

Research on Physical Education Teachers' Digital Literacy under the TPACK Framework: Progress, Problems, and Prospects

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Abstract

With the in-depth advancement of the digital education strategy, physical education (PE) teachers' digital literacy has become a critical issue in the digital transformation of physical education. The TPACK framework provides a structured analytical perspective for understanding teachers' technology integration capabilities. This paper systematically reviews the developmental trajectory, core progress, and existing challenges of research on PE teachers' digital literacy within the TPACK framework. It is found that this field has evolved from conceptual introduction to disciplinary adaptation, and from theoretical discussion to targeted intervention, achieving phased achievements across three dimensions: theoretical exploration, practical application, and assessment tools. However, existing research still faces multiple constraints, including an insufficient theoretical integration between TPACK and digital literacy, homogeneous research methods with uneven population coverage, inadequate practical translation, a lack of disciplinary adaptation, and the long-term neglect of rural PE teachers. Future research should focus on deepening the physical-education-specific adaptation of the TPACK framework, expanding the scope of research methods and participant coverage, facilitating the translation of theory into practice, actively addressing issues surrounding emerging technologies such as artificial intelligence (AI), and advancing the field from "conceptual introduction" to "disciplinary construction" and from "status-quo description" to "targeted empowerment."

Keywords

TPACK framework; physical education teachers; digital literacy; research progress; disciplinary adaptation.

1. Introduction

1.1. Research Background

The Report to the 20th National Congress of the Communist Party of China explicitly proposed to "advance the digitalization of education." Subsequently, the Ministry of Education successively issued the industry standard "Digital Literacy for Teachers" and the "Notice on Organizing and Implementing the Action of Digitally Empowering Teacher Development," making teachers' digital literacy a critical factor in building a leading country in education. As an essential component of school education, physical education depends directly on teachers' digital literacy to determine whether technology can be genuinely implemented in instructional settings.

At the theoretical level, the Technological Pedagogical Content Knowledge (TPACK) framework has been widely applied across various disciplines, offering a structured analytical tool to help understand teachers' technology integration capabilities. In physical education, this framework not only assesses whether teachers can use technology, but also reveals the underlying

competence structure of how they utilize technology within the unique context of physical education.

In recent years, research on physical education teachers' digital literacy has gradually emerged, and the application of the Technological Pedagogical Content Knowledge (TPACK) framework has shifted from theoretical introduction to empirical exploration. However, existing studies still face issues such as the mechanical adoption of generic frameworks, insufficient attention to subject-specific characteristics, and inadequate research on rural teachers, having not yet established a systematic theoretical system or mature research paradigms. In light of this, this paper systematically reviews the research progress on physical education teachers' digital literacy under the TPACK framework, examines existing problems, and outlines future research directions, aiming to provide valuable references for theoretical deepening and practical advancement in this field.

1.2. Conceptual Definition

1.2.1. Theoretical Connotations of the TPACK Framework

Technological Pedagogical and Content Knowledge, abbreviated as TPACK, was proposed in 2005 by Koehler and Mishra, scholars at Michigan State University in the United States, based on Shulman's pedagogical content knowledge (PCK) (Koehler & Mishra, 2009). Koehler and Mishra argue that the TPACK framework comprises three core components: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). The intersection and integration of these three form four composite components: technological content knowledge (TCK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK) (Angeli & Valanides, 2008) (see the figure below for specific components). TPACK is not merely a simple aggregation of the three types of knowledge, but rather a dynamic knowledge system in which teachers integrate technology, pedagogy, and content within authentic teaching contexts. Adopting the TPACK framework as an analytical perspective, this study systematically reviews the progress of its application in research on physical education teachers' digital literacy.

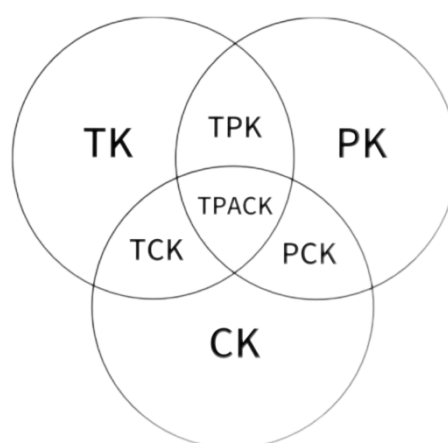


Fig. 1 Framework structure and element diagram of TPACK

1.2.2. Conceptual Definition of Physical Education Teachers' Digital Literacy

Currently, academia has not reached a unified definition of physical education (PE) teachers' digital literacy. Most existing studies reference the Teacher Digital Literacy standard issued by the Ministry of Education and elaborate on it in conjunction with the unique nature of the physical education discipline. Scholars such as Yin Zhihua et al. deconstructed it into a

comprehensive capacity across four dimensions (Yin et al., 2025); Xu Wenxin focused on the integration of tool application attitudes, data critique capabilities, and ethical norms (Xu, 2025); and researchers such as Li Sujun et al. refined a four-element logical framework from the perspective of systems theory (Li et al., 2024). Although scholars differ in their specific emphases, they all point to the common core connotation of "the comprehensive ability of PE teachers to utilize digital technology to optimize PE instruction." However, most definitions remain at the level of a direct transposition of generic frameworks into physical education, failing to adequately address the profound demands that the unique context of the discipline of physical education places on digital literacy. Based on the above analysis, this study defines physical education teachers' digital literacy as: a comprehensive competence system in which physical education teachers utilize digital technology to optimize physical education teaching and promote student development, encompassing dimensions such as digital awareness, digital technological knowledge and skills, digital pedagogical application, digital social responsibility, and professional development, which manifests in practical contexts as the ability to dynamically integrate technology, pedagogy, and subject matter content.

1.2.3. Conceptual Association Between TPACK and Physical Education Teachers' Digital Literacy

There is a profound theoretical connection between teachers' digital literacy and the TPACK framework. On the one hand, the "digital application" dimension in the "Teacher Digital Literacy" standard essentially requires teachers to possess the ability to deeply integrate digital technology with subject teaching, which is precisely the core competence described by the TPACK framework. On the other hand, the TPACK framework provides more detailed analytical dimensions for digital literacy research, thereby revealing teachers' specific shortcomings across various dimensions. Existing studies suggest that research on teachers' digital literacy based on the TPACK framework helps make up for the insufficient attention paid to "pedagogical integration ability" in traditional digital literacy assessments (Huang & Liu, 2024). Therefore, the TPACK framework serves as an appropriate theoretical tool for analyzing the digital literacy of physical education teachers.

2. Progress in Research on Physical Education Teachers' Digital Literacy Within the TPACK Framework

Research on the TPACK framework in the field of physical education has evolved over more than a decade, demonstrating a developmental trajectory from conceptual introduction to discipline-specific adaptation, and from macro-level descriptive assessments to targeted interventions. Early studies primarily focused on interpreting the applicability and analyzing the structural characteristics of the TPACK theory within physical education. Subsequently, researchers began to investigate the current status and influencing factors of physical education teachers' TPACK. In recent years, research has gradually shifted toward restructuring physical education teachers' digital literacy frameworks and constructing tiered cultivation models based on the TPACK framework, while incorporating emerging topics such as AI-TPACK and human-machine collaboration. Accordingly, this paper systematically reviews the research progress and phased achievements in this field across three dimensions: theoretical exploration, practical application, and assessment tools.

2.1. Theoretical Exploration: From Conceptual Introduction to Discipline-Specific Adaptation

During the theoretical introduction stage, the TPACK framework was introduced into the field of physical education teacher professional development. This not only clarified the practical, complex, and contextual characteristics of physical education teachers' TPACK, but also

constructed a structural system encompassing pedagogical beliefs, instructional content, teaching strategies, and classroom teaching environments, laying a theoretical foundation for subsequent research (Shang & Cheng, 2017). On this basis, related studies further elucidated the generative mechanisms of physical education teachers' TPACK from the perspective of transitioning from a "knowledge field" to a "learning community," advancing the theory from static structural analysis to dynamic generative mechanism research (Liu & He, 2018). In addition, from a TPACK perspective and addressing deficiencies in instructional methods and assessments within intercollegiate sport, other studies proposed integrating technology into physical education teaching to strengthen classroom surveillance and feedback, attempting to extend the theory toward practical application (Zhong & Yan, 2017).

As research progressed, scholars gradually recognized an evident adaptation gap between generic teacher digital literacy frameworks and the unique characteristics of physical education, such as bodily practice, situational openness, and data sensitivity. Some studies began attempting to construct competency models based on the TPACK framework, incorporating dimensions such as digital awareness and ethics, digital tool application, digital instructional design, digital resource development, digital evaluation and reflection, and digital collaboration and innovation, aiming to bridge the applicability gap of generic frameworks (Zhou, 2025). Other studies, grounded in competency theory, established a structural framework for physical education teachers' digital literacy comprising four tiers: foundational, application, developmental, and value levels, which further expanded the theoretical landscape of this field (Yin et al., 2025). Building upon this foundation, some scholars have explicitly proposed a "physical education-specific adaptation" based on the TPACK theory and, integrated with the contextual extension of digital ethics, attempted to construct a dedicated connotative framework for physical education teachers' digital literacy (Cheng et al., 2026). Moving from the "application of generic frameworks" to "physical education-specific adaptation" and ultimately to the "reconstruction of connotative frameworks," this evolutionary trajectory clearly illustrates the deepening theoretical construction of the TPACK framework in physical education, while also reflecting researchers' increasingly profound understanding of the pedagogical specificities of the discipline.

2.2. Practical Application: From Theoretical Discussion to Tiered Precision Intervention

In early practice, exploratory applications of the TPACK framework in physical education had already begun. Some studies attempted to introduce it into ball sports instruction for physical education majors in normal universities, accumulating empirical experience through the design and implementation of practical teaching platforms (Wang & Xu, 2014). Meanwhile, other scholars began to focus on instructional methods, assessment, and evaluation in higher education physical education, proposing improvement strategies from the TPACK perspective and preliminarily verifying the applicability and operability of the framework in physical education teaching (Zhong & Yan, 2017). However, research during this stage primarily relied on case explorations and strategic recommendations, having not yet established a systematic empirical research paradigm.

As research progressed, the field gradually shifted from macro-level status descriptions to micro-level targeted interventions. Addressing the systemic dilemmas commonly found in primary and secondary physical education teachers' digital literacy, such as widening competency disparities, suboptimal training effectiveness, and difficulties in practical implementation, a study integrated TPACK theory with the DigCompEdu framework to develop a three-dimensional competency framework spanning basic operations, integrated applications, and innovative leadership, alongside a tiered cultivation model, thereby facilitating a transition in physical education teachers' digital literacy research from theoretical

exposition to tiered, precise development (Xie, 2026). Further diagnosis of the dilemmas in physical education teachers' digital literacy revealed a threefold predicament characterized by insufficient cognitive valuation, a disconnect between application and pedagogical practice, and a lack of personalized support systems for development, which fundamentally stems from a mismatch between digital training content and physical education instructional settings, the inadequacy of digital resource supply in meeting the specific demands of sports disciplines, and the fragmentation between digital evaluation mechanisms and teachers' professional development pathways (Zhou, 2025). This finding indicates that the application of the TPACK framework in physical education cannot simply transplant generic paradigms; rather, it requires contextualized adaptation based on the intrinsic characteristics of physical education as a discipline.

In terms of target populations, research has progressively expanded to specific educational contexts. An investigation into rural primary school physical education teachers demonstrated that their technology integration capabilities urgently require enhancement, with rural educational settings exerting a prominent constraining effect on TPACK (Fu & Qiu, 2018). Physical education teachers in higher education similarly confront dilemmas during the transition to information-based instruction, primarily manifested in insufficient adaptability and a lack of scientific instructional design (Liu, 2022). A cross-regional survey further revealed that the overall TPACK level among physical education teachers remains low, with particularly deficient scores in dimensions related to technological knowledge, which showed no substantial improvement alongside higher educational attainment or increased years of teaching experience (Zhang & Ouyang, 2023). These findings indicate that teaching experience and TPACK competence do not exhibit a simple positive correlation, suggesting that conventional "accumulation of experience" alone is insufficient to naturally foster technology integration competence. Large-scale surveys have further confirmed that technological knowledge is a core predictor influencing teachers' ICT application competence and should serve as a priority entry point for the development of teachers' digital literacy (Ma et al., 2018). The aforementioned group differences suggest that future research needs to pay closer attention to the differentiated needs of physical education teachers across diverse educational contexts to explore more targeted, tiered intervention pathways.

2.3. Assessment Instruments: From Generic Scales to Subject-Specific Assessment

Assessment instruments serve as a critical link connecting theoretical constructs with empirical research, and their level of development directly affects the scientific rigor and reliability of research findings. In research on physical education teachers' digital literacy under the TPACK framework, assessment instruments have evolved from the adaptation of generic scales to the development of subject-specific tools.

Early studies largely drew upon or adapted existing generic scales to conduct investigations; although valuable in advancing empirical exploration, these instruments were limited in subject-specific adaptability, making it difficult to accurately capture the differentiated demands that the unique nature of physical education teaching places on teachers' TPACK competence (Cong & Jin, 2021). As research deepened, significant breakthroughs were achieved in the development of subject-specific assessment instruments. Guided by TPACK theory, researchers developed an evaluation scale specifically tailored to the TPACK competence of physical education pre-service teachers, covering seven dimensions; testing confirmed its good psychometric quality in terms of reliability and validity, marking a transition in physical education teachers' TPACK assessment from "borrowing scales" to "independent development" (Xie, 2020).

Building on independent development, assessment instruments have further evolved toward standardization (Xu, 2025). Drawing upon the evaluation framework in the Teacher Digital Literacy standards issued by the Ministry of Education, subsequent research integrated the Delphi method, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA) to develop a digital literacy scale for primary and secondary school physical education teachers, thereby providing an operationalized instrument for standardized assessment. From early indirect measurement relying on generic scales, to the development of specialized scales, and ultimately to the establishment of standardized assessment instruments, this evolution has laid an increasingly solid instrumental foundation for empirical research on physical education teachers' digital literacy. However, current assessments still rely predominantly on quantitative questionnaires, which fall short of thoroughly capturing the authentic manifestations of teachers' TPACK competencies in real-world classroom settings. Future research should build upon scale development to explore diverse assessment methods, including classroom observation, task performance analysis, and the evaluation of instructional artifacts, thereby more comprehensively reflecting the authentic level of physical education teachers' TPACK competence.

3. Critical Examination of Existing Research

A comprehensive review of the existing literature indicates that research on physical education teachers' digital literacy within the TPACK framework has yielded certain achievements; however, notable deficiencies remain in theoretical construction, research methodology, practical translation, disciplinary adaptation, and research perspectives.

3.1. Theoretical Level: Insufficient Integration of TPACK and Digital Literacy

Although existing studies have introduced the TPACK framework, they mostly treat it as a "label" for analyzing teacher competence rather than deeply integrating it into the structural diagnosis of physical education teachers' digital literacy. Most research still directly references the general standard "Digital Literacy for Teachers" issued by the Ministry of Education, leaving the three-dimensional integrative capacity of "technology, pedagogy, and content" emphasized by the TPACK framework insufficiently articulated. A distinct gap in alignment exists between the generic framework and the disciplinary characteristics of physical education, yet current research has not adequately addressed this issue. Such a "labeling" application prevents the structured diagnostic advantages of TPACK from being fully realized, making it difficult to fundamentally respond to the unique nature of the physical education discipline.

3.2. Methodological Dimension: Single Research Paradigm and Uneven Population Coverage

A systematic scoping review of TPACK research in physical education teacher education from 2012 to 2024 explicitly pointed out that empirical research in this field remains insufficient, with existing studies relying heavily on quantification methods and being geographically concentrated (Wang et al., 2026). Research in China faces the same limitation: research methods predominantly consist of questionnaire surveys, lacking in-depth qualitative exploration into how teachers' TPACK is enacted in actual classrooms; research subjects are largely concentrated on university physical education teachers and preservice physical education teachers, with relatively little attention paid to primary and secondary school physical education teachers, particularly rural physical education teachers. The narrowness of research samples limits the generalizability of the findings and prevents the differentiated characteristics of teachers' TPACK competence across diverse educational contexts from being fully revealed.

3.3. Practical Dimension: The Disconnection Between Training and Evaluation

Currently, the digital literacy of physical education (PE) teachers faces a threefold dilemma: insufficient cognitive attention, the detachment of application from pedagogical practice, and a lack of personalized developmental support. This predicament stems from the poor adaptability of digital training content to PE instructional scenarios, the misalignment between the supply of digital resources and the specific demands of sports programs, and the structural fragmentation between digital evaluation mechanisms and teacher professional development (TPD) pathways. This disconnect between learning and application impedes the effective implementation of the TPACK framework in practical contexts, such as teacher training curriculum design and the development of evaluation metrics. Concurrently, systemic issues, including inadequate safeguards and the unequal allocation of technological resources, as well as incomplete policy and institutional systems, continue to constrain the overall development of PE teachers' digital literacy.

3.4. At the level of disciplinary adaptation: The physical education-specific adaptation of TPACK remains incomplete.

Physical education possesses unique characteristics such as physical practice, situational openness, and data sensitivity, which impose higher demands on technology integration than general disciplines. However, current TPACK research predominantly transplants generic frameworks directly into physical educational contexts, failing to adequately address the differentiated demands of physical education instruction. Physical education instruction faces structural dilemmas, including difficulties in quantification, recording, coaching, and evaluation. Current technology integration remains largely at an instrumental level and has not yet achieved deep integration with disciplinary knowledge, pedagogy, and assessment systems. Although some scholars have become aware of this issue and attempted to adapt the TPACK framework specifically for physical education, related research remains in the preliminary exploratory stage, having not yet formed a systematic theoretical framework and practical system.

3.5. At the level of research perspective: Rural physical education teachers have long been neglected.

Existing TPACK research predominantly focuses on university and pre-service physical education teachers, paying extremely limited attention to primary and secondary school physical education teachers, particularly those in rural areas. Rural physical education teachers face unique circumstances such as resource scarcity, a lack of training, and multidisciplinary teaching duties, and the constraints on their TPACK development differ fundamentally from those of urban teachers. This research gap not only restricts the completeness of the knowledge system in this field, but also leaves the applicability and adaptation pathways of the TPACK framework in rural physical education educational contexts without adequate theoretical consideration, failing to provide effective support for improving the digital literacy of rural physical education teachers. Collectively, these issues limit the systematicity and effectiveness of research on physical education teachers' digital literacy within the TPACK framework, urgently calling for breakthroughs in future research.

4. Prospects for Future Research

Based on the preceding review of research progress and critical examination of existing issues regarding physical education teachers' digital literacy under the TPACK framework, future research can delve further across four dimensions: theoretical construction, research methodology, practical translation, and emerging issues, thereby advancing the field toward greater depth.

4.1. Deepening the theoretical construction of the physical education-specific adaptation of the TPACK framework

Currently, the coupling between the TPACK framework and the disciplinary characteristics of physical education remains insufficient, and its physical education-specific adaptation is still in its infancy. Future research should further clarify the differentiated demands imposed by the unique pedagogical contexts of physical education on each TPACK dimension, thereby constructing a theoretical model of digital literacy that reflects the discipline-specific attributes of physical education. Concurrently, greater emphasis should be placed on the hierarchical and dynamic nature of the theoretical framework. Building upon existing hierarchical structures, researchers should explore the evolutionary patterns of physical education teachers' TPACK competencies across different developmental stages, ultimately constructing a theoretical system with enhanced longitudinal explanatory power.

4.2. Expanding the Diversity of Research Methods and the Coverage of Target Populations

At the methodological level, the imbalance characterized by quantification dominance and qualitative scarcity, combined with the structural narrowness of research subjects marked by an overrepresentation of higher education institutions, a shortage in elementary and secondary schools, and an absence in rural areas, constitutes a major bottleneck constraining knowledge accumulation in this field. Future research should introduce qualitative methods such as classroom observation, in-depth interviews, and narrative research to deeply reveal the generation and transformation processes of teachers' TPACK competence in authentic teaching situations. Concurrently, particular focus should be placed on elementary and secondary physical education teachers, especially rural physical education teachers, to investigate the differentiated characteristics and development pathways of teachers' TPACK competence across diverse educational contexts.

4.3. Reinforcing Practical Transformation and Intervention Studies

The ultimate value of the TPACK framework lies in guiding practice. Future research should focus on opening pathways from theory to practice, designing tiered and targeted intervention programs based on the TPACK framework, and strengthening systematic evaluation and longitudinal tracking of intervention effects. Simultaneously, efforts should be made to promote the integration of the TPACK framework into teacher training curriculum design and the development of evaluation indicators, making TPACK a truly operable tool for guiding Teacher Professional Development (TPD).

4.4. Proactively addressing emerging technology issues such as artificial intelligence (AI)

The rapid development of GenAI is reshaping the educational ecosystem and posing new challenges to the digital literacy of physical education teachers. Future research should advance the evolution of the TPACK framework toward "Intelligent-TPACK" to explore the new competency structures required for physical education teachers in the AI era, including human-AI collaborative teaching competence and the pedagogical adaptability of AI tools. Meanwhile, research on cultivating the intelligent literacy of pre-service physical education teachers should be strengthened, with a focus on the mechanism of self-regulation in the formation of Intelligent-TPACK, thereby providing theoretical support for the forward-looking development of physical education teachers' digital literacy.

5. Conclusion

This article systematically reviews the developmental trajectory of research on physical education teachers' digital literacy within the TPACK framework, revealing the field's evolution from conceptual introduction to discipline-specific adaptation and from theoretical exploration to targeted interventions. Although phased achievements have been made in theory, practice, and tool development, research continues to face deep-seated constraints, including insufficient theoretical integration, methodological homogeneity, inadequate translation into practice, limited disciplinary adaptation, and the neglect of rural physical education teachers. Identifying these gaps provides a reference for understanding the knowledge landscape of the field and indicates directions for subsequent research expansion. Future research should promote the physical education-oriented development of theoretical frameworks, broaden methodological approaches and population coverage, strengthen the integration of theory and practice, and actively address the competency challenges posed by emerging technologies such as Artificial Intelligence (AI). Overall, advancing research in this field will not only enrich the academic discourse on the digital transformation of physical education but also provide tangible support for the professional development of physical education teachers.

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