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Revisiting Pedagogical Content Knowledge (PCK) development for the age of generative AI

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ABSTRACT

This paper examines how Generative Artificial Intelligence (GenAI) in K-12 education interacts with teachers' Pedagogical Content Knowledge (PCK). Using the Refined Consensus Model (RCM) as an analytical framework, we analysed how GenAI influences the three PCK domains: personal PCK (pPCK), collective PCK (cPCK), and enacted PCK (ePCK). Guided by the research question "How can teachers and GenAI collaborate to develop and use PCK and pedagogical reasoning in K-12?", we analysed three researcher-constructed vignettes – hypothetical but plausible scenarios representing GenAI use in planning, classroom interaction, and assessment – to derive analytical propositions about the PCK-GenAI relationship. Our analysis suggests tensions between traditional PCK boundaries and GenAI-mediated practices, particularly regarding the RCM's plan-teach-reflect cycle. We propose that GenAI can amplify teachers' PCK when critically evaluated, but poses risks for novice teachers whose pPCK is still developing. The paper identifies how GenAI reconfigures boundaries between personal and collective knowledge, reshapes enacted practice when AI becomes a co-constructor of teaching, and highlights the continued centrality of teacher expertise. We propose directions for supporting effective human-GenAI collaboration in PCK development and discuss implications for teacher education.

1. Introduction

Pedagogical Content Knowledge (PCK), introduced by Shulman [1–3], refers to the specialised knowledge teachers hold about how to make subject matter learnable. It is through pedagogical reasoning – the deliberate thinking involved in planning, teaching, and interacting with students – that this knowledge is both applied and refined. As generative AI (GenAI) becomes increasingly capable of supporting aspects of teachers' professional practice, there is a pressing need to examine how PCK and pedagogical reasoning each relate to teachers' engagement with GenAI. Understanding this relationship is particularly urgent for teacher education, which must prepare both pre-service and practising teachers with the critical capacities and knowledge needed to engage with GenAI effectively and responsibly.

This paper examines how GenAI may enhance, support, or inhibit teachers' pedagogy and development of professional knowledge, particularly PCK [2,3] and pedagogical reasoning [3]. Guided by the question "How can teachers and GenAI collaborate to develop and use PCK and pedagogical reasoning in K-12?", we constructed three vignettes focused on planning, teaching, and assessment, reflecting the three dominant applications of GenAI addressed in UNESCO's AI Competency Framework for Teachers (see: [4]. We analysed these vignettes

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using the Refined Consensus Model (RCM) of PCK [5], considering the implications for teachers' pedagogical use of GenAI including novice teachers developing their professional knowledge alongside their understanding of GenAI.

The paper begins with an overview of GenAI functionalities for teaching and learning, followed by an examination of the RCM and other relevant PCK models. We present our analysis, discussing insights alongside related K-12 empirical studies. We examine implications for teachers and teacher education.

2. The nature of GenAI functionalities for teaching and learning

GenAI tools, including OpenAI's ChatGPT, Microsoft Copilot, Google Gemini, and Anthropic's Claude, are now widely available and increasingly embedded in teachers' everyday practice. Unlike conventional digital tools, these systems generate outputs statistically rather than through understanding – effectively "guessing" the most probable response – which means outputs are not always accurate. This tendency to "hallucinate" requires teachers to evaluate outputs critically rather than accepting them at face value. Retrieval-augmented generation (RAG) can improve output quality by drawing on specified data sources [6].

GenAI offers potential to reduce teacher workload: it can assist with drafting lesson plans [7,8], generating assessments and formative feedback [9], accelerating marking, long recognised as one of the most burdensome aspects of teachers' work [10], and enabling chatbots to answer student questions and simulate role-play scenarios [7].

While GenAI can generate sophisticated-looking outputs, it remains shaped by biases and training-data limitations. Studies note that GenAI lesson planning tools often reproduce Western cultural assumptions and inadequately address local classroom needs [11]. A case study of GenAI-assisted lesson planning showed that ChatGPT only engages substantively with instructional goals when teachers iteratively refine prompts to specify learners, standards, instructional models, and lesson constraints [12]. Lesson creation is thus best understood as an iterative, dialogic process in which teachers "co-construct" content with GenAI, asking clarifying questions, requesting elaboration, and seeking alternative formulations [13]. Celik et al.'s [13] study of 120 Finnish pre-service teachers demonstrated that this process is shaped by teachers' knowledge: their PCK informs not only how they craft prompts but also how they evaluate, refine, and validate the outputs. Through iterative refinements, teachers draw on cognitive, pedagogical, and contextual competencies to guide GenAI in educationally meaningful directions - a pattern also evident in GenAI-supported assessment and feedback [9] and chatbot-mediated learning [14]. The ability to understand how GenAI generates output, craft informed prompts, and critically evaluate AI-generated content against pedagogical intentions and student needs is part of AI literacy. Building on existing frameworks (e.g. [4], we conceptualise AI literacy as: the integrated set of knowledge, skills and attitudes that enables individuals to understand how AI works and affects society, use AI tools responsibly and effectively, critically evaluate AI outputs and limitations, communicate or collaborate with AI systems, and, at advanced levels, design or adapt AI solutions.

While research has begun exploring teachers' adoption of GenAI and its impact on PCK, limited understanding remains of the nuanced ways GenAI both depends on and may reshape teachers' pedagogical reasoning, subject matter interpretation, and adaptive instructional strategies. This gap provides the foundation for our exploration of PCK and the influence of GenAI. To frame our discussion, we first outline current understanding of PCK.

3. Review of PCK in theory and practice

PCK was proposed originally by Shulman [2,3] as knowledge teachers develop through practice, used alongside pedagogical reasoning [3] for lesson planning and student interaction. In order to examine how teachers use and develop PCK, educators further developed Shulman's framework, leading to the Refined Consensus Model (RCM) [5].

3.1. The refined consensus model (RCM) of PCK

The RCM [5] represents PCK's inherent complexity using concentric circles to convey relationships amongst PCK elements (see Fig. 1).

The RCM identifies three distinct realms of PCK: collective PCK (cPCK), representing specialised professional knowledge shared amongst multiple educators; personal PCK (pPCK), comprising an individual teacher's cumulative knowledge and skills derived from teaching experiences and professional contributions; and enacted PCK (ePCK), the specific subset of knowledge utilised during planning, teaching, and reflecting on lessons and students' progress. Central to the model is the concept of bidirectional knowledge exchange between these realms. The learning context – encompassing educational policy, classroom environment, and student attributes – is positioned between personal and collective knowledge, influencing how teachers develop and apply their pPCK. These realms draw on three further knowledge bases: Content Knowledge (CK), teachers' deep understanding of subject matter; Pedagogical Knowledge (PK), general principles of instruction and assessment; and Contextual Knowledge (CxK), knowledge of learners, curriculum, and sociocultural factors.

3.2. Pedagogical reasoning in the refined consensus model

Pedagogical reasoning is the dynamic mechanism through which teachers' knowledge is transformed into practice across the plan-teach-reflect cycle, encompassing both Schön's [15] reflection *in* action, during direct student interaction and reflection *on* action during planning and post-lesson review. The RCM builds on Shulman's [3] foundational model, which positioned the transformation of content knowledge into pedagogically powerful, student-appropriate forms as the crucial process at the heart of teaching – a process shaped throughout by teachers' subject knowledge, beliefs, and orientations.

3.3. Development in the RCM

Within the RCM, pedagogical reasoning is mediated by amplifiers and filters – such as teacher beliefs, views on content, and role perceptions – which influence how knowledge is transformed into instructional decisions [5]. Critically, this process is reciprocal: whilst pPCK informs ePCK through pedagogical reasoning during instruction, insights gained from each interaction with students subsequently inform and refine the teacher's pPCK, positioning pedagogical reasoning not merely as the application of existing knowledge, but as a generative process that contributes to ongoing PCK development, ideally through collaboration with others and connection to collective professional knowledge [5]. In practice, this reasoning is made visible through teachers' instructional decisions – their choice of representations, responses to student misconceptions, and adaptations of planned activities in the moment.

3.4. Integrating technology into PCK models

Challenges of effective technology use for teachers prompted PCK models foregrounding technology, notably Mishra and Koehler's [16,17] TPACK framework, widely used to support teacher professional learning in their use of technological tools [18,19]. Whilst TPACK has proven valuable for examining teachers' integration of conventional digital tools, it treats technology as an inert resource rather than an agent capable of generating content and mediating knowledge – a distinction that makes the RCM, with its explicit focus on PCK development and the plan–teach–reflect cycle, more analytically appropriate for examining Human-GenAI collaboration, the focus in this paper.

The RCM positions technological tools within the Learning Context

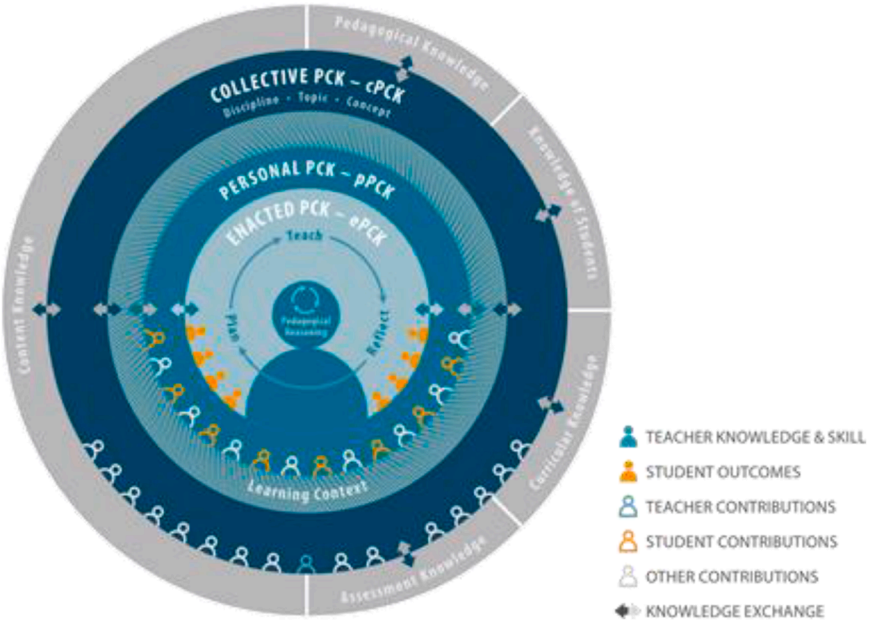


Fig. 1. Representation of the Refined Consensus Model (RCM) of PCK [5], p. 83).

layer alongside other pedagogical resources, and has been used broadly to examine professional knowledge development [20,21]. However, GenAI differs from conventional tools. Floridi [22] argues that AI systems demonstrate "agency without intelligence" – interacting with environments and modifying internal rules without human-like comprehension. This unique agency distinguishes GenAI from both simple tools and human intelligence. Examining teacher-GenAI interaction through the RCM provides a framework for analysing the complex dynamics between teachers, their professional knowledge, and GenAI's capabilities. Unlike earlier interactive technologies, GenAI is also characterised by inherent unpredictability and a tendency to produce pseudo-authoritative outputs – responses that are fluent and confident in register yet potentially inaccurate – placing new demands on teachers' critical judgement that have no direct precedent in prior technology integration frameworks.

4. Methodology

Our literature review revealed two main approaches to examining GenAI in education: studies exploring teachers' use of GenAI (e.g. [23], sometimes combining an analysis of teachers' professional knowledge with their prompt engineering skills (e.g. [13] and researcher-led investigations of GenAI use cases (e.g. [24]. However, research is not yet sufficiently advanced to comprehensively address how teachers and GenAI can collaborate to develop and use PCK, given rapid large language model (LLM) development and the complexity of teachers' professional knowledge. To investigate how GenAI intersects with teachers' PCK, we adopted a vignette-based approach. Vignettes – short, plausible scenarios grounded in real practice – are well-established for examining teacher cognition and professional judgement [25], and are particularly useful for emerging phenomena where empirical work remains limited. The vignettes that we developed are hypothetical but plausible scenarios; they are not accounts of observed classroom events, but analytical tools grounded in documented practice.

4.1. Vignette construction

Eleven internationally recognised researchers and teacher educators, with expertise in educational technology and subject specialisms spanning science, history, computer science, and English education across primary, secondary, and tertiary contexts in the UK, New Zealand, Portugal, Norway, Ireland, Australia, the USA, and North Africa, collaborated to develop three vignettes. The three use cases – lesson planning, supporting learning through chatbots, and assessment – were selected as high-impact applications of GenAI in K-12 settings, reflecting the dominant approaches identified in our literature review and in UNESCO's AI Competency Framework for Teachers [4]. Each vignette was drafted by a small subgroup using empirical literature, professional experience and classroom examples, then critiqued by the full team for plausibility, authenticity, and relevance until consensus was reached (cf [25].

4.2. Analytic procedure

Subgroups analysed how GenAI in each scenario interacted with RCM domains – content, pedagogical, and contextual knowledge, including PCK variants – identifying required teacher competencies and potential risks. These analyses informed Tables 1–3. The full team then conducted two rounds of review to address omissions, inconsistencies, and alignment with the literature, refining the analysis to consensus. Claims were grounded in empirical studies, linking theoretical propositions to limited classroom evidence.

Because the same researchers constructed and analysed the vignettes, there is a risk of bias toward existing theoretical commitments; this limitation is discussed in Section 6.5.

5. GenAI in education: analysis of vignettes

5.1. Vignette 1: planning and preparing a lesson with GenAI

Context: Year 5 (9–10 years old) – Primary School, New Zealand
Subject: Science - Exploring Western and Indigenous Perspectives on the Water Cycle
Amira, a Year 5 teacher, wants to design an engaging science lesson for a unit on the water cycle. She asks a GenAI tool to generate a lesson plan that includes a short experiment, differentiated activities for mixed-ability groups, and links to the New Zealand Curriculum achievement objectives. Given the bicultural nature of the New Zealand context, she wants the lesson to weave together Western scientific explanations (e.g., evaporation, condensation, precipitation) and mātauranga Māori perspectives (the Indigenous knowledge of Māori people) on wai (water), including its spiritual significance and role in local iwi narratives. Within seconds, the GenAI

(*continued on next page*)

Table 1
Vignette 1: Summary of knowledge changes with GenAI.

RCM Knowledge Domain	Established Prior to GenAI	Additional Competencies Required With GenAI	Tensions / Risks Introduced by GenAI
CK	Deep knowledge of Western science and domain-specific concepts; ability to identify misconceptions; integration of mātauranga Māori where relevant.	Ability to critically evaluate GenAI output.	Over-reliance on GenAI may erode teachers' depth of CK; GenAI may introduce errors that teachers overlook; GenAI's Western training data may distort Indigenous knowledge or omit key concepts.
PK	Knowledge of instructional strategies, differentiation, assessment principles, classroom management, and developmental appropriateness; ability to design coherent sequences.	Competence in identifying generic or pedagogically weak AI-generated activities; ability to refine GenAI suggestions into developmentally appropriate tasks; capacity to prompt GenAI effectively.	Teachers may adopt AI-generated pedagogy uncritically; generic sequencing may replace deliberate design; pedagogical reasoning may weaken if teachers outsource planning.
CxK	Understanding of learners, local community, cultural contexts, curriculum expectations, and school policies (e.g., safety, resourcing, tikanga and iwi narratives); bicultural responsiveness.	Capacity to detect contextual misalignment in GenAI outputs; ability to prompt GenAI for localised content; integration of GenAI with school- and community-specific practices.	GenAI defaults may marginalise local knowledge and bicultural obligations; inaccurate assumptions about context may lead to culturally insensitive or unsafe lesson plans; teachers may mistakenly assume GenAI is context-aware.
PCK	Ability to transform CK into teachable forms through representation, explanation, sequencing, anticipating misconceptions, and selecting content-specific strategies; capability to weave mātauranga Māori with Western science.	Critically transforming AI-generated ideas into accurate, culturally grounded pedagogical representations; capacity to filter inappropriate representations; strengthened pedagogical reasoning during transformation.	AI-generated representations may be generic, culturally shallow, or conceptually flawed; teachers may bypass deep transformation, weakening the quality of PCK; risk of tokenistic integration of Indigenous knowledge.
cPCK	Professionally vetted knowledge shared across communities: curriculum documents, exemplars, teacher networks, iwi partnerships, disciplinary literature; grounded in consensus and context.	Ability to distinguish authentic cPCK from AI-generated "pseudo-cPCK"; competence in curating and validating GenAI outputs against shared professional standards; awareness of GenAI's limitations.	Distortion of cPCK if GenAI outputs are circulated uncritically; risk of adopting culturally inappropriate or inaccurate materials; erosion of local expertise or community-developed knowledge.
pPCK	Teacher's internalised, experience-based understanding of how to teach specific content to specific learners; refined through repeated plan–teach–reflect cycles.	Expanded pPCK through critical engagement with AI-generated alternatives; ability to filter, refine, and adapt GenAI outputs.	Heavy reliance on GenAI may weaken pPCK formation; reduced engagement in planning can lead to shallow personal understanding; teachers may lose confidence in their own expertise.
ePCK	Real-time instructional decisions grounded in reflection-in-action; ability to adapt explanations, respond to misconceptions, and manage contingencies; culturally responsive enactment.	Enhanced capacity to interpret and adapt GenAI-designed lessons in situ; ability to modify AI-generated sequences based on student responses; strengthened reflective reasoning-in-action.	Teachers may struggle to adjust AI-generated plans; reduced adaptability if teacher lacks deep understanding of underlying content; potential misalignment with cultural or contextual needs during enactment.

(*continued*)

produces a detailed plan with a melting ice activity, extension questions for advanced learners, and a suggested formative quiz.
Amira scans the plan and notices the GenAI's suggested experiment involves dry ice, which she knows isn't allowed in her school due to safety protocols. The learning outcomes are framed in a very generic way. The plan also accurately explains the Western scientific model but provides only superficial references to Māori knowledge, mostly in the form of translated words and generic statements about kaitiakitanga (guardianship).

5.1.1. *Analysis and discussion of Vignette 1*

Enacting culturally responsive pedagogical reasoning required Amira to integrate Western scientific explanations with mātauranga Māori, drawing on her CxK – local narratives, Māori values, and school expectations. GenAI-assisted planning can supplement pPCK by generating structured lesson plans from vast datasets. While this may resemble cPCK, the latter is collectively developed and validated, whereas GenAI outputs are statistical aggregations lacking pedagogical judgement, cultural sensitivity, and contextual understanding. Empirical research supports this concern. For example, Trust et al. [24] evaluated 310 AI-generated K-8 Civics lesson plans and found they often failed to promote higher-order thinking, inclusivity, or multicultural representation, risking "homogenized, generalized, regularized, mono-cultural learning experiences" (p. 438). Similarly, Belloula [23], studying ten secondary teachers through observations and interviews, found that while GenAI reduced workload, uncritical use undermined pedagogical quality and teacher agency. Trained largely on Western data, GenAI is limited in representing Indigenous knowledge, risking insensitivity and reinforcing inequity. In RCM terms, GenAI, in this vignette, acts as a filter: its defaults narrow the knowledge that reaches Amira's planning, reducing mātauranga Māori to translated words and generic statements (see Table 1). Teachers must therefore act as ethical and cultural filters, ensuring accuracy and contextual integrity [24].

For experienced teachers with strong pPCK, GenAI can serve as an amplifier. In a large-scale mixed-methods study involving 1043 teachers and 23 curators in India, Dennison et al. [26] found that GenAI-supported co-design enabled more efficient prototyping, adaptation, and innovation, expanding pedagogical expertise in multilingual, low-resource environments. Dennison et al.'s findings align with RCM's

conception of PCK development as iterative and contextually mediated. GenAI introduces variation that stimulates reflection and refinement prior to enactment. However, teachers must maintain epistemic authority, mediating between AI outputs and pedagogical intent.

Effective GenAI use requires AI literacy. Celik et al. [13], studying 120 pre-service teachers' engagement with GenAI, found that while GenAI systems can efficiently generate lesson sequences, quality depends on teachers' ability to prompt and critically evaluate outputs. Emerging tools support this process; "Aila", a GenAI lesson assistant developed by Oak National Academy in England, has been specifically trained on the national curriculum in England to develop contextually appropriate lessons [27]. Aila is built on OpenAI's GPT-4o and uses RAG over Oak's corpus of curriculum-aligned lessons, with a re-ranking algorithm and moderation model for safety constraints [28]. While such tools increasingly guide teachers toward optimal prompting, they do not negate the need for AI literacy. In RCM terms, GenAI acts as a new amplifier for rapidly generating draft lessons while demanding new filters grounded in critical evaluation. This shifts the teacher's role from creator to critical evaluator, requiring robust professional judgement to assess accuracy, appropriateness, and contextual alignment. Used uncritically, GenAI risks substituting for pedagogical reasoning, eroding agency and adaptability [23,24].

In this scenario Amira's pPCK could develop through iterative engagement with GenAI - evaluating and refining outputs to fit her context – introducing a reflective cycle where pPCK evolves through human – GenAI dialogue. As summarised in Table 1, GenAI functions primarily as an amplifier in the pedagogical reasoning cycle, but simultaneously increases the need for robust filters grounded in CK, PK, CxK, pPCK, and enabled by AI literacy.

5.2. *Vignette 2: using a chatbot in class - talking to Marie Antoinette*

Context: Year 10 (14–15 years old) - Secondary School
Subject: History - The French Revolution
Ms Clarke introduces an activity where students use a GenAI chatbot to "interview" Marie Antoinette to explore different perspectives from the French Revolution. Ms Clarke explains that the chatbot may reproduce popular myths, so she has instructed the students to be critical of the output and look for errors. To model this to her students, she begins with the prompt: *"Imagine you are Marie Antoinette in 1789. How do you respond to the public's anger toward you?"* The chatbot replies sympathetically, referencing the famous line *"Let them eat cake"*. Ms Clarke pauses to ask students whether this quotation is accurate. Several recall that historians believe she never said this. She takes the opportunity to lead a discussion about how myths form and persist, and how both historical truths and inaccuracies would be included in the training data of GenAI systems, necessitating the validation of all output.
Students then work in pairs to develop further questions (e.g., about her Austrian background, role at court, and trial) and fact-check the chatbot's responses using their textbooks. They note where the GenAI gives accurate information, omits context, or repeats myths. The class finishes with a discussion on the effectiveness of the activity in understanding Marie Antoinette's perspective and supporting their own French Revolution topic understanding, as well as their experience of GenAI in mirroring (or not) historical bias or myth. Students are asked to articulate why a critical mindset is essential during interactions with chatbots.

5.2.1. *Analysis and discussion of Vignette 2*

Teaching historical perspective-taking traditionally draws on teachers' pPCK - their understanding of student misconceptions and discussion techniques - linked to cPCK through shared historiographical methods with ePCK governing moment-to-moment scaffolding of decisions. Integrating a GenAI-chatbot has implications for PCK (Table 2). For cPCK, the discipline needs shared understanding that GenAI is trained on both accurate and inaccurate sources demanding critical judgement rather than passive acceptance. However, the absence of established collective disciplinary knowledge about GenAI leaves teachers experimenting in isolation [1].

For her pPCK, Ms Clarke must understand the chatbot's capabilities and limitations, recognise patterns in student interactions with GenAI

Table 2
Vignette 2: Summary of knowledge changes with GenAI.

RCM Knowledge Domain	Established Prior to GenAI	Additional Competencies Required With GenAI	Tensions / Risks Introduced by GenAI
CK	Deep knowledge of historical content, historiography, and contested interpretations; ability to correct misconceptions; awareness of common historical myths.	Ability to rapidly detect and correct AI-generated inaccuracies, anachronisms, or mythologised content; understanding of how GenAI is trained on popular as well as scholarly sources.	GenAI may propagate myths teachers must identify in real time; insufficient CK increases risk of reinforcing inaccuracies.
PK	Dialogic questioning strategies and modelling to support perspective-taking; facilitation of metacognitive reflection on source reliability.	Integration of source criticism into GenAI-facilitated dialogue; ability to scaffold discussions and manage classroom flow amid unpredictable AI-responses.	Over-reliance on GenAI may reduce teacher-led modelling; managing multiple AI-student interactions taxes attention and risks prioritising novelty over deep reflection.
CxK	Awareness of students' prior conceptions, cultural references, digital literacy levels, and the curriculum relevance of historical figures.	Ability to anticipate how students interpret GenAI personification of historical figures; integrating AI appropriately within age-appropriate discourse.	Students may anthropomorphise GenAI or accept biased narratives uncritically. Underdeveloped CxK increases this risk.
PCK	Transformation of content into teachable moments using discussion techniques and source analysis strategies; identification and remediation of misconceptions.	Using AI "errors" as teachable moments; scaffolding student evaluation of unreliable or biased AI-generated narratives.	Teachers may fail to transform GenAI content critically, especially under time pressure; risk of surface-level historical thinking if GenAI is treated as authoritative.
cPCK	Shared disciplinary norms around historiographical accuracy and source analysis; established practices for perspective-taking.	Development of shared disciplinary standards for GenAI integration in history education; community-driven guidance on AI's epistemological limitations.	Absence of established cPCK leaves teachers experimenting in isolation; risk of inconsistent pedagogical practice across classrooms.
pPCK	Internalised understanding of how students misinterpret historical figures; repertoire of discussion and source evaluation.	Prompting strategies and modelling critical interrogation of GenAI output.	Teachers lacking AI literacy may inadvertently validate flawed outputs; risk of inconsistent modelling of critical source evaluation.
ePCK	Real-time decisions responding to student misconceptions, scaffolding dialogue facilitating metacognitive reflection.	Managing triadic interaction (teacher–student–GenAI); selecting when to intervene, or let students grapple with misinformation.	Teachers may struggle to identify problematic outputs under time pressure; high cognitive load impedes moment-to-moment instructional judgement.

tools and adapt her pedagogical approach to support real-time triadic interactions between herself, students, and GenAI. Humanities teachers possess transferable competencies - analysing bias, examining assumptions, and evaluating reliability – that apply directly to GenAI outputs. Ms Clarke adapts her pPCK to a new technology. She models these approaches by providing an initial example of discerning historical myths, and allocating time to explore and discuss experiences at the lesson's conclusion – building both historical perspective and student AI literacy.

The transformation of ePCK during real-time interaction with unpredictable outputs presents new challenges. Ms Clarke must make split-second decisions about when to intervene, which errors to highlight as teachable moments, and how to manage multiple simultaneous GenAI interactions producing unreliable content. She must scaffold students' evaluation, anticipate responses and maintain lesson flow. Expert teachers, like Ms Clarke, can leverage disciplinary and pedagogical knowledge to turn errors into historiographical discussions, using a chatbot's output to explore how popular memory differs from historical evidence. However, novice teachers may struggle to identify inaccuracies quickly enough to intervene effectively, as their PCK components remain fragmented and they cannot simultaneously process content accuracy, student responses, and pedagogical decisions [29]. Experienced teachers recognise that this activity's value lies in supporting students to develop metacognitive awareness of source evaluation when using GenAI tools. Managing multiple dialogues also strains attentional resources especially for less experienced teachers [29].

A particular risk is that students may accept AI personification of historical figures as authentic perspective, making explicit framing of the activity as interrogating a flawed source essential.

5.3. Vignette 3: using GenAI for marking and feedback

Context: Year 11 (15–16 years old) – Secondary School, United Kingdom
Subject: English Language – Analysing Persuasive Techniques
Mr Patel teaches Year 11 English Language. His students have completed a written assessment where they analyse persuasive techniques in advertising, a standard part of the GCSE curriculum.
To save time on first-draft feedback, Mr Patel uses a GenAI marking assistant with a detailed prompt he has crafted. The prompt ensures the GenAI provides formative comments aligned to the assessment criteria (content, including nuanced material like emotional appeals or cultural references, structure, language use, and technical accuracy). It also instructs the GenAI to give accurate, student-friendly feedback, praising items even in poor work and focusing on detailed feedback highlighting strengths, areas for improvement, and how to achieve this improvement.
Mr Patel uploads anonymised scripts and quickly receives feedback on each student's strengths and areas for improvement. He carefully reviews the feedback, considering each student's capabilities and characteristics, which he knows well. Although most of the feedback is well-focused, Mr Patel makes some changes to ensure clarity for particular students and occasionally reduces the feedback to prevent overwhelming certain students with negative comments. When returning scripts, Mr Patel explains that the initial feedback was AI-generated and encourages students to examine it carefully, seeking clarification from peers or GenAI for any unclear comments.

5.3.1. Analysis and discussion of Vignette 3

Teachers' assessment involves applying multiple judgements based on their CK, PK, CxK and pPCK: aligning students' written assessment with marking criteria, reading every line for logical flow, vocabulary accuracy, tone, and genre-appropriate style. These demands are summarised in Table 3. For teachers managing several classes, this can mean over 150 essays per cycle and nearly a thousand per year – an immense workload.

GenAI assists Mr Patel by generating initial feedback drafts, exemplars, and explanations of marking criteria. However, these serve only preliminary purposes; he must review, verify, and contextualise all outputs. GenAI may misinterpret nuance, misjudge creativity, or miss contextual meaning, requiring teacher judgement. Teachers' pPCK ensures feedback quality and appropriateness, though novice teachers may

Table 3
Vignette 3: Summary of knowledge changes with GenAI.

RCM Knowledge Domain	Established Prior to GenAI	Additional Competencies Required With GenAI	Tensions / Risks Introduced by GenAI
CK	Deep understanding of genre conventions, rhetorical strategies, tone, and language precision relevant to English Language assessments (e.g., GCSE standards).	Ability to assess whether GenAI accurately identifies and comments on rhetorical features, genre conventions, and content relevance; understanding the limitations of GenAI in interpreting nuance and subtext.	GenAI may misjudge creativity, overlook subtle meaning or cultural context, and misalign with expectations; teacher overtrust in GenAI may result in missed or misdirected feedback.
PK	Use of feedback principles (timeliness, clarity, tone); strategies for motivating revision; scaffolding student understanding of assessment criteria.	Competence in designing pedagogically sound GenAI -feedback processes; framing AI-generated feedback as formative, dialogic, and student-centred; guiding students in interpreting GenAI feedback.	If GenAI feedback is poorly framed or lacks personalisation, students may disengage or feel confused; risk of feedback being perceived as impersonal or overly generic; GenAI feedback may not align with students' learning needs.
CxK	Awareness of students' prior writing skills, linguistic backgrounds, and learning histories; sensitivity to cultural and linguistic variation in written expression.	Ability to use GenAI as a diagnostic support tool for culturally and linguistically responsive feedback; competence in recognising when GenAI feedback overlooks student diversity; capacity to localise AI feedback in relation to student context.	GenAI may misinterpret language variation due to multilingualism as error; feedback may lack sensitivity to learner identity or prior knowledge; risk of homogenised marking unless critically mediated.
PCK	Skill in transforming assessment criteria into accessible language; identifying and explaining writing strengths and weaknesses; modelling exemplars; scaffolding rhetorical awareness.	Iterative refinement of AI-generated feedback to align with disciplinary standards and learning intentions; ability to supplement GenAI suggestions with tailored guidance and exemplars; modelling AI-assisted source critique for students.	Risk of shallow feedback if teachers adopt GenAI suggestions uncritically; overreliance may erode capacity to provide high-quality, human-generated formative comments; difficulty teaching metacognitive feedback interpretation if GenAI output is taken at face value.
cPCK	Shared assessment standards and marking practices within departments and exam boards; calibration exercises and moderation practices; collaborative	Co-construction of norms for evaluating and refining AI-generated marking; collaboration to identify best practices and limitations of GenAI tools; developing shared language around	Absence of clear cPCK around GenAI use may result in inconsistent or inequitable marking practices; teacher isolation in trialling tools; lack of shared ethical and practical

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Table 3 (*continued*)

RCM Knowledge Domain	Established Prior to GenAI	Additional Competencies Required With GenAI	Tensions / Risks Introduced by GenAI
	development of feedback rubrics.	GenAI's role in assessment.	standards for GenAI-feedback deployment.
pPCK	Experience-based strategies for assessing writing; tacit knowledge of how to interpret and guide student development; awareness of common misconceptions in student writing.	Understanding tool affordances and limitations; knowing when to accept, reject, or revise AI-generated feedback; developing efficient workflows that maintain pedagogical integrity.	Reviewing GenAI feedback may be time-consuming and cognitively taxing; efficiency may not improve without strong pPCK; novice teachers may be overconfident in or over-reliant on GenAI tools, bypassing deeper judgement.
ePCK	Real-time adaptation of assessment strategies based on student responses; in-class discussions of feedback; facilitation of peer/self-assessment activities.	Ability to integrate AI-assisted feedback into classroom instruction; guiding students in evaluating and responding to AI suggestions; orchestrating student–AI–teacher interactions as part of formative cycles.	Risk of diminished teacher presence in assessment dialogue; GenAI may replace rather than augment human feedback; equity concerns if students do not understand or trust AI-generated marks.

struggle. GenAI can support pPCK by broadening expression and offering alternative interpretations, making marking a collaborative, iterative process of checking and refinement.

A key pitfall is that GenAI use can be as time-consuming as manual marking. Teachers must evaluate both student work and GenAI feedback for accuracy and alignment, meaning efficiency gains are not guaranteed. Success depends on treating GenAI as a critical assistant subordinate to teacher expertise. When used collaboratively, it can enhance pPCK and contribute to shared norms (cPCK), supporting novice teachers' development. Leadership support is essential: professional learning communities can co-construct approaches, building trust and consistency by treating GenAI feedback as a shared resource.

In terms of ePCK, Mr Patel's moderation of AI-generated feedback illustrates reflection-in-action – evaluating outputs against his contextual knowledge of each student's capabilities, characteristics, and attitudes to learning. A recent meta-analysis found no significant difference in learning outcomes between AI-generated and human-provided feedback, suggesting GenAI can effectively support preliminary feedback generation [30]. However, the same study advocates a hybrid approach that leverages GenAI's scalability and immediacy while retaining human feedback's empathetic and contextually rich qualities – the approach Mr Patel's moderation process exemplifies.

Mr Patel anonymised students' scripts before submission, limiting the marking assistant's capacity for tailored feedback. This decision may reflect data protection requirements, institutional policy, or a pedagogical choice to reduce potential GenAI bias. Including student information could enable feedback customised to linguistic backgrounds – scholars recommend customising GenAI prompts to improve feedback relevance and mitigate bias (see: [31] for a systematic review). Mr Patel's transparency about AI-generated feedback promotes student dialogue about assessment criteria deepening their conception of quality work while informing his pPCK.

GenAI outputs can also provide insights into student performance that inform future teaching. The reflection stage of the RCM's plan-teach-reflect cycle is crucial: Mr Patel must generate knowledge of student achievement and make decisions about subsequent learning activities. His decisions about GenAI use illustrate ePCK and pedagogical reasoning, while his reflections on pedagogical success feed back into his developing pPCK – illustrating the RCM's conceptualisation of PCK as dynamic and iterative.

GenAI for assessment remains imperfect and may be time-consuming, requiring strong CK, PK, CxK, and pPCK to validate and revise outputs. Beginning teachers, whose pPCK is still forming, may find this challenging – lacking the contextual knowledge and assessment experience to identify inappropriate or inaccurate AI-generated feedback. When supported by strong cPCK – including departmental collaboration, ethical frameworks, and shared verification practices – GenAI integration can enhance assessment.

6. Discussion and conclusion

Our analysis, summarised in Tables 1, 2 and 3, highlights both similarities and differences across the three vignettes. Beyond their analytical function, these tables may serve a practical purpose: as structured frameworks for teacher educators and professional learning programmes supporting critical reflection on GenAI integration. The plan-teach-reflect cycle remains central: teachers must critically evaluate GenAI outputs during planning and assessment, mediate human-AI-student interactions during teaching, and reflect on pedagogical effectiveness to refine their practice. Our analysis suggests GenAI can act as a resource to filter and amplify teachers' professional knowledge. Across all three domains, GenAI reshapes the plan-teach-reflect cycle, demanding critical evaluation of outputs, mediation of triadic interactions, and development of AI literacy.

6.1. The role of AI literacy in professional knowledge

A key implication concerns the role of AI literacy in teachers' professional practice. AI literacy functions in this context as a mediating filter for effective PCK development and use. Without it, teachers cannot reliably filter GenAI outputs through their CK, PK, and CxK, nor engage in the transformation process central to PCK. As defined in Section 2, AI literacy is a set of teacher capacities rather than a form of PCK. In RCM terms, we therefore position it not as a component of PCK but as operating at the interface between GenAI, located in the learning context, and the teacher's knowledge realms, where it functions as a filter on GenAI's influence on pPCK, cPCK and ePCK (see Section 6.3 and Fig. 2). Its absence is particularly consequential for novice teachers whose pPCK is still forming.

6.2. Novice teachers: opportunities and risks of GenAI use

Novice teachers often lack the established pPCK and contextual knowledge needed to identify inaccurate or inappropriate AI outputs. Without critical engagement, they risk developing overreliance on GenAI, which could stifle pPCK and ePCK development. This risk underscores the importance of strong professional structures – mentoring relationships, departmental collaboration, and shared evaluation practices – to scaffold novice teachers' critical engagement with GenAI and to enable cPCK developments.

6.3. Theoretical implications of GenAI integration for PCK models

This paper is among the first to systematically apply the RCM to examine Human-GenAI collaboration in teaching, extending Shulman's foundational model into a domain its originators could not have anticipated. Our analysis suggests that whilst GenAI can function as an amplifier or filter within the learning context layer of the RCM, it does not operate merely as a new tool; rather, it can act as an active mediating agent that reconfigures the relationships between the model's core elements in ways that require theoretical attention. Specifically, we propose that the RCM be extended to explicitly position GenAI as an active

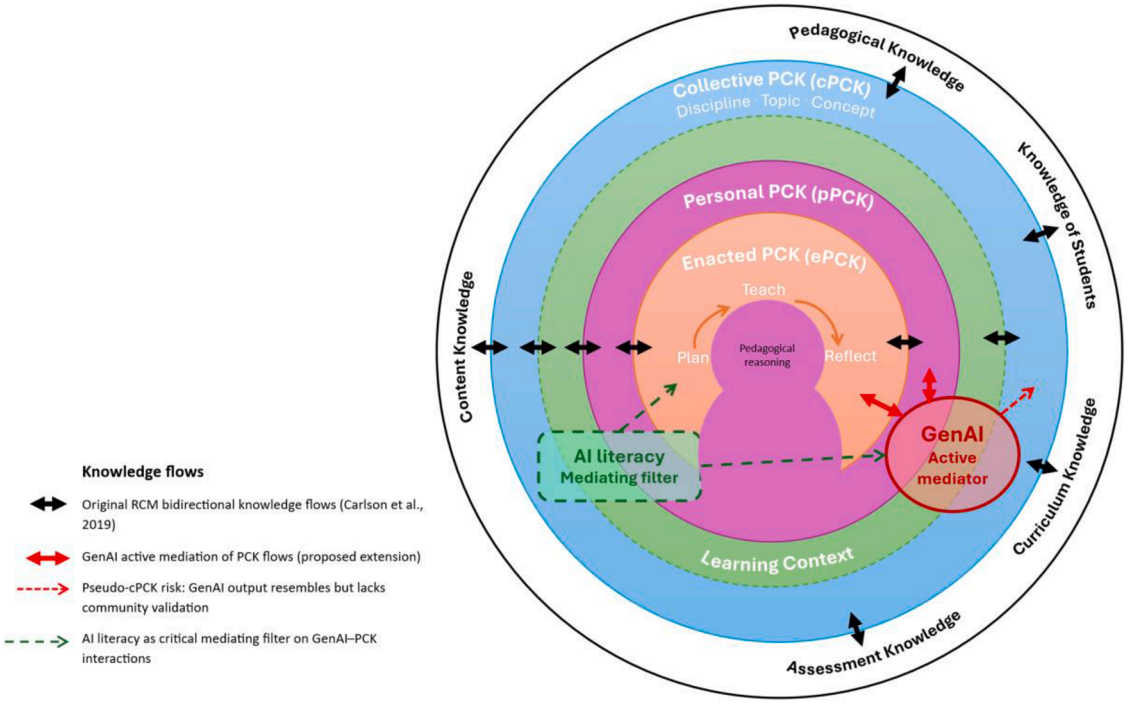


Fig. 2. Proposed extension of the RCM to incorporate GenAI as an active mediating agent within the learning context layer, with AI literacy as the mediating filter on knowledge flows.

mediating agent within the learning context layer – distinct from other contextual factors by virtue of its generative, pseudo-authoritative character and its capacity to simulate aspects of cPCK without the community validation that defines it. In the original RCM, the learning context shapes but does not actively intervene in the flows between pPCK, cPCK, and ePCK; GenAI disrupts this by introducing a non-human interlocutor that actively generates content influencing pPCK development, creates pseudo-cPCK that risks corrupting the pPCK-cPCK boundary, and reconfigures ePCK enactment through triadic teacher-student-GenAI interactions. AI literacy, as argued in Section 6.1, functions as a mediating filter governing whether GenAI's influence on these flows is productive or harmful. Fig. 2 illustrates this proposed extension, situating GenAI within the learning context layer and identifying AI literacy as the mediating filter on its interactions with the model's core knowledge realms.

PCK remains a fundamentally human attribute, developed through pedagogical reasoning. The RCM extends this by conceptualising that reasoning as dynamic and bidirectional, shaped through the plan-teach-reflect cycle and the flows between pPCK, cPCK, and ePCK. In both frameworks, the interlocutors who shape teachers' reasoning have been human – colleagues critiquing lesson plans, mentors observing practice, professional communities refining shared knowledge – interactions characterised by mutual accountability and contextual understanding. GenAI introduces a qualitatively different kind of interlocutor: generative rather than reflective, statistically rather than epistemically driven, and lacking the contextual grounding that gives peer engagement its legitimacy. Where peer dialogue deepens reasoning by requiring teachers to articulate and justify their transformative choices, GenAI risks short-circuiting this by supplying plausible-sounding alternatives that must first be interrogated for basic reliability before any pedagogical judgement can begin – introducing a layer of epistemic vigilance the original models did not envisage. This matters particularly for cPCK: where collective knowledge is legitimated through community consensus, GenAI outputs that superficially resemble cPCK lack this validation, and their uncritical incorporation risks corrupting rather than enriching the knowledge flows the RCM describes.

Tools such as Oak National Academy's Aila, which couples a general-purpose LLM with RAG over curriculum-aligned materials, illustrate how future designs might begin to approximate aspects of cPCK more reliably. Such designs raise important questions about curation, validation, and governance – and open the possibility that GenAI repositories, if built on teacher-evaluated and collectively agreed materials, could accelerate knowledge circulation across the RCM's realms in ways that genuinely support rather than undermine professional knowledge development.

6.4. *Ethical and equity implications of GenAI integration into education*

GenAI training data may reflect historically inequitable patterns; uncritical adoption therefore risks recreating or amplifying these inequities in educational settings. In assessment specifically, teachers with well-developed pPCK can combine instructional expertise with GenAI efficiency to enhance feedback quality. Novice teachers with less developed pPCK, however, might rely on GenAI to carry the weight of assessment, producing feedback insensitive to individual student needs and potentially exacerbating existing inequalities.

More broadly, our analysis highlights the essential role of the human teacher. All three vignettes illustrate that GenAI output must be filtered through teachers' contextual understanding of learners and learning environments – a dimension of PCK that GenAI cannot reliably replicate. Offloading essential teaching tasks to GenAI without such mediation represents an abdication of professional responsibility.

6.5. *Limitations*

While the three vignettes provided a concrete foundation for examining PCK and pedagogical reasoning across subject areas, every topic carries its own pedagogical considerations that the analysis cannot fully capture. As hypothetical constructions, they cannot replicate the full complexity of real-time classroom dynamics – particularly for ePCK; longitudinal ethnographic studies of actual teacher-GenAI interactions are needed to test and extend the analytical propositions developed here. Their validation also rested on researcher judgement rather than external practitioner review, and future iterations would benefit from

broader input from classroom teachers across a wider range of subject and cultural contexts. Since the researchers who constructed the vignettes also conducted the analysis, there is an inherent risk of propositions reflecting our existing theoretical commitments; iterative whole-group review mitigated but cannot eliminate this risk.

The analysis focused on teachers' knowledge and reasoning; how students' own GenAI interactions shape pedagogical dynamics and influence teachers' ePCK remains beyond its scope and represents an important direction for future research. Questions of data protection, institutional accountability, and ethical governance – touched on in the Vignette 3 analysis – similarly warrant systematic treatment in future empirical work. Finally, the vignettes were developed at a point in time; the rapid pace of LLM development and the move toward hybrid AI models means that specific tool characteristics will continue to evolve, even if the analytical framework remains applicable.

6.6. Future technological trajectories and their implications for PCK

Next-generation GenAI tools will likely introduce further shifts in teachers' PCK. As these systems become more refined, contextualised, and reliable, new pedagogical applications will emerge. Developments such as RAG offer potential for curriculum-aligned, culturally grounded, and locally governed datasets to underpin AI outputs [32], providing teachers with information directly relevant to their programmes, communities, and learners.

With more reliable and locally grounded tools, teachers' cognitive work may shift from filtering inaccuracies to curating, refining, and strategically integrating AI-generated ideas – a form of ongoing micro-reflection that can strengthen pPCK. For ePCK, increasingly dynamic systems capable of real-time personalisation may require new practices for orchestrating meaningful human-AI collaboration, with teachers guiding student-AI interactions toward disciplinary goals, equity, and critical understanding. For cPCK, systems that allow educators to contribute local knowledge and refinements could transform GenAI repositories into living archives of effective practice, accelerating knowledge circulation across the RCM's realms.

6.7. Future research directions

Future research should use an RCM lens to examine how levels of criticality and AI literacy influence teachers' ePCK and pPCK development. More challenging is understanding GenAI's role in cPCK formation. Systematic exploration of the lessons and feedback GenAI provides across content areas and educational levels – contrasted with practices of experienced teachers and teacher preparation programmes – could yield valuable insights.

6.8. Concluding remarks

This paper set out to examine how teachers and GenAI can collaborate in the development and use of PCK and pedagogical reasoning in K-12 settings. Through vignette-based analysis using the RCM, we have argued that this relationship is neither straightforwardly enabling nor straightforwardly threatening: GenAI can amplify teachers' professional knowledge when engaged critically, yet it also introduces distinctive risks – particularly for novice teachers whose pPCK is still forming – and reconfigures the relationships between the RCM's core knowledge realms in ways that existing frameworks do not adequately capture. Our central theoretical contribution is a proposed extension of the RCM that positions GenAI as an active mediating agent within the learning context layer, distinct from other contextual factors by virtue of its generative, pseudo-authoritative character, and that identifies AI literacy as a mediating filter determining whether GenAI's influence on knowledge flows is productive or harmful. Across all three domains of PCK, the plan-teach-reflect cycle remains the organising logic of professional practice – but its character changes, demanding new forms of epistemic vigilance, triadic interaction management, and collective sensemaking. The human teacher is not displaced in this account; rather, teacher expertise, contextual judgement, and critical engagement emerge as more essential than ever. These propositions carry direct implications for teacher education, which must develop not only novice teachers' content and pedagogical knowledge but their capacity to interrogate, mediate, and govern their own GenAI use in ways that genuinely serve learners.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the authors used Claude/ChatGPT/Perplexity in order to edit/condense the text. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

CRediT authorship contribution statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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