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Navigating the Future: Establishing a Framework for Educators' Pedagogic Artificial Intelligence Competence

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ABSTRACT

As artificial intelligence (AI) rapidly transforms educational practices, educators worldwide face an urgent need to develop pedagogic competencies that align with AI's evolving capabilities, yet existing frameworks lack systematic guidance for AI-specific skill development. This article introduces a pioneering framework designed to refine educators' pedagogic competencies in the rapidly evolving landscape of AI. Drawing inspiration from esteemed models for teacher knowledge development, such as the Technological Pedagogical Content Knowledge (TPACK) and the Digital Competence of Educators framework, this framework sets out to serve as a fundamental benchmark for a wide array of stakeholders. The framework delineates 12 essential pedagogic AI competencies categorised into four distinct domains, with each domain encompassing six levels of proficiency. Developed through a systematic literature review and iterative expert consultations, the framework's design integrates qualitative analyses. Key findings reveal that its structured approach enables precise diagnostic evaluation of educators' competencies while offering actionable pathways for growth. By offering a detailed roadmap for the integration of AI tools in teaching, learning and assessment, the framework endeavours to equip educators with the necessary skills and knowledge to navigate the complexities of digital pedagogy effectively. Consequently, this article aims to catalyse a shift towards more informed, strategic and proficient use of AI in education, ensuring that educators are well prepared to meet the challenges and opportunities presented by the age of AI.

1 | Introduction

The integration of AI into education has fundamentally transformed teaching and learning (Chiu et al. 2024; Hava and Babayiğit 2024; Ng et al. 2023; Wang et al. 2024). Large language models and AI-powered educational tools can generate human-like text, create educational content, provide instant feedback and facilitate personalised learning experiences at an unprecedented scale (Holmes and Tuomi 2022; Lim et al. 2023). Generative AI tools also enable automated assessment, adaptive learning pathways and intelligent tutoring systems (Huang et al. 2024; Kohnke et al. 2023; Moorhouse 2024). However, these opportunities also raise crucial questions surrounding academic integrity, authentic assessment and educators' changing roles (Kohnke and Zou 2025). Today's educators therefore must develop specific AI-related knowledge and skills, encompassing technical proficiency, ethical considerations and pedagogical applications (Celik 2023; Moorhouse and Kohnke 2024; Ng et al. 2023). This necessitates a comprehensive framework for developing these competencies.

The existing frameworks for teacher knowledge development, such as the technological pedagogical content knowledge (TPACK) model (Koehler and Mishra 2009) and the digital competence of educators (DigCompEdu) framework (Redecker 2017), provide valuable foundations for

understanding how educators can effectively integrate technology into teaching practices. However, these frameworks require adaptations to address AI technologies' unique educational characteristics and implications (e.g., Chan 2023; Mikeladze et al. 2024). For instance, TPACK effectively delineates the intersection of technological, pedagogical and content knowledge, but it does not explicitly address AI tools' distinctive features such as generating content, providing personalised feedback and adapting to learner needs (Luo and Zou 2024; Zou et al. 2022). Similarly, the original DigCompEdu offers a structured approach to evaluating digital competencies but predates AI's widespread adoption in educational contexts.

Moreover, despite the growing body of research on AI in education, a significant gap exists in understanding how to systematically develop and assess educators' AI competencies (Kohnke et al. 2025). Existing studies have examined implementing AI tools in educational settings (Crompton et al. 2024; Holmes and Tuomi 2022) and proposed various frameworks for digital competencies (Redecker 2017). However, limited research specifically addresses AI technologies' unique challenges and opportunities in teaching and learning. This gap is particularly critical given GAI tools' rapid advancement and potential impact on educational pedagogy (Kohnke et al. 2023; Moorhouse and Kohnke 2024; Wei 2023).

Therefore, the urgency of this research lies in the dissonance between AI's accelerating adoption and the absence of a systematic framework to equip educators with the competencies needed to harness its potential responsibly. Without such guidance, educators risk either underutilising AI's transformative capabilities or exacerbating ethical and pedagogical pitfalls, such as over-reliance on automated systems or inequitable resource distribution. This study addresses a critical gap by redefining teacher preparedness for the AI era, ensuring educators can navigate both the opportunities and challenges of AI while fostering equitable, student-centered learning environments. Moreover, as no existing framework provides granular descriptors or progression levels for AI competency development, limiting practical implementation in teacher training, this study aims to establish detailed descriptors and proficiency levels for each AI-competency domain.

2 | Literature Review

2.1 | TPACK

The escalating emphasis on the requisite digital competencies for novice educators, as highlighted by scholars such as Starkey (2020), has catalysed the formulation of numerous frameworks delineating the essential skills and knowledge required for educators to effectively incorporate technology into their pedagogical practices. A notable instance of such frameworks is the TPACK framework (Figure 1) introduced by Mishra and Koehler (2009), which offers a comprehensive model for understanding the intersections between technology, pedagogy and subject content in educational settings.

The TPACK framework integrates technology into teaching in a meaningful way and emphasises the intersection of

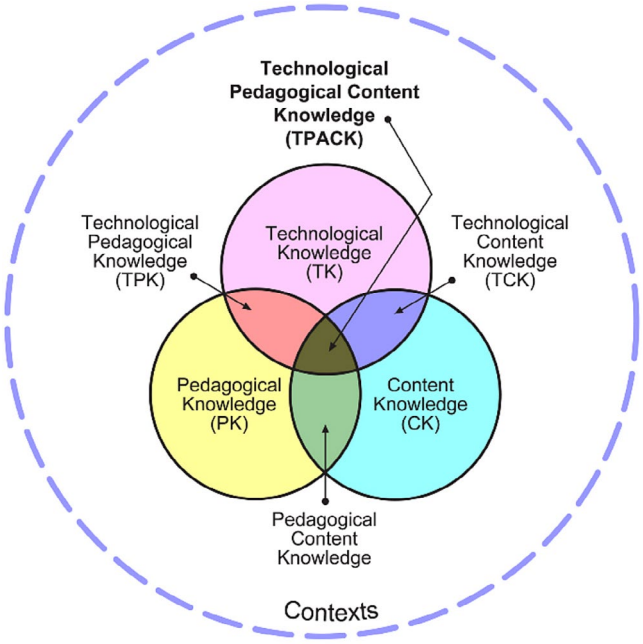

FIGURE 1 | TPACK framework.

three primary forms of knowledge: Content (CK), Pedagogy (PK) and Technology (TK) (Bustamante 2020). CK refers to the subject matter that is to be learned or taught, PK involves the methods and processes of teaching and TK pertains to the use of digital tools and resources (Mishra and Koehler 2009). TPK refers to the knowledge about how teaching and learning can change when particular technologies are used. It encompasses an understanding of the existence, components and capabilities of various technologies as they are used in teaching and learning settings. TCK involves understanding how technology can create new ways of teaching content. PCK is the knowledge of how to teach specific content. It involves understanding the most effective ways to present certain concepts, ideas, or content to learners. This includes knowledge of strategies, methods and approaches that are particularly effective for teaching specific content areas, as well as an understanding of what makes certain concepts difficult or easy to learn. TPCK is the intersection of all three knowledge domains, which represents a holistic understanding of how to effectively integrate technology into teaching specific content, based on an understanding of the content itself, the pedagogical strategies best suited for teaching this content, and the technological tools that can best support these strategies (Bustamante 2020). TPACK is about finding a synergistic integration of these three knowledge domains to create effective and meaningful learning experiences.

Based on the TPACK framework, Celik (2023) introduced Intelligent-TPACK, an extension with an ethical knowledge component, to guide the ethical and pedagogical use of AI-based tools. Intelligent-TPACK encompasses the understanding and interaction with AI-based tools, focusing on their fundamental functionalities and assessing teachers' familiarity with these tools' technical capacities. Intelligent-TPK delves into the pedagogical affordances offered by AI tools, such as providing personal and timely feedback and monitoring student learning, along with interpreting alerts and

notifications from these tools. Intelligent-TCK is concerned with the application of field-specific AI tools to enhance content knowledge, evaluating teachers' use of technology to stay updated in their subject area and their understanding of technologies best suited for their field's learning objectives. Intelligent-TPACK represents the integration of these components, assessing teachers' ability to judiciously select and apply AI tools to achieve instructional goals through effective teaching strategies, such as providing monitoring and timely feedback within specific domains. Ethics evaluates a teacher's assessment concerning the decision on AI-based tools based on principles of transparency, fairness, accountability and inclusiveness (Celik 2023).

In language classrooms, the TPACK framework guides educators in integrating technology to enhance language learning effectively, and language teachers need to understand not only the linguistic content (grammar, vocabulary, etc.) but also the pedagogical strategies best suited for language instruction (Su et al. 2023). When this is combined with technological knowledge, teachers can select and use digital tools (like language learning apps, online collaborative platforms or multimedia resources) that complement their teaching methods and support the learning objectives. For instance, using a blog for students to practice writing skills offers an authentic context for language use, aligning with pedagogical goals while incorporating technology (Wu and Wang 2015). The development of TPACK among language teachers involves a continuous process of learning and adaptation, and teachers need to stay informed about emerging technologies and consider how these can be integrated into their pedagogical practices to enhance language learning (Zou 2020). Professional development programmes focusing on TPACK can help language teachers explore various digital tools and platforms and understand how to align these with their teaching objectives and content requirements (Kohnke et al. 2024). As language teachers develop their TPACK, they become more adept at creating engaging, relevant and effective language learning experiences for their students.

While the TPACK framework offers a theoretical model elucidating the interplay between technological, pedagogical and content knowledge, its application in practical settings has been constrained by its conceptual abstraction. An examination of 51 TPACK-related studies revealed that a mere four explicitly addressed its practical implementation in the context of language education (Tseng et al. 2020). Furthermore, TPACK does not adequately specify the developmental pathways through which educators can acquire the necessary competencies to employ AI tools in language instruction, nor does it pinpoint the precise technological knowledge essential for incorporating these tools within educational settings. This oversight is particularly significant in light of the distinctive functionalities of AI technologies and the unique challenges they introduce, distinct from those associated with conventional educational technologies. Additionally, the TPACK framework appears to neglect other critical dimensions of teaching within AI-enhanced environments, such as ethical considerations, privacy issues and security concerns (Starkey et al. 2023).

2.2 | DigCompEdu

The DigCompEdu framework, conceptualised by the European Commission, constitutes a comprehensive Professional Development Competencies (PDC) master framework within the European Union (EU) context. It functions as a foundational benchmark for various stakeholders, including national states, educational entities, schools and providers of professional development, aiming to craft their distinctive frameworks (Redecker 2017). DigCompEdu systematically organises 22 competencies across six domains, each featuring six levels of proficiency, offering a structured approach to evaluating and enhancing educators' digital competencies.

As illustrated in Figure 2, the first area, Professional Engagement, emphasises the effective and appropriate use of technologies for communication, collaboration and reflection among relevant stakeholders. Second, Digital Resources focuses on the selection, creation, adaptation and management of educational resources and highlights the ethical use of digital content in education. Teaching and Learning concerns the pedagogically meaningful integration of digital technologies into teaching practices and enhancement of collaborative and self-regulated learning. Assessment addresses the use of digital technologies to assess student performance, analyse evidence and provide feedback and support. Empowering Learners features the use of technologies to support differentiation, personalisation, accessibility, inclusion and active student engagement. Lastly, Facilitating Learners' Digital Competence, underlines educators' duty to enhance students' digital literacy and responsible technology use (Punie and Redecker 2017).

The six proficiency levels (A1 to C2), demonstrated in Figure 3, mirror the structure of the Common European Framework of Reference for Languages (CEFR). Educators at the Beginner (A1-A2) levels recognise the potential benefits of digital technologies for pedagogical and professional development but have limited experience in their application. Intermediate (B1-B2) educators can actively integrate digital tools across various teaching and learning contexts, demonstrating a broader understanding and application of digital resources in their pedagogical practices. Advanced (C1-C2) educators lead and innovate in digital technology use, developing new strategies and fostering a culture of learning and innovation. This framework's levels facilitate teacher self-assessment and professional growth by identifying strengths and development areas in digital competencies for effective technology integration in education (Caena and Redecker 2019).

Reisoğlu and Çebi (2020) conducted a study to examine a 70-h DigCompEdu-based training programme for 24 pre-service teachers, focusing on five competence areas: Information/data literacy, communication/collaboration, digital content creation, safety and problem-solving. Their research data, in the formats of diaries and interviews, revealed improvements in sub-competences like information evaluation, digital identity management and copyright awareness, but gaps persisted in environmental protection, content integration and personalised differentiation. Based on such findings, Reisoğlu and Çebi suggested that educator trainers integrate practical, collaborative

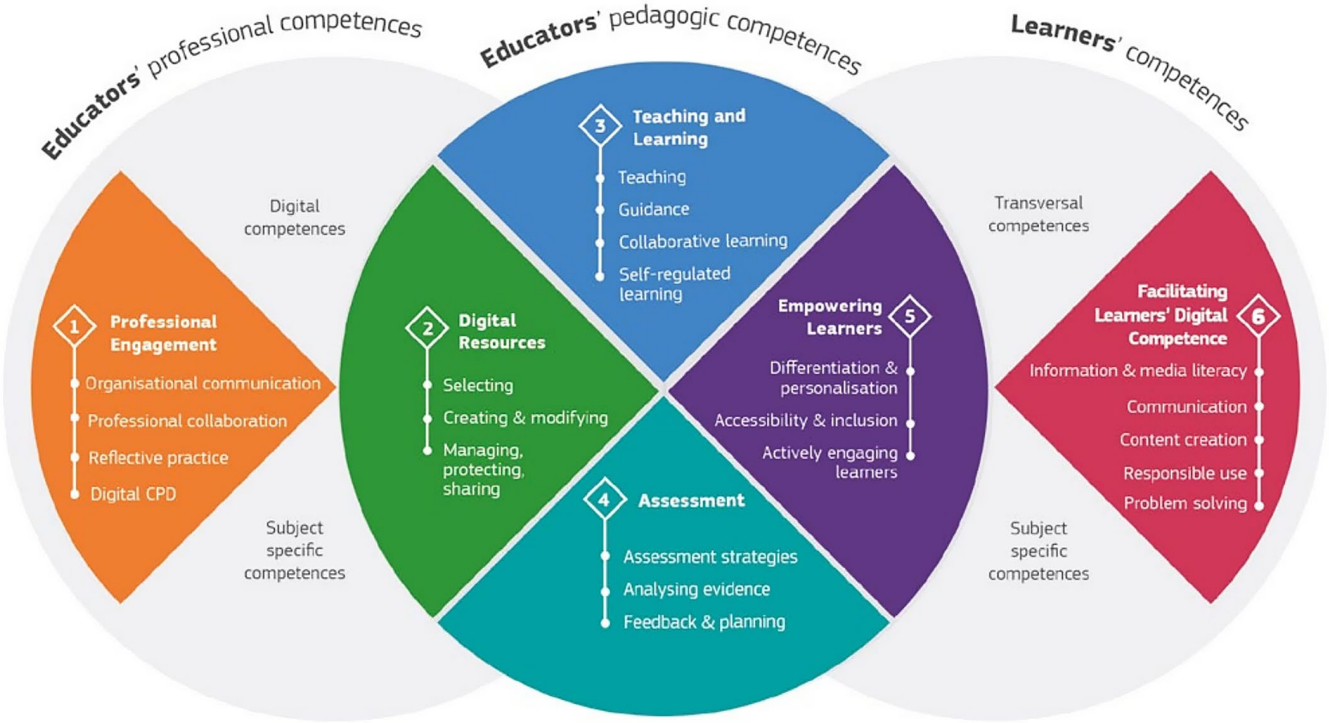

FIGURE 2 | Synthesis of the DigCompEdu framework (Punie and Redecker 2017).

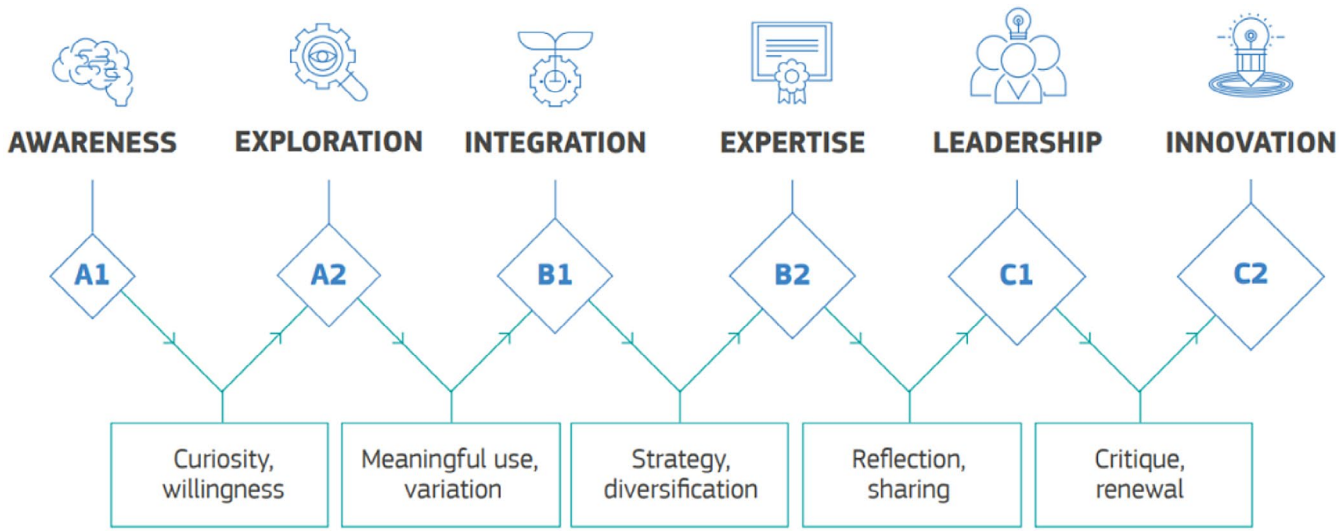

FIGURE 3 | Levels of the DigCompEdu progression model (Punie & Redecker 2017).

tasks and role-modelling to align with DigCompEdu's domains (e.g., professional engagement, digital resources, teaching/learning, assessment and learner empowerment).

In another study, Horváth et al. (2025) assessed the DigCompEdu framework's validity for measuring teacher educators' digital competence (TDC) via a Hungarian sample ($N = 183$). Using structural equation modelling, it confirmed internal validity and highlighted professional engagement's mediating role in fostering student teachers' digital skills. However, self-assessment alignment with test results was weak, and age/competence correlations were inconsistent. Despite sample limitations, the findings underscore DigCompEdu's potential for refining TDC development, emphasising professional engagement while urging caution in self-evaluation accuracy.

While the DigCompEdu framework offers a structured approach to educators' digital competence development, it has a notable limitation. Its narrow focus on pedagogical integration of digital tools (e.g., teaching strategies, assessment) sidelines subject-specific and general digital competences (Caena and Redecker 2019). Unlike the TPACK model, which explicitly intertwines TK, PK and CK, DigCompEdu assumes CK and TK are sufficiently addressed elsewhere, potentially overlooking discipline-specific challenges (e.g., STEM vs. humanities) and evolving technological demands. This limitation highlights the

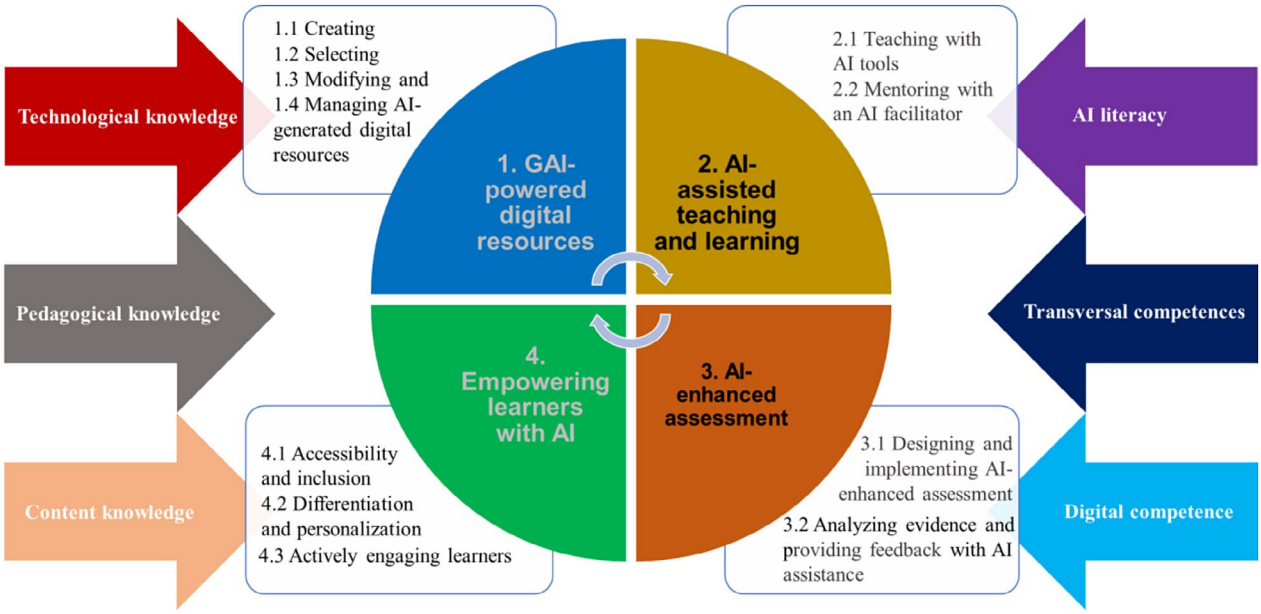

FIGURE 4 | Educators' pedagogic AI competence framework.

need for a complementary framework to address contextual, content-specific and pedagogical dimensions of digital competence development.

3 | Method

Guided by the TPACK and DigCompEdu frameworks, this study employed a three-stage methodological process to develop a framework for educators' AI competencies. The stages included: (1) systematic identification of key competencies through literature analysis, (2) critical evaluation of existing pedagogical models and (3) contextual adaptation of these elements to AI-specific educational contexts.

1. Identification of Key Competencies: The initial phase involves a meticulous review of existing literature to identify essential competencies for educators navigating the complexities of the digital age. This literature review spans both empirical studies and theoretical discussions, aiming to collate a comprehensive list of skills and knowledge areas critical for educators in the context of rapidly evolving AI technologies.
2. Critical Analysis of Existing Models: Subsequent to the identification of key competencies, following Caena and Redecker (2019), the researchers engaged in a critical analysis of well-established models for teacher knowledge development, including, but not limited to, the TPACK framework and the DigCompEdu models. These frameworks were selected based on their prevalence in teacher education literature as revealed at the previous stage. Three researchers assessed each framework's alignment with AI-specific demands critically and independently. Discrepancies were resolved through consensus discussions. This analysis seeks to evaluate the applicability and relevance of these models within the GAI landscape, identifying strengths and limitations in addressing the pedagogic needs of modern educators.
3. Contextualisation in the AI Landscape: The synthesised competencies and model gaps were contextualised for AI through three iterative rounds of expert validation. The three researchers situated the synthesised competencies within the specific context of AI in education. This involves adapting and refining the competencies and models to address the unique challenges and opportunities presented by AI technologies. This step ensures that the proposed framework is not only grounded in established pedagogic theory but also responsive to the dynamic nature of technological advancement.

Through this methodological approach (i.e., triangulation of literature analysis, model evaluation and expert validation), the study aims to contribute a forward-thinking framework that empowers educators to harness the potential of GAI in enhancing pedagogic effectiveness. This research not only addresses the theoretical underpinnings of teacher competencies in the digital age but also offers practical insights for educators seeking to integrate AI into their pedagogic practices.

4 | Proposed Framework

Based on the analysis of this research concerning educators' key competences and models for their knowledge development, we propose a framework for educators' pedagogic competences in the age of generative AI (GAI) with reference to the TPACK and DigCompEdu frameworks. As shown in Figure 4, this educators' pedagogic AI competence (PedAIComp) framework is structured around four foundational areas, namely: Area 1: GAI-powered digital resources, Area 2: AI-enhanced teaching and learning, Area 3: AI-augmented assessment and Area 4: Empowering learners with AI.

The first three areas delineate the effective and innovative application of AI technologies when planning (Area 1), implementing (Area 2) and assessing (Area 3) teaching and learning. Area 4 emphasises the significance of AI technologies in facilitating learner-centered approaches to education. It intersects with the first three areas by providing overarching principles that enhance and complement the competencies outlined therein. For instance, educators skilled in Area 1 will adeptly create, select, modify and manage AI-generated digital resources to align with specific learning goals and the learners' current abilities. They aim to select and/or develop learning activities that directly contribute to achieving desired learning outcomes. Meanwhile, educators excelling in Area 4 focus on tailoring AI-augmented resources to foster learner empowerment, ensuring accessibility for and inclusion of all students, enabling personalised learning trajectories, designing resources to actively involve and captivate every learner and providing them with real-time interactions. A proficient AI educator will, therefore, integrate the objectives of both Area 1, focusing on the direct learning goals, and Area 4, centering on learner empowerment. While the former pertains specifically to the selection or creation process, the latter universally applies to competencies across Areas 1–3.

Beyond these core pedagogic elements, the framework incorporates wider digital and transversal competencies, as well as AI literacy, and the integration of technological, pedagogical and content knowledge. These components recognise that pedagogic AI competence extends beyond mere operational use of AI in education to encompass a holistic understanding of the broader teaching and learning environment. Pedagogically AI-competent educators are thus encouraged to consider the complete educational ecosystem in which they operate.

Specifically, the six foundational elements (i.e., Technological Knowledge, AI Literacy, Pedagogical Knowledge, Transversal Competence, Content Knowledge and Digital Competence) holistically support the four core areas. Area 1 (GAI-powered digital resources) relies on TK to operate AI tools, AI Literacy to leverage GAI capabilities, Digital Competence to navigate platforms and CK to ensure subject-specific relevance. Area 2 (AI-enhanced teaching and learning) draws on TPK to design AI-integrated instructional strategies, AI Literacy to apply tools like adaptive learning systems and Transversal Competence to adapt methods across diverse contexts. Area 3 (AI-augmented assessment) combines PK for designing evaluations, AI Literacy to automate feedback and analytics and Digital Competence to manage ethical data practices. Finally, Area 4 (Empowering learners with AI) hinges on Transversal Competence to cultivate critical thinking and self-regulation, AI Literacy to teach students responsible AI use and TCK to align AI applications with disciplinary goals. Across all areas, Digital Competence serves as the bedrock, enabling seamless interaction with AI technologies, while TK and AI Literacy ensure educators can innovate within evolving digital landscapes. Together, these elements create a synergistic foundation for educators to harness AI's potential ethically, creatively and effectively in pedagogy.

4.1 | Area 1: GAI-Powered Digital Resources

Pedagogic AI competencies for educators in digital resource management encompass a multifaceted understanding of how to create, select, modify and manage AI-generated digital resources. This area includes four competencies.

1.1. *Creating AI-generated digital resources*: The ability to create or co-create new digital resources using GAI is becoming increasingly important. Educators should be able to guide GAI tools and models in developing accurate and ethical resources that meet specific learning objectives and pedagogical strategies. Beyond understanding GAI's capabilities and limitations, educators need proficiency in designing and revising prompts that effectively communicate the desired output from GAI tools, ensuring the generated content meets educational standards and learning goals. They should be skilled in prompting GAI to generate content that fits curriculum requirements and suit student levels. Moreover, educators should be adept in iterative design processes, where prompts are continuously refined based on the AI's responses to better align with educational objectives.

1.2. *Selecting AI-generated digital resources*: Educators must be skilled in selecting AI-generated resources that are relevant and appropriate. This requires an intricate blend of subject-specific knowledge and pedagogical expertise. Educators firstly need to evaluate the AI-generated content, ensuring it aligns with academic standards and enriches the curriculum. They also must sift through available content to find resources that accurately represent the subject area, free from biases and errors and that are appropriate for the educational context. Moreover, making informed decisions about selecting AI-generated resources necessitates a comprehensive understanding of students' needs and preferences. Educators must be adept at analysing these factors to choose materials that not only meet educational objectives but also engage and motivate learners. Critical evaluation skills are paramount for assessing the relevance, accuracy and pedagogical value of AI-generated materials.

1.3. *Modifying AI-generated digital resources*: Upon selecting AI-generated digital resources, it is imperative for educators to modify the content to align with the accuracy, lesson plans, intended learning outcomes and the current learning status of students, ensuring the materials are accurate, ethical, relevant and engaging. This adaptation process necessitates a deep understanding of curriculum design, allowing educators to refine resources to seamlessly integrate into the overarching curriculum, thereby enriching the educational journey. This involves tailoring materials to foster learning outcome progression and accommodate both individual and group learning settings. Effective adaptation also hinges on a detailed comprehension of the diverse needs and preferences of students. Educators are tasked with modifying resources to engage students' interests, accommodate their learning preferences and bridge any knowledge or skill gaps. In essence, the customisation of GAI-powered digital resources demands a synergistic application of subject matter expertise, pedagogical insight, attentiveness to student needs and meticulous curriculum planning.

1.4. *Managing AI-generated digital resources*: Educators need competencies in managing digital libraries and

ensuring that the resources are accessible to all learners. They also should be aware of the importance of protecting sensitive data and are responsible for sharing digital resources in a way that respects copyright and privacy laws. Understanding the use of open licences and the principles of open educational resources is crucial for legally sharing AI-generated materials and attributing them properly. Moreover, educators must possess knowledge in digital ethics, including navigating data privacy concerns, addressing biases within AI algorithms and understanding intellectual property issues to use AI-powered resources responsibly.

Table 1 provides a structured outline for each of the four competencies related to GAI-powered digital resources. Each level reflects increasing proficiency, from basic awareness to advanced leadership and innovation in the use of AI tools within education. This approach aligns with a comprehensive progression model for educators, enhancing their digital competencies in a strategic and scalable manner.

4.2 | Area 2: AI-Assisted Teaching and Learning

The second area involves effectively leveraging AI to support a learner-centred teaching and learning approach through integrating AI in teaching and mentoring learners using AI technologies. The two focal competencies are further explained below.

2.1. *Teaching with AI tools*: Incorporating AI tools into teaching practices offers educators unparalleled opportunities to enhance instruction and foster a more engaging, personalised learning environment. The key to effectively leveraging these tools lies in understanding their diverse functionalities and integrating them into pedagogical strategies to support and enrich the learning journey. Educators can harness AI to tailor educational content and experiences to individual learners' needs and preferences.

This personalisation is achieved through Intelligent Tutoring Systems (ITSs) and adaptive or personalised learning platforms that analyse students' performance, learning needs and engagement levels to provide customised guidance, exercises and feedback. By adjusting to each student's unique learning path, AI tools can help bridge knowledge gaps more efficiently, making education more accessible and effective for everyone.

Natural Language Processing (NLP) technologies enable real-time, interactive communication between students and AI, allowing for immediate feedback and continuous checking for comprehension. This instant feedback mechanism is crucial in education, facilitating continuous improvement and confidence.

Collaborative learning is another area where AI tools can significantly impact. Through analysis of group interactions and learning patterns, AI can offer insights to educators on how to optimise group work, promote effective communication and encourage peer learning. Moreover, AI-powered systems can identify the most beneficial collaboration patterns and suggest adjustments to maximise the educational outcomes of group activities.

The role of AI in fostering an inclusive learning environment cannot be overstated. Specialised AI applications provide support for learners with diverse needs, including those with disabilities, by offering customised resources and learning strategies. This not only aids in accommodating individual learning differences but also ensures equitable access to education.

Furthermore, AI's capability to analyse vast amounts of data offers educators insights into classroom dynamics and student engagement, enabling them to make informed decisions about teaching strategies and interventions. By understanding patterns of engagement and learning, educators can fine-tune their instruction to better meet their students' needs.

In essence, the effective use of AI in teaching requires a holistic approach that integrates various AI tools and techniques into the curriculum and pedagogical practices. Educators should aim to leverage AI not just as a supplementary tool but as an integral part of the learning ecosystem that enriches the educational experience. By doing so, they can provide a more dynamic, interactive and personalised learning environment that prepares students for the challenges of the future.

2.2. *Mentoring with an AI facilitator*: Using AI as mentors marks a significant transformation in educational methodologies, emphasising the utilisation of AI to enhance mentorship roles. This innovative approach enables educators to employ AI for personalised guidance, promoting self-directed learning among students. AI mentors facilitate a learning environment where students can set their own goals, monitor their advancements and reflect on their educational progress, thereby personalising and enhancing the mentorship experience.

A crucial aspect of this evolution is the educator's understanding of AI's ability to customise learning experiences according to the individual needs and preferences of each student. At the heart of AI's mentorship capabilities are ITSs and personalised learning environments that exemplify how AI can provide detailed, adaptive feedback and instructions that correspond with the learner's pace and requirements.

For example, ITSs have been effectively used to offer autistic learners tailored support that addresses both their academic and emotional needs, mirroring the support typically provided by human mentors. NLP also enables AI mentors to engage in meaningful dialogues with learners, offering immediate feedback that is relevant to the learning context. Educational robots as AI mentors introduce an element of interactivity, challenging students with tasks that enhance their critical thinking and problem-solving abilities. Beyond imparting knowledge, these AI mentors stimulate curiosity and foster a passion for discovery.

Affective computing highlights the role of emotional intelligence in learning, with AI mentors capable of

TABLE 1 | Levels of the PedAIComp progression (Area 1: GAI-powered digital resources).

Competency	Awareness (A1)	Exploration (A2)	Integration (B1)	Expertise (B2)	Leadership (C1)	Innovation (C2)
Creating AI-generated digital resources	Understands basic functions of GAI tools and their potential in creating educational content	Experiments with generating simple resources that align with learning objectives, using basic prompts	Designs effective prompts to produce content aligned with specific curriculum needs; refines prompts iteratively	Creates complex, tailored resources that accurately align with pedagogical strategies; adapts prompts based on response	Leads sessions on using GAI to create digital resources; guides peers in designing effective prompts	Innovates by co-creating sophisticated resources with GAI, advancing prompt techniques to enhance learning outcomes
Selecting AI-generated digital resources	Recognises a range of GAI-generated resources and begins to identify relevant educational materials	Begins evaluating resources for subject alignment, relevance and appropriateness for students' needs	Selects resources that accurately represent subject matter, free from biases; considers student engagement factors	Critically evaluates resources, ensuring relevance, accuracy and alignment with curriculum and students' preferences	Supports colleagues in identifying high-quality resources; establishes guidelines for resource selection	Develops frameworks for evaluating and selecting GAI-generated resources across diverse educational contexts
Modifying AI-generated digital resources	Understands the need for adapting AI-generated resources to meet curriculum requirements and student needs	Makes minor modifications to align resources with specific lesson plans and learning outcomes	Customises resources to fit lesson objectives, student interests and engagement levels; addresses biases as needed	Adapts resources extensively, ensuring ethical considerations and relevance to curriculum; tailors for diverse learners	Provides training on modifying AI resources; shares best practices for adaptation to meet diverse educational goals	Creates innovative customisation techniques, setting standards for ethical and effective adaptation of AI resources
Managing AI-generated digital resources	Aware of digital resource management principles, including data privacy and copyright basics	Organises a small library of GAI-generated resources; begins to understand open licences and copyright	Manages a resource library with ethical practices; ensures accessibility and proper licensing of digital materials	Oversees a digital repository, enforcing data privacy, copyright respect, and equitable access to resources	Leads policy development for ethical resource management, data privacy, and copyright in GAI usage	Develops innovative resource management strategies that ensure secure, ethical and inclusive access to AI-generated materials

identifying and responding to the emotional states of learners, thus offering support that is sensitive to their emotional well-being. Recommender systems further personalise the mentoring process by selecting learning materials and paths tailored to the learner's profile, continuously adapting recommendations to suit the learner's evolving needs.

AI mentorship represents a comprehensive application of AI technologies to deliver support that is not only academically focused but also considers the emotional and social development of students. By integrating AI, educators can provide a mentorship experience that is both deeply personalised and broadly supportive, fundamentally altering the educational experience.

Table 2 provides a structured framework for educators to progress in their AI-assisted teaching and mentoring competencies, enabling a more personalised, dynamic and supportive learning environment through AI.

4.3 | Area 3: AI-Enhanced Assessment

The third area involves effectively designing and implementing AI-empowered assessment and analysing evidence and providing feedback with AI assistance. The two focal competencies are further explained below.

3.1. *Designing and implementing AI-enhanced assessment*. This new paradigm requires a strategic redesign of assessment tasks to leverage the unique capabilities of GAI, thereby enhancing learning outcomes. Central to it is the emphasis on designing assessments that stimulate creativity and critical thinking, embed contextual elements by linking course content with real-life experiences and implement authentic assessments for practical application of concepts in real-world scenarios. We propose six key strategies for designing and implementing AI-enhanced assessment.

1. *Innovative design*: Educators are encouraged to craft assessments that demand creativity and critical analysis, areas where GAI tools currently face limitations. This includes posing genuine questions tied to contemporary debates within disciplines, expecting students to engage in critical thinking supported by evidence and reasoning.
2. *Contextual and authentic assessments*: Incorporating contextual elements into assignments – such as connecting course content to students' lived experiences and discussions – enhances relevance and student motivation. Authentic assessments, including case studies and problem-based inquiries, allow students to apply theoretical knowledge in practical settings, thereby improving engagement and reducing academic dishonesty.
3. *Diverse representation*: Offering students a variety of ways to express their knowledge beyond traditional text is important. This encompasses creating images, slides, videos, audio recordings and facilitating discussions, thus promoting the use and development of a variety of knowledge and skills.
4. *Process and staged assessment design*: Emphasising the assessment process encourages deeper engagement with the task. Suggestions include incorporating proposals, drafts, annotations and peer feedback into assignments and breaking larger tasks into smaller, manageable segments. This approach can reduce grade anxiety and provide valuable insights into student performance and opportunities for formative feedback.
5. *Integration of GAI tools*: A novel approach involves students interacting with GAI tools, such as ChatGPT, DALL-E and Sora, both as a means of generating content and as a subject of critical analysis. This fosters digital literacy and necessitates ethical considerations, including acknowledging the use of such tools.
6. *In-class assessments*: In-class assessments to counter the reliance on GAI for assignments are highly recommended. This might include handwritten essays or oral presentations conducted within a controlled environment, though caution is advised to ensure equity and inclusivity for all students.

3.2. *Analysing evidence and providing feedback with AI assistance*. In the realm of education, leveraging AI to enhance the analysis of evidence and delivery of feedback represents a significant leap forward. AI assistance in these areas facilitates a more nuanced understanding of student performance and engagement, enabling educators to offer tailored support and interventions. This area involves exploring the integration of learning analytics tools, performance prediction AI tools, AI-generated feedback and strategies to enhance feedback engagement and responsiveness.

1. *Learning analytics tools*: These AI-driven platforms analyse vast amounts of data generated by students' interactions with digital learning environments. By tracking metrics such as time spent on tasks, engagement levels and progression through learning materials, educators can gain insights into individual and collective learning patterns. This real-time data allows for the early identification of students who may need additional support, enabling targeted interventions that are responsive to each learner's unique needs.
2. *Performance prediction AI tools*: AI algorithms can predict student performance by analysing historical and real-time data. These tools assess patterns in academic achievements, engagement behaviours and other relevant factors to forecast future outcomes. Such predictions help educators identify at-risk students before they fall behind, offering a window for timely support. Additionally, performance predictions can guide curriculum adjustments and personalised learning pathways, ensuring that teaching strategies align with students' evolving needs.
3. *AI-generated feedback*: AI can automate the process of providing immediate, personalised feedback on student assignments and assessments. By utilising natural language processing and machine learning algorithms, these systems can offer constructive feedback on a wide range of submissions, from written essays to coding assignments. AI-generated feedback can highlight areas of strength, pinpoint weaknesses and suggest resources for improvement, thus supporting students' self-directed learning and revision practices.

TABLE 2 | Levels of the PedAIComp progression (Area 2: AI-assisted teaching and learning).

Competency	Awareness (A1)	Exploration (A2)	Integration (B1)	Expertise (B2)	Leadership (C1)	Innovation (C2)
Teaching with AI tools	Understands basic functionalities of AI tools in education, such as ITSs and adaptive learning platforms	Experiments with using AI tools for basic personalised learning activities; uses NLP for simple feedback tasks	Integrates ITSs, adaptive platforms and NLP to customise learning paths and deliver real-time feedback to students	Expertly utilises multiple AI tools (ITSs, NLP) to create interactive, tailored learning experiences for diverse needs	Leads workshops on AI-assisted teaching; mentors colleagues in selecting and using AI tools effectively in classrooms	Innovates AI integration strategies, advancing personalised and collaborative learning through novel AI applications
Mentoring with an AI facilitator	Recognises AI's potential in personalised mentoring, including ITSs and recommender systems	Explores using AI mentors for basic guidance tasks, such as setting student goals and tracking progress	Implements AI mentors (ITSs, recommender systems) to support self-regulated learning, adapting guidance to student needs	Provides in-depth mentoring through AI, using emotional recognition and adaptive feedback to meet both academic and emotional needs	Trains other educators on leveraging AI in mentorship; establishes best practices for AI-guided student mentorship	Innovates mentorship approaches, developing unique AI-driven mentorship experiences that enhance critical thinking and curiosity

4. *Feedback engagement and responsiveness*: Enhancing how students engage with and respond to feedback is crucial for their academic development. AI tools can play a pivotal role in this by not only delivering personalised feedback but also tracking students' interactions with this feedback. Educators can use this data to understand how effectively students are using the feedback to improve their work. Moreover, AI systems can recommend strategies for students to more effectively incorporate feedback into their learning process, thereby fostering a more responsive and reflective learning environment. Incorporating AI assistance into the analysis of evidence and provision of feedback transforms the educational landscape. It enables a more individualised, data-driven approach to teaching and learning, where feedback is not just informative but also a catalyst for growth and improvement. As AI technologies continue to evolve, their potential to refine the feedback loop and enhance educational outcomes becomes increasingly significant.

Table 3 outlines detailed descriptors and proficiency levels for educators' AI-enhanced assessment competencies.

4.4 | Area 4: Empowering Learners With AI

The fourth area highlights the crucial role of educators in empowering learners through strategic use of AI technologies. It underscores the importance of enhancing learner autonomy and engagement, while simultaneously fostering the development of their digital competencies.

4.1. *Accessibility and inclusion*. To effectively enhance the accessibility and inclusion of education through AI, teachers must develop a strong foundation in AI competencies. This includes understanding the principles of AI technology and its application in educational settings, being aware of various AI affordances and being proficient in employing AI to create adaptive learning resources and environments that accommodate different learning needs and preferences and consider various learner factors such as prior knowledge, cognitive capacity and special educational needs.

Moreover, educators need to stay informed about ethical considerations and data privacy issues related to AI in education. By integrating AI responsibly and professionally, educators need to ensure that such technologies do not widen existing inequalities but instead foster an inclusive learning atmosphere where every student can succeed.

4.2. *Differentiation and personalisation*: Educators should be adept at employing AI tools and models for differentiation and personalisation, allowing learners to progress at their own pace. This might include using GAI to provide customised vocabulary exercises, grammar challenges and interactive speaking opportunities that are tailored to individual learner profiles. Educators should also be able to create and provide a learning environment that facilitates personalised education pathways, enhancing learner engagement and allowing them to progress at their own pace, based on their unique goals.

4.3. *Actively engaging learners*: Educators should understand how to leverage AI technologies to transform passive learning into an active, engaging experience. For example, teachers can use AI-powered chatbots to simulate real-life conversations, allowing students to practice language skills in diverse, practical scenarios such as ordering at a restaurant or navigating travel situations. Educators need to be skilled at selecting and using these tools to ensure that interactions are tailored to students' language levels, guiding them to improve fluency and cultural understanding.

To foster critical thinking in language learning, educators might use AI-assisted writing tools that provide real-time feedback on grammar, vocabulary and style. Teachers should know how to guide students to critically evaluate this feedback, distinguishing between helpful suggestions and potentially incorrect AI-generated advice. This approach not only improves writing accuracy but also develops students' critical analysis of language use.

For building creativity, educators can integrate AI tools that generate visual or multimedia content based on students' language input, like AI-driven storytelling platforms where students craft narratives in the target language. Teachers should know how to structure these activities to encourage expressive language use, allowing students to explore language beyond conventional assignments. By thoughtfully integrating AI in these ways, educators empower students to engage deeply and creatively in language learning, while building essential language skills and critical thinking abilities.

Table 4 outlines detailed descriptors and proficiency levels for educators' competencies in empowering learners with AI.

In conclusion, the four key areas and the 12 focal competencies are interconnected and mutually reinforcing. The *Integration of AI in teaching* closely interacts with concepts of *Accessibility and inclusion, Differentiation and personalisation* and *Learner engagement*, creating a synergistic effect that enhances the overall educational experience. Similarly, *AI mentorship* ties directly into *Accessibility and inclusion* as well as *Learners' digital competence development*, indicating a foundational relationship in fostering an inclusive and digitally competent learning environment. Moreover, *AI-driven assessment design and implementation* are intrinsically linked with *Differentiation and personalisation*, alongside *Active learner engagement*, suggesting that effective assessment practices are pivotal in personalising learning experiences and promoting active engagement among learners.

5 | Teacher Training Programs

Teacher training programs in the age of GAI should be meticulously designed to equip educators with the competencies necessary for navigating the complexities of digital resource management, teaching, learning, assessment and empowering learners with digital skills. We suggest that such programs can be structured in the following approach to cover the three key areas of pedagogic AI competences.

TABLE 3 | Levels of the PedAIComp progression (Area 3: AI-enhanced assessment).

Competency	Awareness (A1)	Exploration (A2)	Integration (B1)	Expertise (B2)	Leadership (C1)	Innovation (C2)
Designing and implementing AI-enhanced assessment	Recognises potential of AI in assessment, such as using GAI to facilitate creativity and real-world application	Experiments with basic AI-enhanced assessments, such as contextual questions and simple authentic assessments	Integrates innovative assessment designs, using AI tools to promote critical thinking, creativity, and contextual relevance	Expertly designs diverse AI-driven assessments (e.g., case studies, GAI-supported projects) to foster practical application and engagement	Leads professional development on designing AI-driven assessments; guides peers on crafting authentic assessments with GAI	Develops and pilots new AI-powered assessment strategies, setting benchmarks for creative and critical assessments in the field
Analysing evidence and providing feedback with AI assistance	Understands basics of AI in data analysis and feedback, such as learning analytics and predictive tools	Explores AI tools for initial performance analysis and simple feedback mechanisms on student work	Integrates learning analytics and performance prediction tools to identify trends, provide targeted interventions and improve feedback quality	Utilises AI-generated feedback and advanced analytics to deliver personalised, responsive and actionable insights on student progress	Coaches others on using AI for formative feedback and evidence analysis; establishes best practices for effective feedback engagement	Innovates in feedback delivery, developing new AI-driven strategies to foster self-directed learning and improve feedback responsiveness

TABLE 4 | Levels of the PedAIComp progression (Area 4: Empowering learners with AI).

Competency	Awareness (A1)	Exploration (A2)	Integration (B1)	Expertise (B2)	Leadership (C1)	Innovation (C2)
Accessibility and inclusion	Recognises AI's potential for enhancing accessibility and inclusion in education	Explores AI tools for basic adaptive learning (e.g., adjusting reading level or pace) to support diverse needs	Integrates AI tools to create adaptive resources that consider individual needs, prior knowledge, and cognitive abilities	Expertly implements AI to foster inclusive learning environments, addressing special educational needs and promoting equity	Leads workshops on inclusive AI practices; mentors peers in ethical considerations, data privacy and responsible AI usage	Develops new approaches to use AI in promoting accessibility and inclusion, setting standards in inclusive digital education
Differentiation and personalisation	Understands basic AI applications for personalisation, such as customising exercises based on student level	Experiments with AI tools for tailored vocabulary and grammar activities that adapt to individual progress	Employs AI to facilitate personalised learning pathways, enhancing learner engagement by allowing self-paced progression	Develops and manages personalised education plans using AI, supporting unique learner goals and encouraging active participation	Coaches others in using AI for differentiation; shares best practices for creating personalised learning experiences	Innovates personalised AI-based educational pathways, advancing the practice of learner-centered education in the field
Actively engaging learners	Understands the concept of active learning and AI's role in facilitating it	Trials AI tools (e.g., chatbots) for practical language scenarios to enhance student engagement	Integrates AI-powered tools to create immersive and interactive language experiences, such as real-world conversation practice	Proficiently uses AI to transform passive learning into active engagement, guiding students in critical analysis of AI feedback	Leads initiatives on AI-enhanced active learning strategies, helping others use AI to foster deep, engaging learning activities	Pioneers new AI-driven methods to actively engage students in learning, encouraging creativity, cultural understanding, and critical thinking

1. Incorporate modules that teach the selection, creation and evaluation of AI-generated resources, emphasising ethical considerations, accuracy, relevance and alignment with learning objectives. Offer hands-on workshops on human-AI collaboration in creating and modifying digital resources, including customisation for diverse learner needs. Facilitate practicums or project-based assignments where educators select, create and modify digital resources using GAI tools, followed by peer and instructor feedback. Use case studies to explore challenges in digital resource management and collaboratively develop solutions.
2. In terms of teaching, learning and assessment with AI, we suggest that the curriculum includes comprehensive courses on integrating AI into language teaching, covering planning, implementation and evaluation of AI-enhanced learning experiences. Include modules on AI mentorship, focusing on personalised guidance, fostering autonomous learning and facilitating collaborative projects with AI. Offer specialised training in AI-driven assessment design and implementation, highlighting innovative approaches and data analysis techniques for informed teaching. Implement simulation-based training for AI integration in teaching, allowing educators to design and test AI-enhanced lesson plans. Conduct workshops on AI mentorship strategies, including role-play scenarios that simulate different learner interactions. Organise assessment design labs where educators create and apply AI-driven assessments, analyse learner data and adjust teaching strategies accordingly.
3. Regarding empowering learners and promoting their digital competence development, it is necessary to design modules on using AI to enhance accessibility and inclusion, ensuring all learners, including those with special needs, can benefit from language education. Teach differentiation and personalisation techniques using AI, enabling educators to tailor learning experiences to individual learner profiles. Integrate courses on engaging learners with GAI, including creative and critical thinking exercises and real-world applications. Facilitate projects where educators use AI tools to create inclusive and personalised learning environments. Organise interactive workshops where educators employ AI to engage learners in language activities, encouraging creative expression and problem-solving. Conduct seminars on developing learners' digital competence, focusing on responsible digital content creation, collaboration and problem-solving with AI. Blend theoretical coursework with practical, hands-on experience to ensure comprehensive understanding and application of competencies. Utilise a variety of delivery methods, including online modules for theoretical knowledge and in-person workshops for practical skills. Encourage reflective practice and continuous professional development through forums, peer collaboration and mentorship programmes.

By focusing on these structured components, language teacher training programs can effectively prepare educators to harness the power of GAI, transforming language teaching, learning and assessment and ultimately empowering learners for success in the digital age.

6 | Conclusions

In this research, we propose the PedAIComp Framework as a pioneering model to support educators in the effective integration of AI within their teaching practices. Building on foundational frameworks such as TPACK and the DigCompEdu, our PedAIComp framework provides a structured pathway through 12 essential competencies across four critical areas: AI-powered digital resources, AI-enhanced teaching and learning, AI-augmented assessment and learner empowerment through AI. This comprehensive approach not only equips educators to plan, implement and assess AI applications in education but also emphasises the importance of promoting inclusivity, accessibility and learner-centered methodologies.

This PedAIComp Framework encourages educators to think beyond operational AI skills, incorporating broader digital and transversal competencies and fostering a holistic understanding of AI's role within the educational ecosystem. By prioritising both learning outcomes and student empowerment, this framework supports educators in navigating the rapidly evolving AI landscape with confidence and purpose. Ultimately, PedAIComp is a significant step forward in developing a new generation of AI-proficient educators who are well prepared to address the challenges and harness the opportunities of AI in education.

A key limitation of this research lies in its conceptual nature: The proposed framework was developed through a synthesis of existing literature and the authors' professional expertise in AI education and teacher training, rather than empirical validation. While the framework draws on rigorous analysis of scholarly works and decades of practical experience in AI-integrated pedagogy, the absence of systematic data collection (e.g., educator surveys, classroom observations or longitudinal studies) limits its generalisability and practical applicability. As such, the framework remains a theoretically grounded prototype that requires further empirical testing to assess its efficacy across diverse educational contexts. Future research should prioritise validating the framework through quantitative and qualitative studies, such as competency assessments, case implementations or educator feedback loops, to refine its components and ensure alignment with real-world classroom dynamics.

Specifically, to validate the scientific credibility and robustness of the framework and its descriptors, a multi-method approach is essential. First, expert validation through Delphi studies or focus groups with AI researchers, educational technologists and practitioners can verify the framework's comprehensiveness, clarity and applicability across contexts. Second, empirical testing via longitudinal studies, classroom implementations or competency assessments can assess the framework's predictive validity, measuring how well its proficiency levels correlate with observable improvements in teaching practices or student outcomes. Quantitative methods like confirmatory factor analysis or partial least squares structural equation modelling can statistically validate the internal structure of the descriptors, while qualitative analyses (e.g., educator interviews) can capture nuanced insights into usability. Finally, iterative refinement based on feedback and cross-cultural replication studies will enhance

generalisability. By triangulating theoretical, empirical and methodological rigour, the framework's scientific robustness can be demonstrated, positioning it as both evidence-based and actionable for diverse educational ecosystems. Nevertheless, this study serves as a critical first step in redefining educator preparedness for the AI era, bridging theoretical innovation with actionable pathways for future inquiry.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

Bustamante, C. 2020. "TPACK-Based Professional Development on Web 2.0 for Spanish Teachers: A Case Study." *Computer Assisted Language Learning* 33, no. 4: 327–352. https://doi.org/10.1080/09588221.2018.1564333.

Caena, F., and C. Redecker. 2019. "Aligning Teacher Competence Frameworks to 21st Century Challenges: The Case for the European Digital Competence Framework for Educators (Digcompedu)." *European Journal of Education: Research, Development and Policy* 54, no. 3: 356–369. https://doi.org/10.1111/ejed.12345.

Celik, I. 2023. "Towards Intelligent-TPACK: An Empirical Study on Teachers' Professional Knowledge to Ethically Integrate Artificial Intelligence (AI)-Based Tools Into Education." *Computers in Human Behavior* 138: 107468. https://doi.org/10.1016/j.chb.2022.107468.

Chan, K. Y. C. 2023. "A Comprehensive AI Policy Education Framework for University Teaching and Learning." *International Journal of Educational Technology in Higher Education* 20: 38. https://doi.org/10.1186/s41239-023-00408-3.

Chiu, T. K. F., Z. Ahmad, M. Ismailov, and I. T. Sanusi. 2024. "What Are Artificial Intelligence Literacy and Competency? A Comprehensive Framework to Support Them." *Computers and Education Open* 6: 100171. https://doi.org/10.1016/j.caeo.2024.100171.

Crompton, H., A. Edmett, N. Ichaporia, and D. Burke. 2024. "AI and English Language Teaching: Affordances and Challenges." *British Journal of Educational Technology* 55, no. 6: 2503–2529. https://doi.org/10.1111/bjet.13460.

Hava, K., and Ö. Babayiğit. 2024. "Exploring the Relationship Between Teachers' Competencies in AI-TPACK and Digital Proficiency." *Education and Information Technologies* 30: 3491–3508. https://doi.org/10.1007/s10639-024-12939-x.

Holmes, W., and I. Tuomi. 2022. "State of the Art and Practice in AI in Education." *European Journal of Education: Research, Development and Policy* 57, no. 4: 542–570. https://doi.org/10.1111/ejed.12533.

Horváth, L., T. M. Pintér, H. Misley, and I. Dringó-Horváth. 2025. "Validity Evidence Regarding the Use of DigCompEdu as a Self-Reflection Tool: The Case of Hungarian Teacher Educators." *Education and Information Technologies* 30, no. 1: 1–34. https://doi.org/10.1007/s10639-024-12914-6.

Huang, F., Y. Wang, and H. Zhang. 2024. "Modeling Generative AI Acceptance, Perceived Teachers' Enthusiasm, and Self-Efficacy to English as Foreign Language Learners' Well-Being in the Digital Era." *European Journal of Education* 59: e12770. https://doi.org/10.1111/ejed.12770.

Koehler, M., and P. Mishra. 2009. "What Is Technological Pedagogical Content Knowledge (TPACK)?" *Contemporary Issues in Technology and Teacher Education* 9, no. 1: 60–70.

Kohnke, L., D. Foung, and D. Zou. 2024. "Microlearning: A New Normal for Flexible Teacher Professional Development in Online and Blended Learning." *Education and Information Technologies* 29, no. 4: 4457–4480. https://doi.org/10.1007/s10639-023-11964-6.

Kohnke, L., B. L. Moorhouse, and D. Zou. 2023. "ChatGPT for Language Teaching and Learning." *RELC Journal* 54, no. 2: 537–550. https://doi.org/10.1177/00336882231162868.

Kohnke, L., and D. Zou. 2025. "Artificial Intelligence Integration in TESOL Teacher Education: Promoting a Critical Lens Guided by TPACK and SAMR." *TESOL Quarterly*. https://doi.org/10.1002/tesq.3396.

Kohnke, L., D. Zou, A. W. Ou, and M. M. Gu. 2025. "Preparing Future Educators for AI-Enhanced Classrooms: Insights into AI Literacy and Integration." *Computers and Education: Artificial Intelligence* 8: 100398. https://doi.org/10.1016/j.caeai.2025.100398.

Lim, W. M., A. Gunasekara, J. L. Pallant, J. I. Pallant, and E. Pechenkina. 2023. "Generative Ai and the Future of Education: Ragnarök or Reformation? A Paradoxical Perspective From Management Educators." *International Journal of Management in Education* 21, no. 2: 100790. https://doi.org/10.1016/j.ijme.2023.100790.

Luo, S., and D. Zou. 2024. "A Systematic Review of Research on Technological, Pedagogical, and Content Knowledge (TPACK) for Online Teaching in the Humanities." *Journal of Research on Technology in Education* 56, no. 3: 332–346. https://doi.org/10.1080/15391523.2022.2139026.

Mikeladze, T., P. C. Meijer, and R. P. Verhoeff. 2024. "A Comprehensive Exploration of Artificial Intelligence Competence Framework for Educators: A Critical Review." *European Journal of Education: Research, Development and Policy* 59, no. 3: e12663. https://doi.org/10.1111/ejed.12663.

Mishra, P., and M. Koehler. 2009. "Too Cool for School? No Way! Using the TPACK Framework: You Can Have Your Hot Tools and Teach With Them, Too." *Learning & Leading With Technology* 36, no. 7: 14–18.

Moorhouse, B. L. 2024. "Generative Artificial Intelligence in ELT." *ELT Journal* 78, no. 4: 378–392. https://doi.org/10.1093/elt/ccae032.

Moorhouse, B. L., and L. Kohnke. 2024. "The Effects of Generative AI on Initial Language Teacher Education: The Perceptions of Teacher Educators." *System* 112: 103290. https://doi.org/10.1016/j.system.2024.103290.

Ng, D. T. K., J. K. L. Leung, J. Su, R. C. W. Ng, and S. K. W. Chu. 2023. "Teachers' AI Digital Competencies and Twenty-First Century Skills in the Post-Pandemic World." *Educational Technology Research Development* 71: 137–161. https://doi.org/10.1007/s11423-023-10203-6.

Punie, Y., and C. Redecker. 2017. *European Framework for the Digital Competence of Educators: DigCompEdu, EUR 28775 EN*. Publications Office of the European Union.

Redecker, C. 2017. *European Framework for the Digital Competence of Educators: DigCompEdu (No. JRC107466)*. Joint Research Centre (Seville site).

Reisoğlu, İ., and A. Çebi. 2020. "How Can the Digital Competences of Pre-Service Teachers Be Developed? Examining a Case Study Through the Lens of DigComp and DigCompEdu." *Computers & Education* 156: 103940. https://doi.org/10.1016/j.compedu.2020.103940.

Starkey, L. 2020. "A Review of Research Exploring Teacher Preparation for the Digital Age." *Cambridge Journal of Education* 50, no. 1: 37–56. https://doi.org/10.1080/0305764X.2019.1625867.

Starkey, L., A. Yates, M. de Roiste, et al. 2023. "Each Discipline Is Different: Teacher Capabilities for Future-Focussed Digitally Infused Undergraduate Programmes." *Educational Technology Research and*

Development 71, no. 1: 117–136. https://doi.org/10.1007/s11423-023-10196-2.

Su, F., D. Zou, and L. Wang. 2023. "Learning-by-Doing in a Professional Learning Community: Technological Pedagogical and Content Knowledge Development of Hong Kong University Teaching Staff." *Asia Pacific Education Review*: 1–16. https://doi.org/10.1007/s12564-023-09918-1.

Wang, Y. L., H. W. Wu, and Y. S. Wang. 2024. "Engagement and Willingness to Communicate in the L2 Classroom: Identifying the Latent Profiles and Their Relationship With Achievement Emotions." *Journal of Multilingual and Multicultural Development*. https://doi.org/10.1080/01434632.2024.2379534.

Wei, L. 2023. "Artificial Intelligence in Language Instruction: Impact on English Learning Achievement, L2 Motivation, and Self-Regulated Learning." *Frontiers in Psychology* 14: 1261955. https://doi.org/10.3389/fpsyg.2023.1261955.

Wu, Y. T., and A. Y. Wang. 2015. "Technological, Pedagogical, and Content Knowledge in Teaching English as a Foreign Language: Representation of Primary Teachers of English in Taiwan." *Asia-Pacific Education Researcher* 24: 525–533. https://doi.org/10.1007/s40299-015-0240-7.

Zou, D. 2020. "Gamified Flipped EFL Classroom for Primary Education: Student and Teacher Perceptions." *Journal of Computers in Education* 7, no. 2: 213–228. https://doi.org/10.1007/s40692-020-00153-w.

Zou, D., X. Huang, L. Kohnke, X. Chen, G. Cheng, and H. Xie. 2022. "A Bibliometric Analysis of the Trends and Research Topics of Empirical Research on TPACK." *Education and Information Technologies* 27, no. 8: 10585–10609. https://doi.org/10.1007/s10639-022-10991-z.