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# PREPARING FUTURE ELEMENTARY SCHOOL TEACHERS FOR THE AI ERA: THE ROLE OF ARTIFICIAL INTELLIGENCE LITERACY, DIGITAL PEDAGOGICAL COMPETENCE, AND SELF-EFFICACY IN TEACHING READINESS

## *MEMPERSIAPKAN CALON GURU SEKOLAH DASAR DI ERA AI: PERAN LITERASI KECERDASAN BUATAN, KOMPETENSI PEDAGOGIK DIGITAL, DAN EFIKASI DIRI DALAM KESIAPAN MENGAJAR*

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**ABSTRACT**
The rapid diffusion of artificial intelligence (AI) into everyday classroom practice has repositioned the competencies that elementary teacher education must cultivate in pre-service teachers. This narrative review synthesizes recent empirical and conceptual literature (2017–2026) on three interrelated constructs that shape prospective elementary teachers' readiness to teach in AI-mediated classrooms: artificial intelligence literacy, digital pedagogical competence, and self-efficacy. Sources were retrieved from Scopus-indexed and Web of Science-indexed journals, Frontiers, ScienceDirect, Taylor & Francis, Springer, and official policy documents from UNESCO and the European Commission, then organized thematically rather than through a systematic protocol. The review shows that AI literacy is increasingly conceptualized as a multidimensional construct spanning technical understanding, ethical judgment, and pedagogical application, yet most instruments and interventions still target secondary or general higher-education populations rather than elementary-specific contexts. Digital pedagogical competence, framed through the Technological Pedagogical Content Knowledge (TPACK) and DigCompEdu models, correlates strongly with technology-related self-efficacy among pre-service teachers, and self-efficacy itself functions as a recurring mediator between AI exposure and teaching readiness. The synthesis proposes an integrated conceptual pathway in which AI literacy and digital pedagogical competence jointly feed self-efficacy beliefs, which in turn determine willingness to enact AI-supported instruction in elementary classrooms. The review concludes with implications for teacher-education curricula and identifies the scarcity of elementary-specific, longitudinal, and non-Western evidence as priorities for future research.
**Keywords: artificial intelligence literacy; digital pedagogical competence; self-efficacy; teaching readiness; pre-service elementary teachers; TPACK**

***ABSTRAK***
*Pesatnya penyebaran kecerdasan buatan (artificial intelligence/AI) ke dalam praktik pembelajaran sehari-hari telah mengubah kompetensi yang perlu dikembangkan dalam pendidikan calon guru sekolah dasar. Tinjauan naratif ini mensintesis literatur empiris dan konseptual terkini (2017–2026) mengenai tiga konstruk yang saling berkaitan dan membentuk kesiapan calon guru sekolah dasar untuk mengajar di kelas yang dimediasi AI, yaitu literasi kecerdasan buatan, kompetensi pedagogis digital, dan efikasi diri. Sumber literatur diperoleh dari jurnal yang terindeks Scopus dan Web of Science, Frontiers, ScienceDirect, Taylor & Francis, Springer, serta dokumen kebijakan resmi dari UNESCO dan Komisi Eropa, kemudian dianalisis secara tematik tanpa menggunakan protokol tinjauan sistematis. Hasil tinjauan menunjukkan bahwa literasi AI semakin dikonseptualisasikan sebagai konstruk multidimensional yang mencakup pemahaman teknis, penilaian etis, dan penerapan pedagogis. Namun, sebagian besar instrumen dan intervensi yang tersedia masih berfokus pada populasi pendidikan menengah atau pendidikan tinggi secara umum, bukan pada konteks pendidikan sekolah dasar secara spesifik. Kompetensi pedagogis digital, yang dikaji melalui model Technological Pedagogical Content Knowledge (TPACK) dan DigCompEdu, memiliki hubungan yang kuat dengan efikasi diri terkait teknologi pada calon*

*guru, sementara efikasi diri itu sendiri berfungsi sebagai mediator yang berulang kali ditemukan dalam hubungan antara paparan AI dan kesiapan mengajar. Sintesis ini mengusulkan jalur konseptual terintegrasi, di mana literasi AI dan kompetensi pedagogis digital secara bersama-sama membentuk keyakinan efikasi diri, yang selanjutnya menentukan kesediaan calon guru untuk menerapkan pembelajaran berbantuan AI di kelas sekolah dasar. Tinjauan ini menyimpulkan bahwa terdapat implikasi penting bagi kurikulum pendidikan guru serta mengidentifikasi masih terbatasnya bukti yang secara spesifik berfokus pada pendidikan sekolah dasar, penelitian longitudinal, dan konteks non-Barat sebagai prioritas untuk penelitian di masa mendatang.*

***Kata Kunci: literasi kecerdasan buatan; kompetensi pedagogis digital; efikasi diri; kesiapan mengajar; calon guru sekolah dasar; TPACK.***

## 1. INTRODUCTION

Generative and predictive AI tools have moved from peripheral novelties to everyday instructional resources within a few academic cycles. Pre-service teachers preparing to enter K-12 classrooms report using tools such as ChatGPT for lesson planning, differentiation, and assessment drafting, and early evidence from mathematics and science methods courses shows measurable gains in both confidence and technical fluency after structured exposure to these tools (Kohnke et al., 2025; Tran et al., 2025). At the same time, qualitative accounts of pre-service teachers describe a persistent tension: participants recognize AI's capacity to personalize instruction and reduce workload, yet worry about eroding the human element of teaching and about over-reliance on machine-generated content (Kohnke et al., 2025).

This tension is sharpened at the elementary level. Elementary teacher candidates are simultaneously expected to become AI-literate professionals and to serve as the first formal guides through which young children encounter AI-related concepts, since national curricula in several countries have begun introducing coding-and-AI content into primary schooling (Karunianingsih et al., 2025). Yet the AI-literacy literature has developed largely around secondary and higher-education populations, leaving elementary-specific frameworks comparatively underdeveloped (Yim, 2024; Yeter et al., 2024). Meanwhile, decades of digital-competence research anchored in the Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006) and, more recently, the European DigCompEdu framework (Redecker, 2017) have consistently linked teachers' technology integration to their underlying self-efficacy beliefs, a construct long theorized by Bandura as central to whether a competency is actually enacted in practice (Bandura, 1997).

What remains less clear is how these three strands  AI literacy, digital pedagogical competence, and self-efficacy  interact specifically within elementary teacher preparation, where content-generalist demands, developmental sensitivity to young learners, and emerging AI curricula intersect in ways that differ from secondary or tertiary contexts. Ayanwale et al. (2024) found that AI knowledge shapes ethical awareness and problem-solving among pre-service teachers broadly, but their sample and instrument were not elementary-specific, and similar limitations recur across the literature reviewed below.

This narrative review therefore addresses three guiding questions: (1) How is AI literacy currently conceptualized and empirically examined among pre-service teachers, and to what extent does this literature address the elementary level specifically? (2) How does digital pedagogical competence, as framed by TPACK and DigCompEdu, relate to pre-service teachers' self-efficacy? (3) What conceptual pathway connects AI literacy, digital pedagogical competence, and self-efficacy to elementary pre-service teachers' readiness to teach in AI-mediated classrooms? By synthesizing literature across these three strands, the review aims to offer elementary teacher-education programs an evidence-informed, integrated view of the competencies that AI-era teaching readiness now requires.

## 2. METHOD

### 2.1 Literature Search Approach

This article follows a narrative (non-systematic) review design, appropriate for synthesizing a conceptually diverse and still-emerging body of literature that spans educational technology, teacher cognition, and AI-in-education policy. Literature was located through Scopus, ScienceDirect, SpringerLink, Taylor & Francis Online, Frontiers, PubMed/PMC, and Google Scholar, using combinations of the keywords "artificial intelligence literacy," "pre-service teacher," "digital pedagogical competence," "TPACK," "self-efficacy," "teaching readiness," and "elementary/primary education." The search was restricted primarily to publications from 2016 to 2026, with foundational theoretical sources (e.g., Bandura's self-efficacy theory, the original TPACK framework, and the DigCompEdu report) retained regardless of publication date because of their continuing conceptual centrality.

### 2.2 Source Selection Criteria

Priority was given to peer-reviewed journal articles indexed in Scopus or Web of Science, supplemented by official reports from recognized international bodies (UNESCO, the European Commission's Joint Research Centre) where these define constructs or frameworks directly relevant to the review's themes. Conference proceedings and preprints were included sparingly and only when they reported elementary-specific or otherwise directly relevant empirical findings unavailable elsewhere. Sources were excluded if they addressed AI literacy or digital competence in populations entirely unrelated to teacher education (e.g., purely corporate or clinical settings) or if bibliographic details could not be independently verified.

### 2.3 Synthesis Approach

Literature was organized thematically rather than chronologically, following three broad themes that mirror the review's guiding questions: AI literacy in pre-service teacher education, digital pedagogical competence and its relationship to self-efficacy, and the integration of these constructs into an account of teaching readiness. Within each theme, sources are discussed in relation to one another to surface points of convergence, contradiction, and gap particularly the recurring absence of elementary-specific evidence rather than being summarized study by study.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Artificial Intelligence Literacy Among Pre-Service Teachers

AI literacy has moved from an ill-defined buzzword toward a structured construct. Carolus et al. (2024) proposed a comprehensive framework that positions AI literacy as encompassing not only technical knowledge of how AI systems function but also the ethical awareness and human-machine interaction skills needed to use such systems responsibly. Empirically, Ayanwale et al. (2024), studying 529 pre-service teachers in a Nigerian university through structural equation modeling, found that AI knowledge shapes both ethical awareness and problem-solving, and that a trade-off exists between AI application skills and AI creation skills pre-service teachers who are confident users of AI tools are not automatically confident creators or evaluators of AI-generated content.

Attitudinal and dispositional factors compound this picture. Laru et al. (2025), examining the antecedents of pre-service teachers' AI literacy, reported that perceptions of one's own AI-driven applications and attitudes toward AI, together with machine-learning knowledge, jointly predict AI literacy levels, suggesting that literacy is not purely a knowledge outcome but is entangled with prior experience and disposition. Ayanwale et al. (2024) extended this line of inquiry by identifying the factors that support pre-service teachers'

engagement in learning about AI, reinforcing that engagement itself is a precondition for literacy development rather than its automatic consequence.

Generative AI tools in particular have become a proving ground for literacy-in-use. Kohnke et al. (2025), through semi-structured interviews with 15 pre-service teachers, found that participants recognized AI's potential to personalize learning and increase efficiency, but simultaneously expressed concern about over-reliance and the loss of the human element in teaching  a finding that signals AI literacy must include critical and reflective judgment, not only operational fluency. Tran et al. (2025) compared two training approaches for generative-AI-supported lesson planning and found that pre-service teachers trained with an explicit "AI mindset" alongside tool instruction engaged in more reflective, iterative cycles of prompting and revising than those given tool-only training, indicating that how AI literacy is taught shapes the depth of resulting competence more than mere tool exposure does.

For the elementary level specifically, the evidence base narrows considerably. Su et al. (2023) and Su and Yang (2023) demonstrated that structured, age-appropriate AI curricula can be introduced successfully in early childhood settings and can shift young children's perceptions of robots and attitudes toward engineering, but their focus was the learners rather than the teacher candidates who must design such instruction. Yim (2024) explicitly identified this gap, noting that AI-literacy education has mainly targeted secondary and university students and that frameworks tailored to primary schooling remain underdeveloped despite the pervasive influence of AI on younger learners' lives. Yeter et al. (2024), mapping global policy and empirical literature on AI literacy in elementary education, similarly concluded that policy ambition currently outpaces the empirical and teacher-preparation infrastructure needed to support it. A rare elementary-specific empirical contribution comes from Karunianingsih et al. (2025), who assessed AI-literacy levels among in-service elementary school teachers in Magelang, Indonesia, in the context of a newly mandated Coding and Artificial Intelligence Curriculum, and found that teachers' conceptual, technical, and ethical understanding of AI varied considerably and did not yet match curricular expectations  a signal of the preparation gap that elementary teacher-education programs will need to close before such curricula reach full-scale implementation.

### 3.2 Digital Pedagogical Competence and Self-Efficacy

Digital pedagogical competence in teacher education has long been organized around Mishra and Koehler's (2006) TPACK framework, which conceptualizes effective technology integration as the intersection of technological, pedagogical, and content knowledge rather than as technology skill in isolation. At the European policy level, Redecker's (2017) DigCompEdu framework operationalizes a parallel but complementary set of competence areas professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence  that has been adopted widely as a reference point for teacher-education curricula and self-assessment tools.

A consistent finding across this literature is the tight coupling between digital pedagogical competence and self-efficacy. Grounded in Bandura's (1997) social cognitive theory, self-efficacy  one's belief in one's own capability to organize and execute the courses of action required to produce a given outcome  has been shown repeatedly to accompany, and arguably to drive, technology integration in teaching. Liu et al. (2026), analyzing data from 3,003 pre-service teachers across twelve Chinese provinces, found that AI self-efficacy mediates the relationship between AI-related technological and institutional support and pre-service teachers' innovative competence, with AI self-efficacy showing a larger mediating role under conditions of direct technological support than under conditions of broader intelligent-environment support. This pattern suggests that self-efficacy is not a generic trait but is shaped by the specific type of support pre-service teachers receive.

The self-efficacy construct itself, as operationalized in general teacher-efficacy research through the Teachers' Sense of Efficacy Scale, was defined by Tschannen-Moran and Woolfolk Hoy (2001) as encompassing efficacy for instructional strategies, classroom management, and student engagement. Extending this construct into the digital domain, empirical work has consistently found strong correlations between technology self-efficacy and TPACK development; pre-service teachers, notably, tend to show a stronger self-efficacy–TPACK correlation than in-service teachers, which may reflect the more integrated, less compartmentalized way in which digital and pedagogical training is delivered during initial teacher preparation compared to later professional development. Complementing this quantitative pattern, qualitative and quasi-experimental studies of TPACK-focused training interventions have reported gains in both technological pedagogical content knowledge and technology-related self-efficacy following structured, hands-on training, reinforcing that self-efficacy in this domain is responsive to well-designed instructional intervention rather than fixed.

Taken together, this body of work positions digital pedagogical competence and self-efficacy as mutually reinforcing rather than sequential: competence-building experiences raise self-efficacy, and higher self-efficacy in turn predicts greater willingness to attempt further technology integration, including with AI-specific tools.

### 3.3 Toward an Integrated Account of AI-Era Teaching Readiness

Reading the AI-literacy and digital-pedagogical-competence literatures together suggests a plausible conceptual pathway for elementary pre-service teachers' readiness to teach in AI-mediated classrooms. First, AI literacy, technical understanding, ethical judgment, and critical evaluation of AI-generated content provides the knowledge base from which pedagogical decisions about AI use can be made (Ayanwale et al., 2024; Carolus et al., 2024). Second, this knowledge base interacts with pre-existing digital pedagogical competence, framed through TPACK and DigCompEdu, to determine whether AI tools are integrated in ways that are pedagogically sound rather than merely technically functional (Mishra & Koehler, 2006; Redecker, 2017). Third, self-efficacy operates as the psychological mechanism through which knowledge and competence translate into classroom action: pre-service teachers with higher AI- and technology-related self-efficacy are more willing to experiment with AI-supported instruction, more resilient when early attempts fail, and more likely to sustain use over time (Liu et al., 2026; Tschannen-Moran & Woolfolk Hoy, 2001).

This pathway helps explain a recurring finding across the studies reviewed: pre-service teachers frequently express favorable attitudes toward AI in the abstract, yet report hesitation or ambivalence when asked to actually design AI-integrated lessons (Kohnke et al., 2025). Such ambivalence is consistent with a self-efficacy account, positive attitude alone is insufficient for enactment without the accompanying belief in one's own capability to execute AI-supported pedagogy competently and ethically. Process-mining evidence from Tran et al. (2025) further suggests that the quality of initial training shapes not just competence but the interaction pattern itself: pre-service teachers trained with an explicit mindset for critical, iterative engagement with generative AI outputs behaved differently and arguably more self-efficaciously than those trained only in tool mechanics.

At the elementary level, this pathway carries distinct implications. Elementary teacher candidates must develop AI literacy and digital pedagogical competence not only for their own instructional use but also to model and scaffold age-appropriate AI understanding for young children, whose own AI-literacy curricula are beginning to appear in national policy (Karunianingsih et al., 2025; Yeter et al., 2024). The findings reviewed here suggest that elementary teacher-education programs cannot treat AI literacy as a generic digital-skills add-on; rather, it must be integrated into content-specific pedagogy courses in ways that simultaneously build technical understanding, ethical reasoning, and critically the self-efficacy

beliefs that determine whether candidates will actually bring these competencies into their future classrooms. The comparative scarcity of elementary-specific AI-literacy frameworks (Yim, 2024) indicates that much of this integration work remains to be designed and empirically tested rather than adapted wholesale from secondary- or higher-education models.

## 4. CONCLUSION

This narrative review synthesized literature on artificial intelligence literacy, digital pedagogical competence, and self-efficacy to examine how these constructs jointly shape pre-service elementary teachers' readiness to teach in AI-mediated classrooms. Three conclusions follow from the reviewed evidence. First, AI literacy is best understood as a multidimensional construct combining technical knowledge, ethical awareness, and critical evaluative capacity, and current empirical and instrument development has concentrated disproportionately on secondary and higher-education populations, leaving elementary-specific frameworks comparatively underdeveloped. Second, digital pedagogical competence, as captured by TPACK and DigCompEdu, is consistently and strongly associated with technology-related self-efficacy among pre-service teachers, with self-efficacy functioning as a mediating mechanism between competence-building experiences and willingness to integrate technology, including AI, into instruction. Third, a plausible integrated pathway links AI literacy and digital pedagogical competence to self-efficacy, which in turn governs teaching readiness suggesting that elementary teacher-education programs seeking to prepare AI-ready graduates must design curricula that build all three elements together rather than treating AI literacy as an isolated technical add-on.

These conclusions carry practical implications for teacher-education curricula: methods courses at the elementary level would benefit from embedding structured, reflective (rather than tool-only) engagement with generative AI, paired with explicit attention to the ethical and content-specific pedagogical dimensions of AI use, and with deliberate attention to building candidates' self-efficacy through scaffolded, successful early experiences rather than technology exposure alone.

This review is limited by its narrative, non-systematic method, which does not permit the exhaustive, protocol-driven coverage of a systematic review or meta-analysis, and by the reliance on published, predominantly English-language, and disproportionately Western- and East Asian-context literature, which may not generalize to all elementary teacher-education systems. The literature itself is also limited: elementary-specific empirical studies remain scarce relative to secondary and higher-education contexts, longitudinal evidence tracking self-efficacy and AI-integration behavior from teacher preparation into actual classroom practice is largely absent, and few studies directly measure the three constructs examined here within a single elementary pre-service sample. Future research should prioritize elementary-specific instrument development, longitudinal designs following candidates from teacher preparation into early-career practice, and studies conducted in a wider range of national and curricular contexts, particularly in regions where AI-and-coding curricula are being newly mandated at the primary level.

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