



RESEARCH ARTICLE

Teacher Digital Literacy, Digital Competence, and AI Teaching Competence: Conceptual Clarification and a Pyramid Framework for Teachers' Professional Development in the AI Era

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ABSTRACT

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The rapid advancement of artificial intelligence (AI) is transforming educational environments and redefining the competencies required for teachers' professional development. While digital literacy and digital competence have been widely recognized as essential capabilities for educational digitalization, the emergence of AI-enhanced teaching and learning has highlighted the need for a more advanced competency framework. However, the conceptual boundaries and relationships among teacher digital literacy, digital competence, and AI teaching competence remain unclear in existing studies. This study aims to clarify the concepts of teacher digital literacy, digital competence, and AI teaching competence and to examine their developmental relationships. Using a conceptual analysis approach, relevant literature was reviewed and synthesized to explore the evolution, characteristics, and educational functions of these three constructs. The findings indicate that the three concepts represent distinct but interconnected levels of teacher professional capability. Digital literacy serves as the foundational capability that enables teachers to participate effectively in digital environments. Digital competence reflects teachers' ability to integrate digital technologies into pedagogical practices. AI teaching competence extends beyond technology integration and emphasizes the use of artificial intelligence for instructional innovation, intelligent decision-making, ethical governance, and educational transformation. Based on these findings, this study proposes the AI Teacher Competency Pyramid Framework (AITCP), which conceptualizes teacher capability development as a progressive hierarchy from digital literacy to digital competence and ultimately to AI teaching competence. The framework contributes to the theoretical understanding of teacher professional development in the AI era and provides practical implications for teacher education, competency assessment, and policy development.

INTRODUCTION

The rapid development of artificial intelligence (AI) technologies is reshaping educational systems worldwide and creating unprecedented opportunities and challenges for teachers' professional development (Holmes et al., 2022). The widespread adoption of generative AI tools, such as ChatGPT, Gemini, Claude, and Copilot, has transformed how educational content is created, delivered, and evaluated (Tlili et al., 2023). As educational institutions increasingly integrate AI into teaching and learning processes, teachers are expected not only to possess

fundamental digital skills but also to effectively utilize AI technologies to support pedagogical innovation and enhance learning outcomes.

Over the past two decades, teacher professional development in digital environments has been primarily discussed through the concepts of digital literacy and digital competence (Redecker, 2017). Digital literacy generally refers to an individual's ability to access, understand, evaluate, and utilize digital information and technologies effectively. Building upon this foundation, digital competence emphasizes the integration of digital technologies into professional practices, particularly teaching and learning activities. Consequently, digital competence has become one of the key indicators for evaluating teachers' readiness to participate in digital transformation initiatives.

However, the emergence of AI-driven educational environments has exposed limitations in existing conceptual frameworks. Although teachers may demonstrate adequate levels of digital literacy and digital competence, these capabilities do not necessarily enable them to effectively design AI-supported learning activities, critically evaluate AI-generated content, address ethical concerns associated with AI use, or cultivate students' AI literacy (Kasneci et al., 2023). As a result, a growing body of literature has introduced new concepts, including AI literacy, AI competence, AI pedagogical competence, and AI teaching competence, to describe the specialized abilities required for teaching in the AI era (Long & Magerko, 2020).

Despite increasing scholarly interest, significant conceptual ambiguity remains regarding the relationships among teacher digital literacy, digital competence, and AI teaching competence. Existing studies often use these concepts interchangeably or fail to clearly distinguish their boundaries, leading to theoretical fragmentation and practical confusion in teacher education and professional development programs (Ng et al., 2021). The lack of a coherent conceptual framework limits the development of effective strategies for preparing teachers to meet the demands of AI-enhanced educational environments.

Therefore, it is necessary to systematically clarify the conceptual meanings of teacher digital literacy, digital competence, and AI teaching competence, and to explore the relationships among these constructs. Understanding how these concepts are interconnected can contribute to a more comprehensive interpretation of teachers' professional capabilities in the digital and AI era.

This study aims to: (1) review the historical evolution of teacher digital literacy, digital competence, and AI teaching competence; (2) clarify the conceptual boundaries and distinctive characteristics of these three constructs; (3) analyze their developmental and hierarchical relationships; and (4) propose an AI Teacher Competency Pyramid Framework to explain the progressive development of teachers' professional capabilities from digital literacy to AI teaching competence. The proposed framework seeks to provide theoretical guidance for teacher education, professional development, and policy-making in the context of educational digital transformation and artificial intelligence integration.

2. LITERATURE REVIEW

2.1. Teacher Digital Literacy

The concept of digital literacy emerged alongside the rapid expansion of information and communication technologies (ICTs) during the 1990s. Gilster (1997) was among the first scholars to define digital literacy as the ability to understand and use information from a variety of digital sources (Martin, 2006). Unlike traditional literacy, digital literacy emphasizes not only technical proficiency but also critical thinking, information evaluation, and effective communication in digital environments (Bawden, 2008).

As digital technologies became increasingly embedded in educational settings, researchers began to explore the specific implications of digital literacy for teachers (Koehler & Mishra, 2009). Early studies primarily focused on teachers' abilities to operate computers, access online resources, and utilize educational software. However, subsequent research expanded the concept to include information management, digital communication, online collaboration, content creation, and digital citizenship (Spante et al., 2018).

International organizations have also contributed significantly to the development of digital literacy frameworks. UNESCO emphasized digital literacy as a fundamental competency for participation in the knowledge society, while the European Commission incorporated digital literacy into broader digital competence frameworks (Ferrari, 2013). In recent years, China's Teacher Digital Literacy Standard has further highlighted the importance of digital awareness, digital technology knowledge, digital application skills, digital responsibility, and professional development in the context of educational digitalization.

Although definitions and frameworks vary across countries and organizations, the evolution of teacher digital literacy demonstrates a clear developmental trend. The concept has gradually expanded from a narrow focus on technical skills toward a broader understanding that incorporates information literacy, digital communication, digital citizenship, and professional development. These developments indicate that digital literacy has evolved from a technical skill concept to a comprehensive framework for teacher development in the digital era.

2.2 Teacher Digital Competence

While digital literacy focuses on fundamental digital knowledge and skills, the concept of digital competence extends beyond technological operation to emphasize the effective integration of digital technologies into professional practice (Ferrari, 2013). The notion of competence originates from competency-based education and refers to the combination of knowledge, skills, attitudes, and values required to perform specific tasks successfully (Mulder, 2014).

Within the educational field, teacher digital competence has become one of the most influential frameworks for understanding teachers' technology-related professional capabilities. The concept gained prominence through several internationally recognized frameworks, including UNESCO's ICT Competency Framework for Teachers (ICT-CFT), the Technological Pedagogical Content Knowledge (TPACK) framework, and the European Framework for the Digital Competence of Educators (DigCompEdu).

These frameworks share a common assumption that effective technology integration requires more than technical skills alone (Redecker, 2017). Teachers must be capable of selecting appropriate digital tools, designing technology-enhanced learning environments, facilitating student engagement, assessing learning outcomes through digital means, and continuously improving their instructional practices.

Compared with digital literacy, digital competence represents a higher-order capability. It reflects teachers' ability to transform digital resources into meaningful educational experiences and to employ technology strategically to improve teaching effectiveness (Redecker, 2017). Consequently, digital competence is often regarded as a critical indicator of teachers' readiness to participate in educational digital transformation initiatives (Bergman et al., 2018).

2.3 AI Teaching Competences

The rapid advancement of artificial intelligence technologies, particularly generative AI tools

such as ChatGPT, Gemini, Claude, and Copilot, has introduced profound changes to educational environments (Holmes et al., 2022). Unlike previous digital technologies that primarily supported information access and communication, AI systems are increasingly capable of generating content, providing personalized feedback, facilitating intelligent tutoring, and supporting instructional decision-making. Consequently, teachers are confronted with new opportunities as well as complex challenges in integrating AI into educational practices.

In response to these developments, researchers have proposed a range of AI-related concepts, including AI literacy, AI competency, AI readiness, AI pedagogical competence, and AI teaching competence (Ng et al., 2021). Although these concepts differ in emphasis, they collectively highlight the need for teachers to develop specialized capabilities for understanding, evaluating, and utilizing AI technologies in educational contexts.

Initially, AI literacy focused on teachers' and students' understanding of the fundamental principles, applications, opportunities, and risks associated with artificial intelligence. As AI technologies became increasingly integrated into teaching and learning processes, scholars began to argue that AI literacy alone is insufficient for effective educational practice (Ng et al., 2021). Teachers must also possess the ability to select appropriate AI tools, design AI-supported learning activities, critically evaluate AI-generated outputs, address ethical and privacy concerns, and foster students' responsible use of AI technologies.

Recent frameworks have therefore shifted attention toward AI teaching competence. This concept extends beyond basic AI awareness and emphasizes teachers' capacity to integrate AI into pedagogical practices in meaningful, ethical, and innovative ways (Ji et al., 2024). Drawing upon emerging studies and international initiatives, AI teaching competence can be understood as a multidimensional construct comprising five key dimensions:

- (1) AI Knowledge and Understanding: the ability to understand the basic concepts, functions, limitations, and implications of AI technologies;
- (2) AI Tool Application: the ability to effectively utilize AI tools to support teaching preparation, instruction, assessment, and professional development;
- (3) AI-Supported Pedagogical Design: the ability to design learning activities that strategically integrate AI technologies to enhance student learning experiences;
- (4) AI Ethics and Governance: the ability to recognize and address ethical issues related to privacy, bias, transparency, academic integrity, and responsible AI use;
- (5) AI Evaluation and Reflection: the ability to critically evaluate AI-generated outputs and continuously reflect on the effectiveness of AI-supported teaching practices.

3. CONCEPTUAL CLARIFICATION OF TEACHER DIGITAL LITERACY, DIGITAL COMPETENCE AND AI TEACHING COMPETENCE

Although teacher digital literacy, digital competence, and AI teaching competence are frequently discussed in contemporary educational technology research, the boundaries among these concepts remain unclear (Chiu et al., 2024). In many studies, they are used interchangeably, resulting in conceptual ambiguity and theoretical fragmentation. Therefore, it is necessary to clarify their distinct meanings and developmental relationships.

3.1. Teacher Digital Literacy as Digital Participation

Teacher digital literacy represents the foundational capability required for participation in digital society and digital education (Falloon, 2020). Although digital literacy is often

associated with technological skills, its deeper significance lies in enabling meaningful participation in digitally mediated environments. For teachers, digital literacy is not merely the ability to operate digital devices or access online resources. Rather, it reflects the capability to access, understand, evaluate, create, and communicate information through digital technologies (Zhao et al., 2024).

At this stage, teachers are expected to possess basic digital knowledge and operational skills, including information retrieval, digital communication, online collaboration, and digital content creation. These competencies enable teachers to adapt to increasingly digitalized educational contexts and participate effectively in teaching and professional activities. Therefore, digital literacy emphasizes participation and adaptability rather than pedagogical transformation.

From this perspective, teacher digital literacy can be understood as digital participation. It enables teachers to engage with educational resources, communicate within digital learning environments, and function effectively in technology-rich educational settings. Without this foundational capability, meaningful engagement with educational digitalization would be difficult to achieve.

Consequently, teacher digital literacy addresses a fundamental professional question:

Can teachers effectively function and participate in a digital environment?

From a professional development perspective, digital literacy serves as the entry point for teachers' engagement with educational digitalization and provides the necessary foundation for more advanced technology-related competencies.

3.2 Teacher Digital Competence as Pedagogical Integration

While digital literacy focuses on technological awareness and basic digital skills, teacher digital competence emphasizes the effective integration of digital technologies into teaching and learning processes (Caena & Redecker, 2019). It moves beyond participation in digital environments and focuses on the pedagogical application of technology to improve educational outcomes.

Digital competence requires teachers not only to understand and use digital tools but also to strategically apply them to enhance instructional design, classroom management, student engagement, assessment, and professional development (Cabero-Almenara et al., 2021). Frameworks such as TPACK and DigCompEdu highlight the pedagogical dimension of technology integration and position digital competence as a professional teaching capability rather than a purely technical skill.

Compared with digital literacy, digital competence reflects a higher level of professional expertise because it combines technological knowledge with pedagogical and disciplinary knowledge. Teachers are expected not only to use technology but also to make informed instructional decisions regarding when, why, and how digital technologies should be integrated into learning activities.

From this perspective, teacher digital competence can be understood as pedagogical integration. It represents the ability to transform digital technologies into meaningful educational value and to employ technology strategically in support of teaching and learning objectives.

Therefore, teacher digital competence addresses the following professional question:

Can teachers effectively teach and improve learning through digital technologies?

In this sense, digital competence can be regarded as an application-oriented capability that transforms digital skills into educational value and serves as the bridge between digital participation and educational innovation.

3.3 AI Teaching Competence as Educational Transformation

The emergence of artificial intelligence has fundamentally changed the nature of educational technology integration (Holmes & Tuomi, 2022). Unlike traditional digital tools, AI systems possess the ability to generate content, provide adaptive feedback, support decision-making, and automate complex tasks. These characteristics require teachers to develop new forms of professional capability that extend beyond conventional digital competence (Kasneci et al., 2023).

AI teaching competence emphasizes teachers' ability to design, implement, evaluate, and continuously improve AI-supported teaching practices. It requires not only technological proficiency but also the capacity to critically evaluate AI-generated outputs, address ethical concerns, manage data privacy risks, mitigate algorithmic bias, and promote responsible AI use in educational settings (Al-Kfairy et al., 2024).

Unlike digital literacy, which focuses on participation, and digital competence, which focuses on technology integration, AI teaching competence focuses on the transformation of teaching and learning. Teachers are expected to rethink instructional design, assessment strategies, student support, and learning experiences within AI-enhanced educational environments (Ng et al., 2023).

From this perspective, AI teaching competence can be understood as educational transformation. It reflects teachers' ability to leverage artificial intelligence not merely as a technological tool but as a catalyst for pedagogical innovation and educational change (Tlili et al., 2023).

Therefore, AI teaching competence addresses the following advanced professional question:

Can teachers effectively leverage artificial intelligence to transform teaching and learning in innovative, ethical, and educationally meaningful ways?

This capability represents the highest stage of teachers' professional development in the AI era, integrating technological expertise, pedagogical creativity, ethical responsibility, and educational leadership.

3.4 Distinctions Among the Three Concepts

Table 1: Comparison of Teacher Digital Literacy, Digital Competence and AI Teaching Competence

Dimension	Digital Literacy	Digital Competence	AI Teaching Competence
Focus	Digital Participation	Technology Integration	Educational Transformation
Development Role	Foundation	Application	Transformation
Main Goal	Digital Participation	Pedagogical Integration	Educational Transformation
Core Question	Can I function in digital environments?	Can I teach effectively with digital technologies?	Can I transform education through AI?
Capability Level	Basic	Intermediate	Advanced

Although the three concepts are closely related, they represent distinct yet progressively connected stages of teachers' professional capability development. As shown in Table 1, teacher digital literacy primarily emphasizes digital participation, enabling teachers to access, evaluate, and communicate information in digital environments. Teacher digital competence

extends this foundation by focusing on pedagogical integration, whereby digital technologies are strategically employed to support teaching and learning processes. AI teaching competence further advances this progression by emphasizing educational transformation through the effective, ethical, and innovative use of artificial intelligence.

From a professional development perspective, the three concepts can also be interpreted as responses to three progressively deeper professional questions faced by teachers in technology-rich educational environments:

Can I function? Can I teach? Can I transform?

These questions reflect a developmental progression from participation, to integration, and ultimately to transformation. Therefore, the three concepts should not be viewed as synonymous or interchangeable. Rather, they represent different stages in the evolution of teachers' professional capabilities in response to ongoing technological advancement.

4. RELATIONSHIP ANALYSIS AMONG TEACHER DIGITAL LITERACY, DIGITAL COMPETENCE AND AI TEACHING COMPETENCE

4.1 From Digital Literacy to Digital Competence

Teacher digital literacy serves as the foundation of digital competence (Falloon, 2020). Without basic digital literacy, teachers may encounter difficulties in accessing digital information, operating digital technologies, and participating in digital learning environments.

However, digital literacy alone does not guarantee effective technology integration in educational settings. Teachers must further develop the ability to combine digital technologies with pedagogical knowledge and subject matter expertise. This developmental process gives rise to digital competence (Kiryakova & Kozhuharova, 2024).

Therefore, digital literacy can be viewed as a necessary but insufficient condition for digital competence (Caena & Redecker, 2020). While digital literacy emphasizes technological participation, digital competence focuses on pedagogical application and instructional effectiveness.

In this sense, digital competence represents the pedagogical extension and practical application of digital literacy.

4.2 From Digital Competence to AI Teaching Competence

The emergence of artificial intelligence has introduced new challenges and opportunities that extend beyond the scope of traditional digital competence (Peiró & Martínez-Tur, 2022). While digital competence enables teachers to effectively integrate digital technologies into teaching and learning processes, AI technologies require a broader set of capabilities associated with intelligent systems, automated decision-making, and ethical governance.

Teachers who possess strong digital competence may be capable of integrating digital technologies into classroom instruction. Nevertheless, they may still encounter difficulties when utilizing AI systems to support learning design, personalized instruction, learning analytics, assessment, or educational decision-making. The ability to operate digital tools does not automatically translate into the ability to critically evaluate AI-generated outputs, address algorithmic bias, protect data privacy, or guide students' responsible use of artificial intelligence (Nguyen, 2025).

AI teaching competence therefore builds upon digital competence while incorporating additional capabilities related to AI understanding, AI-supported pedagogy, ethical

governance, critical evaluation, and educational innovation (Ren & Wu, 2025). In this sense, AI teaching competence represents not merely an extension of digital competence but a qualitatively different capability required for teaching in AI-enhanced educational environments.

Compared with digital competence, AI teaching competence requires teachers to move beyond technology integration toward educational transformation. Rather than focusing solely on the effective use of digital tools, teachers must be capable of redesigning learning experiences, facilitating human-AI collaboration, promoting responsible AI use, and critically reflecting on the implications of AI for teaching and learning (Hutson & Plate, 2023).

Accordingly, digital competence provides the essential foundation upon which AI teaching competence can be developed. However, the latter extends beyond technological application and represents a more advanced and transformative stage of teachers' professional development.

Therefore, AI teaching competence addresses a new and increasingly important question: Can teachers effectively leverage artificial intelligence to transform teaching and learning in ways that are pedagogically meaningful, ethically responsible, and educationally innovative? This progression suggests that AI teaching competence should be viewed as a higher-order capability that enables educational transformation in the age of artificial intelligence (George, 2023).

4.3 A Progressive Development Logic

Based on the above analysis, teacher capability development in the digital and AI era can be understood as a progressive process consisting of three interconnected stages.

The first stage is teacher digital literacy. This stage enables teachers to participate effectively in digital environments through the acquisition of fundamental digital knowledge, skills, and awareness. It serves as the entry point for teachers' engagement with educational digitalization.

The second stage is teacher digital competence. Building upon digital literacy, this stage emphasizes the pedagogical integration of digital technologies into teaching and learning processes. Teachers move beyond participation and begin to apply technology strategically to improve educational outcomes.

The third stage is AI teaching competence. Based on the foundation of digital literacy and digital competence, this stage enables teachers to leverage artificial intelligence to redesign instructional practices, support innovation, and facilitate educational transformation.

Accordingly, teacher capability development can be viewed as a progressive pathway:

Digital Literacy → Digital Competence → AI Teaching Competence

This progression reflects an evolution from digital participation, to pedagogical integration, and ultimately to educational transformation. Therefore, the three competencies should be understood as progressively connected stages rather than isolated or interchangeable constructs.

4.4 Implications of the Progressive Development Relationship

The progressive relationship among teacher digital literacy, digital competence, and AI teaching competence has important theoretical implications for understanding teacher capability development in the digital and AI era.

First, the findings suggest that teacher professional capabilities should not be viewed as

isolated or parallel constructs. Instead, they represent a developmental sequence in which higher-order competencies are built upon the successful acquisition of lower-order competencies (Zhang et al., 2025).

Second, digital literacy serves as the essential foundation for subsequent capability development. Without adequate digital literacy, teachers may struggle to effectively engage with digital technologies, thereby limiting the development of digital competence. In other words, if teachers cannot function effectively in digital environments, they are unlikely to integrate technology meaningfully into teaching and learning practices.

Third, digital competence provides the necessary bridge between digital participation and educational transformation. Teachers who possess basic digital skills but lack digital competence may be able to use technology, yet they may fail to employ it strategically for pedagogical purposes. Consequently, AI teaching competence cannot be fully developed without a solid foundation of pedagogically integrated digital competence (Zou et al., 2025).

Finally, AI teaching competence represents the highest stage of capability development because it requires teachers not only to use technologies but also to transform educational practices through innovative and responsible applications of artificial intelligence. This suggests that teacher capability development in the AI era should be understood as a progression from participation, to integration, and ultimately to transformation.

The hierarchical nature of this developmental pathway provides the theoretical basis for the AI Teacher Competency Pyramid Framework proposed in the following section.

5. THE AI TEACHER COMPETENCY PYRAMID FRAMEWORK

The relationships identified in the previous section suggest that teacher competency development is hierarchical rather than parallel (Wu et al., 2022). Digital literacy provides the fundamental capabilities required for participation in digital environments. Building upon this foundation, digital competence enables teachers to integrate digital technologies into pedagogical practice. AI teaching competence further extends these capabilities by supporting educational transformation through artificial intelligence.

Because each level depends on the successful acquisition of capabilities at the preceding level, teacher competency development can be understood as cumulative and progressive. Higher-order competencies cannot be developed effectively without the support of lower-order competencies. Therefore, a pyramid structure is appropriate for representing the developmental sequence from digital literacy to digital competence and ultimately to AI teaching competence (Peiró & Martínez-Tur, 2022).

Accordingly, this study proposes the AI Teacher Competency Pyramid Framework (AITCP) as a conceptual model for understanding teachers' professional capability development in the AI era. As illustrated in Figure 1, the proposed framework conceptualizes teacher capability development as a progression from participation, to integration, and ultimately to transformation. Each level serves as the prerequisite for the development of the subsequent level.



Figure 1. AI Teacher Competency Pyramid Framework (AITCP)

Figure 1 illustrates the proposed AI Teacher Competency Pyramid Framework (AITCP). The framework conceptualizes teacher professional capability development as a hierarchical progression from digital literacy, to digital competence, and ultimately to AI teaching competence, with each level serving as the foundation for the next.

5.1 Level One: Digital Literacy as the Foundational Layer

As illustrated in Figure 1, digital literacy forms the foundational layer of the AI Teacher Competency Pyramid Framework. It is positioned at the base of the pyramid because it provides the fundamental capabilities required for teachers to participate effectively in digital environments. Before teachers can integrate digital technologies into pedagogy or utilize artificial intelligence to transform teaching and learning, they must first acquire the basic knowledge, skills, and awareness necessary for digital participation. Therefore, digital literacy serves as the prerequisite for all higher-order competencies within the framework.

At this level, teachers acquire fundamental digital knowledge and skills, including information retrieval, digital communication, online collaboration, digital content creation, and responsible technology use. These competencies enable teachers to navigate digital environments and access educational resources.

Digital literacy serves as the foundation for all subsequent capability development. Without adequate digital literacy, teachers may struggle to utilize educational technologies effectively and may encounter barriers to professional growth in increasingly digitalized educational systems.

Therefore, digital literacy answers the foundational question:

"Can teachers effectively function in a digital environment?"

Therefore, digital literacy serves as the indispensable foundation upon which all subsequent competencies are developed.

5.2 Level Two: Digital Competence as the Application Layer

The middle layer of Figure 1 represents teacher digital competence, which serves as the bridge between foundational digital literacy and advanced AI teaching competence. Building upon digital literacy, this layer enables teachers to strategically integrate digital technologies into teaching and learning. Rather than focusing solely on technology use, digital competence emphasizes pedagogical application, instructional design, and technology-enhanced learning. Its intermediate position within the pyramid reflects its essential role in connecting digital

participation with educational transformation.

At this stage, teachers move beyond technological operation and begin integrating digital technologies into pedagogical practices. They develop the ability to design technology-enhanced learning experiences, facilitate student engagement through digital tools, assess learning outcomes using digital platforms, and continuously improve instructional effectiveness (Kiryakova & Kozhuharova, 2024).

Digital competence reflects the transformation of digital knowledge into educational practice. Teachers at this level are capable of utilizing technology strategically to support teaching and learning objectives.

Consequently, digital competence addresses the following question:

"Can teachers effectively integrate digital technologies into teaching and learning?"

This level serves as the bridge between technological understanding and pedagogical application.

Therefore, digital competence functions as the critical bridge connecting foundational digital literacy and transformational AI teaching competence.

5.3 Level Three: AI Teaching Competence as the Transformational Layer

The top layer of Figure 1 represents AI teaching competence, which reflects the highest stage of teacher capability development in the AI era. Positioned at the apex of the pyramid, this layer builds upon both digital literacy and digital competence while enabling teachers to redesign teaching, learning, and assessment through the effective, innovative, and responsible use of artificial intelligence. As the transformational layer of the framework, AI teaching competence emphasizes educational innovation, ethical AI integration, and sustainable professional development.

At this stage, teachers are capable of leveraging artificial intelligence technologies to transform educational practices and create innovative learning environments. They possess not only technological and pedagogical knowledge but also the ability to critically evaluate AI-generated outputs, address ethical issues, manage AI-related risks, and facilitate responsible AI use among students (Zou et al., 2025).

Teachers with strong AI teaching competence can utilize AI technologies to personalize learning experiences, support adaptive instruction, enhance assessment processes, and promote higher-order thinking skills (Al-Kfairy et al., 2024).

More importantly, they are capable of reimagining teaching and learning in response to emerging AI-driven educational ecosystems (Ren & Wu, 2025).

Therefore, AI teaching competence addresses the following question:

"Can teachers utilize AI technologies to transform education in innovative, effective, and responsible ways?"

This level represents the highest stage of professional capability development in the AI era.

Therefore, AI teaching competence represents the culmination of teacher capability development within the proposed framework.

5.4 Structure of the AI Teacher Competency Pyramid

Figure 1 illustrates that the AI Teacher Competency Pyramid Framework is designed to represent the cumulative and hierarchical nature of teacher capability development in the

digital and AI era. Rather than depicting the three competencies as parallel constructs, the pyramid emphasizes that higher-order capabilities are built upon the successful acquisition of lower-order capabilities.

The pyramid structure conveys three important characteristics. First, it reflects hierarchy, indicating that digital literacy serves as the foundation upon which more advanced competencies are developed. Second, it illustrates progression, demonstrating how teachers move from digital participation, to pedagogical integration, and ultimately to educational transformation. Third, it highlights accumulation, suggesting that higher levels do not replace lower levels but instead incorporate and extend them (Peiró & Martínez-Tur, 2022).

Therefore, the pyramid provides a visual representation of teacher capability development as a structured and developmental process. It explains not only the relationships among the three competencies but also the logic underlying their progression from foundation, to application, and ultimately to transformation. The pyramid is more appropriate than a parallel or circular model because teacher capability development is cumulative and prerequisite-based. Higher-order competencies cannot emerge independently of foundational competencies. Therefore, the pyramid more accurately represents the sequential and developmental nature of teacher professional growth in the AI era.

5.5 Theoretical Contributions of the Framework

The AI Teacher Competency Pyramid Framework contributes to the existing literature in three important ways.

First, it clarifies the conceptual boundaries among digital literacy, digital competence, and AI teaching competence.

Second, it explains the developmental relationship among these three constructs through a hierarchical progression model.

Third, it provides a comprehensive theoretical framework for understanding teachers' professional capability development in AI-enhanced educational environments.

More importantly, the proposed AI Teacher Competency Pyramid Framework moves the discussion of teacher competencies beyond isolated conceptual comparisons toward an integrated developmental perspective. Unlike existing studies that primarily examine teacher digital literacy, digital competence, or AI teaching competence as separate constructs, this framework conceptualizes them as progressively connected stages of teacher professional capability development. By explaining how teachers advance from digital participation, to pedagogical integration, and ultimately to educational transformation, the framework provides a new theoretical lens for understanding teacher professional development in AI-enhanced educational environments. It also establishes a conceptual foundation for future empirical research, teacher education, competency assessment, and educational policy development (Zou et al., 2025).

6. IMPLICATIONS FOR TEACHER PROFESSIONAL DEVELOPMENT

The rapid integration of artificial intelligence into education requires a reconsideration of existing teacher professional development strategies (Mikeladze et al., 2024). The proposed AI Teacher Competency Pyramid Framework provides a theoretical foundation for designing systematic and progressive teacher development programs. Based on the framework, this study proposes a three-dimensional approach consisting of development goals, development pathways, and assessment mechanisms.

6.1 Implications for Teacher Education Programs

Based on the proposed AI Teacher Competency Pyramid Framework (AITCP), teacher education institutions should design competency-based curricula that correspond to the three hierarchical levels of teacher capability development (Blanco-Figueredo & Arias-Ortega, 2023). The framework suggests that teacher education should not focus solely on AI-related skills but should progressively cultivate digital literacy, digital competence, and AI teaching competence.

At the foundational level, teacher education programs should cultivate digital literacy by strengthening information management, digital communication, and digital citizenship (Villar-Onrubia et al., 2022).

At the intermediate level, programs should focus on developing teachers' capacity to integrate digital technologies into pedagogical practice through technology-enhanced instructional design and classroom applications (Kiryakova & Kozhuharova, 2024).

At the transformational level, teacher education programs should introduce AI-related competencies, including AI-supported pedagogy, ethical AI use, learning analytics, and AI-driven instructional innovation (Ren & Wu, 2025).

6.2 Implications for Professional Development and Training

Guided by the proposed AITCP framework, professional development initiatives should align training activities with teachers' current competency levels. Since teacher capability develops progressively, professional development programs should provide differentiated learning opportunities according to teachers' developmental stages rather than adopting a one-size-fits-all approach (Mogale, 2025).

Teachers who lack foundational digital literacy should receive support in basic digital skills and digital participation. Teachers who already possess digital competence should be provided with opportunities to strengthen technology integration and instructional innovation. For advanced practitioners, specialized AI training should focus on AI-supported teaching, responsible AI use, prompt engineering, intelligent assessment, and educational transformation (Tomaskinova et al., 2025).

6.3 Implications for Competency Assessment

The AITCP framework also provides a conceptual basis for developing competency assessment systems. Because teacher capability develops hierarchically, assessment should evaluate teachers according to different competency levels rather than using a single evaluation standard (Wahyuni et al., 2022).

Assessment indicators can be designed to correspond to the three layers of the framework. Digital literacy assessment may focus on digital participation and basic operational abilities; digital competence assessment may emphasize technology integration and pedagogical application; AI teaching competence assessment should evaluate teachers' abilities to design AI-supported learning, address ethical issues, and promote educational transformation.

Such differentiated assessment mechanisms can provide more targeted feedback and support teachers' continuous professional development.

6.4 Policy Implications

Based on the proposed AITCP framework, educational policymakers should incorporate AI teaching competence into national teacher competency standards and professional development frameworks. The framework provides a systematic reference for designing teacher competency policies that reflect the progressive nature of professional capability development.

Teacher education curricula should be updated to reflect the growing importance of artificial intelligence in education. Similarly, professional development programs should provide teachers with continuous opportunities to acquire AI-related knowledge and skills (Nguyen, 2025).

In addition, educational institutions should establish supportive environments that encourage experimentation, collaboration, and innovation in AI-enhanced teaching practices.

Such policy initiatives can contribute to the development of a future-ready teaching workforce capable of responding to the opportunities and challenges of artificial intelligence (George, 2023).

7. CONCLUSION

This study addressed the growing need to clarify the relationships among teacher digital literacy, digital competence, and AI teaching competence in the context of rapid educational digitalization and artificial intelligence development. By reviewing and synthesizing existing literature, the study clarified the conceptual boundaries among the three constructs and examined their developmental relationships.

The findings suggest that teacher digital literacy, digital competence, and AI teaching competence should not be regarded as isolated or interchangeable constructs. Instead, they constitute a progressive pathway of teacher capability development, moving from digital participation, to pedagogical integration, and ultimately to educational transformation. This progression reflects the evolving professional roles of teachers in increasingly digitalized and AI-enhanced educational environments.

Based on these findings, this study proposed the AI Teacher Competency Pyramid Framework (AITCP) as a hierarchical model explaining the relationships among the three competencies. The framework conceptualizes teacher capability development as a cumulative process in which higher-order competencies are built upon the successful acquisition of lower-order competencies. This study not only clarifies the conceptual boundaries among teacher digital literacy, digital competence, and AI teaching competence, but also proposes the AI Teacher Competency Pyramid Framework (AITCP), which offers a new theoretical lens for understanding teacher professional development in the AI era.

The proposed framework provides practical implications for teacher education institutions, professional development programs, competency assessment systems, and educational policymakers. It offers a conceptual foundation for designing teacher training initiatives and supporting teachers' professional development in AI-enhanced educational environments.

Despite its contributions, this study remains conceptual in nature. Future research may empirically validate the proposed framework through quantitative, qualitative, or mixed-method approaches and examine its applicability across different educational contexts and cultural settings.

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Author Contribution

The authors confirm contribution to the paper as follows: study conception and design: Siya Wang, Mohamed Yusoff Bin Mohd Nor; literature review and theoretical synthesis: Siya Wang, Mohamed Yusoff Bin Mohd Nor; framework development and conceptualization: Siya Wang; supervision and

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