonomous, promoting a new teaching culture of human-AI collaboration and teacher-student co-creation. Embracing the philosophy that "the wisdom of the smart classroom originates from the intelligent synergy achieved by the teacher based on a humanistic standpoint, educational ethics, and teaching experience" [1], will enable teachers to truly embrace the changes of the intelligent era psychologically.

6. Conclusion and Future Outlook

6.1. Research Conclusion

From the perspective of Generative AI, the professional development of vocational college teachers is undergoing a profound paradigm shift. GenAI is not only a challenge to the existing TPACK competencies of teachers but also a catalyst for their reshaping and enhancement. This study posits that effectively addressing this challenge cannot rely on sporadic, ad-hoc training, but requires the construction of a systematic strategy for competency development. This strategic framework, structured in a progressive hierarchy of "foundational-integrative-comprehensive," synergistically advances teachers' competencies across the multiple dimensions of technology, subject matter, pedagogy, and ethics. It is supported by guarantees at the institutional, organizational, and cultural levels. The ultimate goal is to facilitate the fundamental role transition of vocational teachers from "transmitters of knowledge" to "designers and facilitators of human-AI collaborative, intelligent learning."

6.2. Research Limitations

The strategic framework constructed in this study is primarily based on literature review and theoretical speculation and lacks the support of empirical data. Its universality and effectiveness await validation through large-scale empirical research in the future. Furthermore, vocational colleges encompass a wide variety of disciplines, and the needs and strategic priorities for TPACK competency development may differ significantly between fields (e.g., engineering versus liberal arts). This study has not undertaken an in-depth, differentiated exploration of these areas.

6.3. Future Outlook

Future research could be extended in the following directions: First, developing a TPACK competency assessment scale specifically for vocational college teachers would provide a scientific tool for the precise diagnosis of their abilities and the effective evaluation of development strategies. Second, quasi-experimental studies could be conducted to empirically test the proposed strategic framework and examine its actual impact on teacher competency improvement. Finally, as the "teacher-student-machine" tripartite interactive model deepens, future research should intensify its focus on new pedagogical relationships, cognitive learning processes, and educational evaluation systems, with the aim of constructing a more complete educational theory for the intelligent age.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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