

Developing AI Competence through AI-TPACK: A Course-Embedded Pathway for Pre-Service Primary English Teachers

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Abstract: Artificial intelligence (AI) is increasingly embedded in educational practice, yet effective teaching use requires teachers to understand AI capabilities and limitations, evaluate AI-generated outputs, connect AI affordances with pedagogical purposes and subject content, and retain professional responsibility for instructional decisions. The TPACK framework provides a basis for understanding such integrated professional knowledge, and recent scholarship has extended it to Intelligent-TPACK or AI-TPACK. However, the literature is more developed in describing and measuring AI-related competence than in specifying how teacher education can systematically develop it. This paper therefore proposes a course-embedded AI literacy development pathway within a Primary English Teaching Methods and Curriculum Theory course, conceptualising AI literacy as a foundational enabling competence for AI-TPACK rather than as a component of it. The pathway consists of five stages: AI awareness, AI tool competence, pedagogical integration, critical and ethical application, and reflective professional development, supported by multi-source formative assessment. The paper contributes by shifting attention from describing what teachers need to know toward considering how such knowledge can be developed through authentic teaching problems. Its effectiveness remains to be established through future empirical implementation.

Keywords: Artificial intelligence; AI literacy; AI-TPACK; Pre-service teachers; Primary English education

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1. Introduction

Artificial intelligence (AI) is increasingly influencing educational practice through teaching-material generation, classroom activities, adaptive learning, automated feedback, and personalised support. In English language education, generative AI can produce reading passages, vocabulary exercises, stories, dialogues, games, and differentiated materials rapidly. These affordances are particularly relevant to primary English education, where teachers must adapt language input to learners' age, proficiency, interests, limited attention spans, and developmental needs. However, the availability of AI tools does not automatically produce

effective teaching. Teachers need to evaluate outputs, connect AI capabilities with pedagogical purposes, adapt generated materials, and retain responsibility for instructional decisions.

This challenge can be understood through the Technological Pedagogical Content Knowledge (TPACK) framework. Building on Shulman's ^[1] pedagogical content knowledge, Mishra and Koehler ^[2] conceptualised effective technology integration as an interaction among technology, pedagogy, and content within particular contexts. The emergence of AI has encouraged researchers to reconsider conventional TPACK. Celik ^[3] developed Intelligent-TPACK, incorporating AI-specific knowledge and ethical assessment, while Ning et al. ^[4] showed that AI-related knowledge elements form an interconnected system rather than a single technical competence.

Recent research has increasingly examined pre-service teachers. Radloff et al. ^[5] found that pre-service elementary teachers recognised AI applications for differentiated learning and resource generation but showed uneven understandings of broader educational implications. Külekci and Kızıltas ^[6] reported positive AI-TPACK perceptions and attitudes among pre-service English teachers but no significant relationship between the two, while Gong ^[7] identified an “attitude-leading, skills-lagging” pattern among 315 pre-service English teachers in China. Celik et al. ^[8] further found that AI-specific knowledge was associated with more sophisticated prompting, which was associated with more adaptive lesson plans.

These findings raise a further question: how should teacher education cultivate AI-related professional competence systematically and in subject-specific contexts? Sperling et al. ^[9] noted that AI literacy remains underdeveloped in teacher education, particularly regarding situated practical knowledge and professional judgment, while Chiu et al. ^[10] distinguished AI literacy from AI competency, with the latter involving effective and reflective application. This issue is particularly important for pre-service primary English teachers, whose future teaching involves games, songs, storytelling, scaffolding, differentiation, classroom interaction, and gradual development of learner autonomy.

This paper therefore proposes a course-embedded AI literacy development pathway within the Primary English Teaching Methods and Curriculum Theory course. Rather than proposing another AI-TPACK framework, it uses existing AI-TPACK scholarship as its theoretical foundation and focuses on how AI-related professional competence can become teachable and developable through authentic teaching problems. The proposed pathway comprises five stages: AI awareness, AI tool competence, pedagogical integration, critical and ethical application, and reflective professional development.

2. Literature review

2.1. From TPACK to AI-TPACK

TPACK conceptualises technology integration as professional knowledge arising from the interaction of technology, pedagogy, and content ^[2]. Schmidt et al. ^[11] subsequently developed and validated an assessment instrument for pre-service teachers. Importantly, TPACK frames technology integration as more than technical operation. Tondeur et al. ^[12], synthesising qualitative evidence on teacher preparation, highlighted learning technology by design, authentic technology experiences, scaffolding, and teacher educators as models. These principles support embedding AI learning within subject-specific methods courses.

AI creates additional challenges because AI systems can generate, transform, and evaluate content while also producing inaccurate, biased, or inappropriate outputs. Mishra et al. ^[13] argue that generative AI is characterised by generativity, opacity, and instability, requiring a critical rather than purely instrumental

stance. Celik ^[3] extended TPACK through Intelligent-TPACK and emphasised AI-specific knowledge and ethical assessment. Ning et al. ^[4] examined seven knowledge elements—PK, CK, AI-TK, PCK, AI-TCK, AI-TPK, and AI-TPACK—and showed that these elements are interconnected. Together, this work establishes AI-related teacher competence as an integrated professional capability.

2.2. AI-TPACK among pre-service teachers

Recent evidence indicates that AI exposure and positive attitudes do not necessarily produce professional competence. Radloff et al. ^[5] found emerging but diverse views among pre-service elementary teachers regarding AI in classrooms. Külekci and Kızıltas ^[6] reported positive AI-TPACK levels and attitudes among 244 pre-service English teachers but no significant relationship between attitudes and AI-TPACK. Gong ^[7], studying 315 pre-service English teachers in China, identified relatively strong ethical awareness and human-centred values alongside weaker technical application competence. The study also reported higher AI literacy among participants with teaching internship experience.

These findings suggest that teacher education should provide structured opportunities to develop knowledge, practical competence, pedagogical judgment, ethical awareness, and reflection rather than focusing only on attitudes.

2.3. From measuring AI-TPACK to developing competence

Celik et al. ^[8] found that AI-specific technological and pedagogical knowledge was associated with more sophisticated prompting, which was associated with lesson plans showing greater student agency and adaptive strategies. Prompting can therefore be understood as a pedagogical act shaped by professional knowledge, not simply a technical command.

This evidence highlights a distinction between AI-TPACK as a knowledge construct and AI-TPACK as enacted competence. AI-TPACK describes what teachers need to know, whereas a developmental pathway addresses how teacher education can help them acquire, integrate, and enact that knowledge. Generic tool training is insufficient: generating a worksheet is different from judging whether it suits a particular group of primary learners, adapting it, and justifying its use. Primary English Teaching Methods already involves learning objectives, lesson planning, materials development, interaction, scaffolding, differentiation, and assessment, making it a natural context for developing AI competence through authentic pedagogical problems.

3. Theoretical framework

The proposed pathway is grounded in three complementary concepts: TPACK as an integrated model of teacher knowledge, Intelligent-TPACK/AI-TPACK as an AI-specific extension, and AI literacy as a foundational enabling competence for responsible AI use. TPACK establishes that technology integration should be understood in relation to pedagogy and content ^[2]. Intelligent-TPACK extends this logic to AI and highlights AI-specific knowledge and ethical assessment ^[3]. AI literacy research emphasises understanding AI capabilities and limitations, evaluating outputs, considering ethical consequences, and applying AI knowledge appropriately ^[9,10].

This paper distinguishes AI literacy from AI-TPACK. AI literacy is conceptualised as a foundational

enabling competence rather than a direct component of AI-TPACK; it concerns understanding AI capabilities, limitations, risks, and responsible use. AI-TPACK concerns the situated integration of AI-related knowledge with pedagogical and content knowledge. A teacher may know how to operate an AI tool without knowing how to use it appropriately to teach vocabulary to primary pupils. The goal is therefore context-sensitive professional judgment about when, why, and how AI should or should not be used.

The pathway comprises five interconnected stages: AI awareness, AI tool competence, pedagogical integration, critical and ethical application, and reflective professional development. Adapted from the progression logic of Aldemir et al. ^[14], the model treats pedagogical integration as a distinct stage and combines evaluation and ethics into critical and ethical application. The stages are developmental rather than rigid or irreversible; reflection or ethical problems may require learners to revisit earlier knowledge.

Table 1. Mapping the Developmental Pathway onto AI-Related Professional Competence

Developmental Stage	Main Competence Focus	Relevant AI-TPACK Dimension(s)
Stage 1: AI Awareness	Understanding AI capabilities, limitations, and risks	AI-TK
Stage 2: AI Tool Competence	Interacting with, evaluating, refining, and verifying AI outputs	AI-TK, AI-TCK
Stage 3: Pedagogical Integration	Connecting AI affordances with content, pedagogy, and learner needs	AI-TCK, AI-TPK
Stage 4: Critical and Ethical Application	Evaluating accuracy, bias, fairness, privacy, age appropriateness, and responsibility	Ethics, AI-TPACK
Stage 5: Reflective Professional Development	Integrating AI-related knowledge into context-sensitive professional judgment	AI-TPACK

4. Developing AI literacy: A five-stage pathway

4.1. Design principle: Embed AI within existing methods education

The central design principle is course embeddedness: AI learning is incorporated into the existing Primary English Teaching Methods curriculum rather than introduced as an independent technical course. This avoids separating AI from the pedagogical knowledge that gives it educational purpose and allows trainees to encounter AI through authentic problems. The instructional logic is: Teaching problem → AI affordance → Teacher evaluation → Adaptation → Classroom use → Learning evidence.

For example, rather than asking trainees to complete a generic activity on generative AI, the methods course can ask them to design a vocabulary activity for Grade 4 pupils. AI may generate examples, games, or differentiated materials, but trainees decide whether to select, evaluate, adapt, or reject these outputs. This approach is consistent with authentic technology experiences, learning by design, and scaffolding ^[12], as well as evidence linking AI-specific knowledge with AI-supported instructional design ^[8].

4.2. Stage 1: AI Awareness

The first stage develops conceptual awareness. Trainees examine common educational uses of AI and what AI systems can and cannot reliably do. Activities may include comparing AI-generated materials, introducing basic principles such as probabilistic generation and hallucination, and mapping AI tools relevant to primary English teaching. For example, trainees can ask AI to generate a short passage for Grade 3 pupils, adapt it for another proficiency level, and create a speaking activity, then compare linguistic difficulty and learner

appropriateness. The expected outcome is informed awareness, not technical mastery: trainees should understand AI's potential, limitations, and the need for human evaluation.

4.3. Stage 2: AI tool competence

The second stage develops practical interaction with AI. Trainees learn to formulate purposeful prompts, refine instructions, compare outputs, request alternatives, and verify information. A prompt such as “Make a vocabulary activity” can be progressively specified by adding learner age, proficiency, objectives, activity type, time limits, and classroom conditions. Trainees then compare outputs and identify which prompt features improve pedagogical relevance.

Evaluation tasks use vocabulary examples, stories, phonics activities, games, and differentiated reading materials. An evaluation sheet can address linguistic accuracy, age appropriateness, cultural suitability, and pedagogical usability. Trainees are deliberately exposed to inaccurate or inappropriate outputs and must correct or reject them. Tool competence is therefore defined as interaction plus evaluation and decision-making, not prompt writing alone.

4.4. Stage 3: Pedagogical integration

The third stage moves from using AI to using AI to teach. Trainees identify instructional problems in existing primary English lessons that AI might help address, such as generating differentiated materials, creating age-appropriate examples, developing storytelling resources, preparing vocabulary games, or adapting reading tasks. The decision sequence is: What do pupils need to learn? What teaching problem needs to be solved? Could AI contribute? Which AI affordance is appropriate? How should the output be evaluated and adapted? How will learning be supported and assessed?

Trainees may create different versions of a reading activity for lower-, middle-, and higher-proficiency learners and explain the rationale for each version. AI-integrated microteaching provides opportunities to enact these designs. Assessment focuses on whether AI use is justified in relation to objectives, learner characteristics, content, interaction, scaffolding, differentiation, and assessment. This operationalises the TPACK principle that technology becomes educationally meaningful through its connection with pedagogy and content.

4.5. Stage 4: Critical and ethical application

The fourth stage develops critical and ethical judgment. Trainees evaluate AI-generated materials for factual and linguistic accuracy, cultural bias, stereotyping, age appropriateness, difficulty, privacy, fairness, accessibility, teacher responsibility, and excessive dependence on AI. Relevant cases include whether speech-recognition systems disadvantage pupils with particular accents, whether AI-generated stories reproduce cultural stereotypes, and what safeguards are needed when tools collect children's voices or other personal information.

Each trainee can contribute an “AI dilemma case” to a shared course resource with a short pedagogical and ethical analysis. This stage is particularly important in primary education because young learners may be less able than adults to identify inaccurate or inappropriate information. Teachers therefore retain responsibility for screening, adapting, and contextualising AI-generated materials. The stage draws on the ethical dimension of Intelligent-TPACK ^[3].

4.6. Stage 5: Reflective professional development

The fifth stage focuses on reflection and professional judgment. After AI-supported activities, trainees review: What did I ask AI to do? What did it produce? What did I accept, modify, or reject? Why? Did AI improve the learning design? What would I change? Importantly, successful integration cannot be measured by the amount of AI use. A trainee may conclude that AI was unnecessary for a particular problem; this can represent professional judgment rather than failure to use technology.

A final reflective report can document developing competence, remaining uncertainties, and conditions under which trainees would or would not use AI in future primary English classrooms. Reflection thus connects AI literacy with continuing professional development.

4.7. Assessment design

Assessment is multi-source and formative rather than dependent on a single self-report measure. Peer assessment uses a rubric addressing pedagogical justification, age appropriateness, learner needs, and AI-tool selection. Instructor assessment carries primary weight and focuses on pedagogical justification, developmental appropriateness, and integration rather than platform-specific technical fluency. Reflective self-assessment records what trainees accepted, modified, or rejected and why.

For future empirical implementation, an existing AI-TPACK instrument may be adapted to primary English teacher education, such as Xie and Luo's^[15] measure, supplemented with ethics-related items informed by Celik^[3]. Such adaptation requires separate validity and reliability testing. The assessment structure therefore captures what trainees know, what they can do, and how they justify their decisions.

5. Contributions, limitations and future directions

5.1. Contributions

The proposal makes three main contributions. First, it shifts attention from describing AI-TPACK to developing AI-related professional competence. Existing research establishes AI-TPACK as a framework for understanding teachers' AI-related knowledge; this paper asks how such competence can become teachable and developable.

Second, it contributes pedagogically through course embeddedness. AI competence is developed within Primary English Teaching Methods through lesson planning, material selection, input adaptation, classroom interaction, differentiation, and assessment. Generating a worksheet with AI demonstrates tool use, whereas judging its suitability for particular pupils, adapting it, and justifying the decision demonstrates a more meaningful form of professional competence.

Third, it provides a context-specific contribution for pre-service primary English teachers. Primary English education involves young learners' limited attention spans, games, storytelling, scaffolding, developmental differences, and strong requirements for teacher oversight. These characteristics become criteria for judging appropriate AI use.

The pathway also clarifies the distinction between technology acceptance and technology competence. Positive attitudes toward AI do not necessarily correspond to stronger AI-TPACK; therefore, teacher education should develop the ability to make informed decisions about when, why, and how to use AI, and when not to. The model is intentionally platform-independent because specific tools may change rapidly, whereas evaluation, adaptation, pedagogical integration, ethical judgment, and reflection are more durable competencies.

5.2. Limitations and future directions

The pathway is conceptual and has not yet been empirically implemented; no claims can therefore be made about its effectiveness. The five stages should be treated as a developmental logic rather than a rigid sequence. AI literacy, AI-TPACK, and technology acceptance are related but distinct constructs, and increased AI literacy is not assumed to increase acceptance or behavioural intention automatically. Implementation also assumes that teacher educators have sufficient AI-related knowledge to guide evaluation, adaptation, and microteaching. Finally, the pathway is designed around a Chinese teacher education context, so transferability requires investigation.

Future research should begin with a small-scale pilot. A semester-long implementation could establish baseline AI literacy, AI-TPACK, and technology acceptance, embed the pathway into Primary English Teaching Methods and Curriculum Theory, and evaluate change using both AI-TPACK measures and performance evidence such as lesson plans, teaching demonstrations, material-evaluation tasks, reflective journals, and interviews. Because the three constructs are distinct, future studies should examine whether changes in knowledge accompany changes in perceived usefulness, confidence, behavioural intention, and actual classroom use. A comparison between course-embedded AI development and stand-alone AI training would be particularly informative. Implementation should also remain flexible regarding teaching hours, AI platforms, assignments, and assessment instruments.

6. Conclusion

This paper has proposed a course-embedded AI literacy development pathway for pre-service primary English teachers, grounded in the development from TPACK to AI-TPACK. Rather than proposing another AI-TPACK framework, it addresses how AI-related professional competence can be cultivated through subject-specific teacher education. The pathway includes five interconnected stages: AI awareness, AI tool competence, pedagogical integration, critical and ethical application, and reflective professional development. These stages are developmental processes through which AI-related knowledge can become situated professional competence.

The central principle is that AI literacy should not be developed as an isolated technical competence but situated within the pedagogical and content knowledge developed through Primary English Teaching Methods. The starting point should therefore be a teaching problem or learner need, not an AI tool. AI becomes meaningful when trainees learn to evaluate whether it can serve an instructional goal, adapt outputs to young learners, recognise limitations, and justify decisions.

Emerging research indicates the importance of AI-specific technological, pedagogical, and ethical knowledge while revealing competence gaps among pre-service teachers. The next step is to move from describing AI-TPACK toward developing AI competence. The proposed pathway offers one possible bridge, but its effectiveness cannot be established through conceptual reasoning alone. Future empirical implementation is needed to determine whether course-embedded AI literacy development can strengthen pre-service primary English teachers' AI-TPACK, critical judgment, and capacity to design meaningful and responsible AI-supported learning experiences.

Disclosure statement

The authors declare no conflict of interest.

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