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Theoretical and Practical Pathways of Artificial Intelligence Empowering Development of Primary School Physical Education Teachers

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Abstract: *Teachers are central agents of educational development, and the quality of education is fundamentally shaped by their professional competence. With the advancement of educational digitalization, artificial intelligence (AI) has emerged as a key driver of teacher professional development. Through data analytics, intelligent feedback, and personalized support, AI offers new possibilities for addressing the limitations of traditional professional development models for primary school physical education (PE) teachers, which have long relied on experiential transmission and centralized training. Aligned with the United Nations Sustainable Development Goal 4 (SDG4), which emphasizes inclusive, equitable, and high-quality education, primary school PE teachers play a critical role in implementing physical education curricula and promoting students' physical well-being. However, due to disciplinary characteristics and institutional constraints, PE teachers often face limited professional support and restricted career development opportunities. Guided by the research perspective of AI-enabled professional development, this study employs literature review and logical analysis to examine the current status, key challenges, and developmental pathways of AI-supported professional growth among primary school PE teachers. The findings indicate that AI applications in this field remain underdeveloped, with challenges including limited pedagogical innovation, uneven digital literacy, insufficient integration of intelligent technologies, and weak professional engagement. Accordingly, this study proposes four AI-empowered development pathways professional philosophy, professional knowledge, professional competence, and professional commitment providing theoretical insights to support sustainable teacher development and educational digital transformation.*

Keywords: Artificial Intelligence; Primary School Physical Education Teachers; Professional Development; Educational Digitalization; SDG4

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1. Introduction

Against the backdrop of ongoing technological revolution and industrial transformation, emerging information technologies, particularly artificial intelligence (AI), are profoundly reshaping societal operations and knowledge production models (Zhiheng, 2025a). As the foundational domain for talent cultivation and social development, education is undergoing a critical transition from traditional approaches toward digitalized and intelligent educational formats. Meanwhile, the United Nations Sustainable Development Goal 4 (SDG4) explicitly emphasizes the provision of inclusive, equitable, and high-quality education while promoting

lifelong learning for all. These objective places higher demands on the continuous improvement of educational quality and the sustained development of teachers' professional competencies ("The Practical Challenges and Breakthrough Pathways of AI Empowering University Physical Education," 2025a). In this context, the technical advantages of AI in data processing, intelligent analysis, and personalized support provide new foundations and practical opportunities for educational reform and teacher professional development. At this time, the technical strengths of AI in data processing, intelligent analysis, and personalized assistance offer new bases and practical paths for educational reform and teacher professional development. At the national level, several policies have been introduced to advance educational digitalization and drive the deep integration of information technology with teaching practice, thereby laying institutional and practical bases for AI-enabled teacher professional development (Zha et al., 2025).

Teacher professional development serves as a cornerstone for enhancing educational quality, a vital component of educational modernization, and a key driver in achieving the high-quality education goals advocated by SDG4.Traditionally, the development of teachers has mainly relied on centralized training, experience-sharing sessions, and expert guidance, which have helped in their professional development to a certain extent(Wang & Wang, 2024). However, with the complexity of educational situations and the growing differences among teachers, deficiencies in traditional professional development models, such as lack of personalized assistance, continuity in practice, and personalization for teachers, have gradually become apparent. Dependence on regular training and accumulated experience is no longer sufficient to meet the current requirements for professional development. Consequently, there is an urgent demand for innovative technological approaches that enable more precise, efficient, and sustainable professional growth.

With in the basic education system, physical education plays a vital role in enhancing students' physical fitness, supporting balanced physical and mental development, and cultivating healthy lifestyles (Wei et al., 2021). The primary school stage represents a critical period for physical development and the formation of long-term sports interests. Primary school physical education (PE) teachers therefore occupy an indispensable position in supporting students' healthy growth. From the perspective of promoting holistic student development and improving educational quality, the professional development level of primary school PE teachers directly influences the effective implementation of physical education curriculum objectives. This relationship closely aligns with SDG4's emphasis on quality and equity in education (Küçükuncular & Ertugan, 2025). Nevertheless, due to factors such as disciplinary characteristics, resource allocation constraints, and evaluation orientations, primary school PE teachers often encounter challenges including limited training opportunities, insufficient professional support, and restricted career development pathways. These constraints hinder the continuous enhancement of their professional competencies and ultimately affect the overall quality of school physical education.

As AI technologies are increasingly integrated into educational contexts, their potential to support teacher's professional development has become more evident. Through the continuous collection and analysis of teaching behaviors, classroom processes, and student learning data, AI provides evidence-based feedback that supports more systematic teaching reflection and informed professional decision-making. Compared with traditional experience-based reflection approaches, AI-supported professional development models offer clear advantages in terms of precision, continuity, and personalization. These features present new opportunities for primary

school PE teachers to overcome professional development bottlenecks and achieve sustainable growth.

Despite this potential, the practical application of AI in the professional development of primary school PE teachers remains at an early stage (Zhiheng, 2025b). On the one hand, some PE teachers lack adequate awareness of the educational value of AI, leading to misconceptions or anxiety regarding its application. On the other hand, most current AI applications are primarily focused on teaching management and classroom assistance, with less emphasis placed on promoting more profound professional development for teachers. This situation restricts AI's contribution to achieving the high-quality education goals of SDG4. Therefore, it is necessary to systematically examine the underlying logic, practical problems, and implementation paths of AI-enabled professional development of primary school PE teachers from both theoretical and practical perspectives. ("Research on the Application of Artificial Intelligence Empowered Education Management," 2023).

Based on this foundation, the present study is located in the background of educational digitalization and sustainable development of education. Focused on primary school physical education teachers, it systematically examines the theoretical bases, practical manifestations, and implementation paths of AI-assisted professional development from a pedagogical perspective. ("The Practical Challenges and Breakthrough Pathways of AI Empowering University Physical Education," 2025b). The study aims to provide a theoretical basis and practical references for improving the model of professional development for primary school PE teachers, promoting the high-quality development of school sports education, and contributing to achieving Sustainable Development Goal4.

2. Research Objectives

This study aims to review the theoretical foundations of AI-supported professional development and to construct an analytical framework for understanding the professional growth of primary school physical education teachers. Drawing on teacher professional development theory, technology acceptance models, and constructivist learning theory, the study develops a four-dimensional framework comprising professional philosophy, professional knowledge, professional competence, and professional commitment to explain how artificial intelligence supports teacher development (Markauskaite et al., 2023). Building on this framework, the study further examines the current state of AI-supported professional development to identify key problems and underlying causes, including technological cognition bias, uneven digital literacy, and superficial applications of technology. Based on these analyses, the study explores practical implementation pathways and enabling conditions for AI-supported professional growth, with particular attention to professional philosophy guidance, knowledge restructuring, competence enhancement, and emotional engagement. Finally, aligned with the principles of Sustainable Development Goal 4 (SDG4), the study seeks to provide theoretical insights and practical implications for educational administrators, schools, and teachers to support the coordinated development of educational digital transformation and sustainable teacher professional development.

3.Theoretical Foundations

3.1 Theoretical Perspective on Teacher Professional Development

The teacher professional development theory regards teachers' growth as a life-long, continuous process that focuses on the all-round improvement of their professional qualities and moral cultivation through ongoing study, pedagogical reflection, and practice refinement. (Wang, 2026). Within this framework, professional development extends beyond the acquisition of technical skills to include the restructuring of cognitive frameworks, the strengthening of educational beliefs, and the gradual formation of professional identity and emotional commitment.

Under the background of primary school physical education, teachers' professional development also follows this basic principle. Due to the discipline's strong practicability and dynamic teaching environment, professional development has become more dependent on immediate instructional feedback and an enabling learning environment. The traditional way is mainly based on the accumulation of experience and individual reflection by individuals; it is prone to be limited by personal subjectivity and cannot be carried out systematically or continuously in research on teaching practice.

Artificial intelligence provides new ways to overcome the above deficiencies. By continuously collecting data on the classroom process, intelligent analysis of teachers' instructional behavior and students' physical movement states is carried out to provide objective, context-based references for primary school physical education teachers. A data-driven reflective method to help solve the problems of traditional experiential reflection, making it more targeted, continuous, and based on facts for teachers' professional growth. In this way, the application scope of teacher professional development theory in the field of intelligent education is expanded.

3.2 Perspective of Technology Acceptance Theory

Technology acceptance theory posits that individuals' willingness to adopt technological innovations is primarily influenced by perceived usefulness and perceived ease of use. These cognitive factors play a decisive role in determining whether technology is adopted effectively and applied sustainably. In the professional development of primary school physical education teachers, attitudes toward artificial intelligence directly shape the extent to which AI-enabled educational outcomes can be realized.

When primary school physical education teachers have a sense that AI is an external tool that increases their workload or even undermines their professional autonomy, their willingness to accept it and use it meaningfully is greatly reduced. Conversely, if teachers regard AI as an important tool to improve teaching quality, support professional reflection, and enhance teaching ability, and the operating process of AI is in line with their own teaching practice and profession, then they are more willing to integrate AI into their own professional development. Analyzing teachers' cognitive perceptions and attitudes towards AI based on the theory of technology acceptance thus helps clarify the mechanism of AI-enabled teacher professional development and provides a theoretical basis for designing effective implementation strategies.

3.3 Perspective of Constructivist Learning Theory

Constructivist learning theory posits that the process of learners generating meaning from contextualized experience is not only individual reflection but also includes socially collaborative construction. Therefore, in this sense, the professionalization of teachers is

regarded as continuous learning under real teaching situations. Primary school physical education teachers continuously improve their professional knowledge and teaching skills through participation in actual teaching.

Artificial intelligence technologies contribute to the creation of diverse and sustainable professional learning environments through intelligent learning platforms, virtual simulation systems, and online collaborative tools (Wu, 2026). These technologies help teachers take the initiative in their own learning and develop professionally tailored to them, and they can also foster interactions among peers and collaborative thinking. According to constructivism, although AI is an external instrument of technology, it has become an internal cognitive support for teachers in the process of their own development when viewed from this perspective. By realizing the scenario-based learning and interactive support functions, AI can help promote the continuous improvement of not only the specialized knowledge level but also the practical application ability in the teaching of primary school physical education teachers.

4. Multi-dimensional Analysis of Artificial Intelligence Empowering the Professional Development of Primary School Physical Education Teachers

From a multi-dimensional perspective, the professional development of primary school physical education teachers empowered by artificial intelligence reveals several interconnected challenges across professional philosophy, professional knowledge, professional competence, and professional affect. At the conceptual level, professional philosophy functions as the cognitive foundation of teacher development. However, many teachers currently perceive artificial intelligence primarily as a technical tool for improving instructional efficiency or supporting classroom management, rather than as a resource for professional reflection and continuous learning. This technology-oriented perspective underestimates the deeper developmental potential of AI and limits its integration into teachers' intrinsic professional growth processes. At the knowledge level, although primary school physical education teachers possess strong practice-oriented expertise, digital literacy, information technology knowledge, and data awareness have become increasingly important components of professional knowledge in AI-supported contexts. Significant disparities in digital literacy hinder some teachers' effective use of AI platforms, resulting in uneven professional development outcomes and constraining the continuous optimization of their professional knowledge structures. In terms of professional competence, existing AI applications in physical education instruction remain largely focused on data recording and procedural support, with limited integration into core teaching processes such as instructional design, pedagogical decision-making, and evaluation. Superficial technology use and the absence of systematic data-driven reflection mechanisms reduce the effectiveness of AI in enhancing teachers' instructional competence. Finally, at the affective level, professional emotional engagement plays a critical role in sustaining teachers' professional identity and long-term commitment. Current AI-supported practices tend to emphasize efficiency and outcomes while overlooking teachers' emotional experiences and sense of professional belonging, which may generate technological stress and passive adaptation. This neglect of affective dimensions ultimately weakens teachers' sustained engagement with AI-supported professional development and limits the long-term sustainability of its empowering effects.

5. Findings

The findings show that, at the level of professional philosophy, primary school physical education teachers continue to perceive artificial intelligence mainly as a teaching aid or an administrative support tool. Its potential role in supporting professional reflection, continuous learning, and long-term professional growth remains insufficiently recognized. This instrumentally oriented understanding limits the integration of AI into teachers' intrinsic professional development processes and restricts its capacity to deepen and broaden educational empowerment.

At the level of professional knowledge and competence, the results reveal structural constraints on the effectiveness of AI-supported professional development. Significant disparities exist in teachers' information technology knowledge, data awareness, and digital literacy, which create unequal access to AI-supported learning environments. Teachers with weaker technical foundations face higher barriers to participation, resulting in uneven empowerment outcomes and hindering the widespread and sustainable adoption of AI. Furthermore, the application of artificial intelligence in physical education instruction largely remains limited to data collection and procedural support, with insufficient integration into key instructional processes such as teaching design, pedagogical decision-making, and evaluation. This lack of systematic integration reduces the effectiveness of AI in enhancing teachers' professional competencies.

At the affective level, the findings indicate that current AI-supported professional development practices emphasize efficiency and measurable outcomes while paying limited attention to teachers' emotional experiences, professional identity, and developmental motivation. The neglect of affective dimensions weakens teachers' long-term engagement and commitment to AI-supported professional growth. Overall, the synergistic mechanism through which professional philosophy, knowledge, competence, and affect are jointly promoted in AI-enabled professional development has not yet been established. As a result, the empowering effects of artificial intelligence remain partial and stage-specific, underscoring the need for targeted and multi-dimensional implementation pathways in future practice.

6. The Implementation Path of Artificial Intelligence Supporting the Professional Development of Primary School Physical Education Teachers

The implementation of AI-assisted professional development for primary school physical education teachers should begin with the construction of shared professional concept guidance. The educational administration and schools must enhance teachers' sense of the professionalization of artificial intelligence technology through in-service training, case presentations, and practical application demonstrations. These efforts can help teachers move from a passive state of using technology to an active role in AI-assisted professional development. In terms of the institutional level, the teacher evaluation and professional development system should focus on AI-enabled reflection and continuous learning, thus preventing the technology from being regarded as additional work or an extra burden in evaluation and promoting a positive attitude towards the use of AI.

The second essential path is to improve digital literacy through professional knowledge reconstruction. To alleviate the problem of different abilities in using technology among teachers, a tiered professional development support system should be established, and tiered training courses aimed at teachers with varying skill levels should be provided. The basic training focuses on necessary information technology skills and data literacy to reduce the

integration threshold for AI; advanced learning resources can be made available to teachers with stronger technical backgrounds to promote continuous professional development. In particular, the development of knowledge related to AI should be closely integrated with the practical application scenarios of physical education teaching so that the learning of technology can serve as a strong support for instruction and help teachers build a more complete system of professional knowledge.

The continuous impacts of AI-enabled professional development for teachers depend on its integration into teaching practice and care for teachers' emotions. Artificial intelligence should be integrated into all links of instructional design, classroom application, and teaching evaluation to support data-driven decision-making and continuous improvement of instructional design. Encourage schools and educational research institutes to promote school-based research, peer collaboration, and reflective case analysis, helping teachers turn their experiences with AI applications into stable professional skills. At the same time, the AI system design needs to have a feedback mechanism, professional growth records, and supportive interaction functions to enhance teachers' sense of achievement and professional identity. By building a professional atmosphere of autonomy, exploration, and emotional support, schools can enhance teachers' sustained participation in AI-enabled teacher growth programs.

7. Conclusion

In the context of accelerating educational digitalization and the widespread application of artificial intelligence, AI-enabled teachers for professional development have become an important driver of high-quality and sustainable education. Anchored in the principles of the United Nations Sustainable Development Goal 4 (SDG4), this study focuses on primary school physical education teachers and systematically examines the theoretical foundations, practical challenges, and implementation pathways of AI-supported professional development from a pedagogical perspective. By situating teacher development within broader educational transformation agendas, the study highlights the strategic significance of artificial intelligence in advancing equitable and quality education.

The findings indicate that while artificial intelligence holds considerable potential to support the professional development of primary school physical education teachers, its empowering effects remain limited and uneven in practice. These limitations primarily arise from insufficient synergy among key dimensions of professional development, including professional philosophy, professional knowledge, professional competence, and affective commitment. Drawing on teacher professional development theory, technology acceptance theory, and constructivist learning theory, this study proposes an integrated analytical framework encompassing these four dimensions. The framework reveals structural challenges within the current AI-enabled professional development process and underscores the need for coordinated multi-dimensional approaches to fully realize the developmental value of artificial intelligence for primary school physical education teachers.

8. Implication

In terms of policy, the integration of AI-assisted professional development for primary school physical education teachers should be included in the teacher training system and strengthened from an institutional perspective. At the disciplinary level, based on the characteristics of physical education, tailored applications for AI should be explored. At the practical level, schools and teachers need to work together to build an AI-driven professional development

ecosystem, promoting a virtuous cycle of technological advancement and teacher growth.

9. Future Research

There are still some deficiencies in this study, such as an analytical approach based on theory and a lack of empirical evidence. In future research, various empirical methods can be used to conduct a thorough examination of the practical effects of AI-empowered professional development for primary school physical education teachers, and attention should also be paid to regional differences and school characteristics. In addition, further research on the ethical issues and teacher agency in AI application is needed to promote the development of this field. These three aspects should be systematically organized according to the content and logical flow of the full text, ensuring comprehensive coverage.

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Conflict of Interest Statement
The authors declare that there is no conflict of interest regarding the publication of this study.

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