A Preliminary Framework for the Effective Use of Generative Artificial Intelligence (GenAI) by Mathematics Teachers

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This paper reports a framework for the effective use of generative artificial intelligence (GenAI) by mathematics teachers. Informed by the findings of a rapid literature review, the framework outlines the knowledge, skills, dispositions and conditions that support the effective use of GenAI. The preliminary framework provides immediate implications for the development of pre-service and in-service professional learning that aims to support mathematics teachers to work effectively with GenAI for teaching and learning.

Background and Significance

The use of generative artificial intelligence (GenAI) tools has exploded since the introduction of OpenAI's ChatGPT in 2022, with significant focus on how GenAI tools can be harnessed by teachers to support teaching and learning. Initially, the research focus was primarily on the potential time-savings afforded by these tools (e.g., Roy et al., 2024). More recently, the focus has shifted to exploring how teachers can use GenAI tools to support teaching and learning by, for example, using GenAI to brainstorm teaching examples and explanations, generate teaching materials and assessments, and plan units of work (e.g., Cameron et al, 2025; Pepin et al., 2025). The increased interest in GenAI has also seen an explosion in the number and range of professional learning opportunities focused on GenAI, primarily in response to the need for teachers to develop new knowledge and skills to work with the increasing range of tools. The need for effective professional development has been recognised at a systemic level, with the Australian Government calling for universities to work with education systems and both pre-service and in-service teachers to develop teacher capacity to work with GenAI to support effective teaching and learning (Commonwealth of Australia, 2024). In this study, effective use of GenAI is viewed as the ability to use GenAI in an efficient manner to complete a range tasks to a high-standard whilst also positioning the teacher as the expert on mathematics teaching and learning.

The demand for professional learning on GenAI has far outpaced the current research base, thus creating an urgent need for evidence to inform professional learning initiatives that help teachers understand and use GenAI to enhance their teaching (e.g., Commonwealth of Australia, 2024). The study reported in this paper, involving a rapid review of literature, establishes an evidence base from which we were able to develop a preliminary framework for the effective use of GenAI by mathematics teachers. This framework will inform the design of GenAI-focused professional learning opportunities for pre-service and in-service teachers through by identifying the core knowledge, skills and dispositions mathematics teachers require to integrate GenAI effectively into their practice.

The overarching research question for this study was *What knowledge, skills and dispositions do mathematics teachers need to make effective use of GenAI for mathematics teaching and learning?*

Methodology

The work reported in this paper is part of a larger program of research exploring mathematics teachers' use of GenAI for mathematics teaching and learning. Inspired by previous frameworks which have provided structured guidance on integrating new and

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powerful technologies into mathematics teaching and learning (e.g., Computer Algebra Systems; Pierce & Stacey, 2004), our framework offers a research-informed basis for considering teachers' effective use of GenAI and for the design of professional learning. The preliminary framework, presented in this paper, will serve as a foundation for future research and will be refined and validated in later stages of the study in collaboration with mathematics teachers who are familiar with using GenAI tools to support mathematics teaching and learning.

Rapid Literature Review

The rapid review protocol, when compared to systematic reviews, enables the accelerated synthesis of existing knowledge (Garritty et al., 2020). This accelerated process, which places less emphasis on critical appraisal than systematic reviews, serves to enable time-critical decision-making. This rapid approach aligned with our need to establish a preliminary framework capturing key concepts evident in the literature for use in later stages of our study. The review also contributes to the emerging evidence base that informs the development of professional learning for mathematics teachers working with GenAI. Furthermore, the ever-increasing evidence base and research interest in GenAI will require us to repeatedly sample the field and update the framework, a process that would be impractical given the time demands of a systematic review. Informed by the Cochrane rapid review guidelines (Garritty et al., 2024), this section details the process of identifying and screening relevant research articles.

Following the development of the research question, a research librarian was consulted to assist with developing the search strategy (see Figure 1 for sample search string). The research question was based upon existing research on technology use in mathematics which has shown the importance of skills, knowledge and affect for effective use (e.g., Pierce & Stacey, 2004). Databases were identified based on the research librarian's initial experimentation with different databases; this approach is consistent with the rapid review protocol which prioritises searching the databases that are most likely to contain relevant literature (Garritty et al., 2024). Databases searched were Discovery (including Complementary index, ERIC, Academic Search Complete, Directory of Open Access Journals, Science Direct), ProQuest Central, Dimensions and Scopus. Articles were restricted to English language publications published after 2020.

Figure 1

Sample Search String

(TI (math* teacher* OR numeracy* teacher*)OR AB (math* teacher* OR numeracy* teacher*))) AND (((AI OR "Artificial Intelligence" OR "artificial neural networks" OR Chatbot OR ChatGPT OR "CLAUDE" OR GenAI OR "Generative AI" OR "Google Gemini" OR "Large Language Models" OR LLM OR "MS Copilot" OR OpenAI))) AND (AB(Teacher* N2 (Aptitude OR Assumptions OR Attitude OR Capability OR Capacity OR Dislikes OR Efficacy OR Experiences OR fluency OR Grasp OR "Human-computer interaction" OR Insight OR Knowledge OR Likes OR Literacy OR Mindset OR Outlook OR Preferences OR Prerequisite OR proficiency OR Skills OR skill-level OR Talent OR Understanding OR Viewpoints)))

Articles were screened using Covidence software following the Cochrane rapid review protocol guidelines (Garritty et al., 2024). Extraction focused on demographic data (e.g., country of study, in-service cf. pre-service teachers, etc) and identifying findings that provide insight into the factors that support mathematics teachers to make effective use of GenAI tools. Screening and extraction were conducted by a single researcher. Peer debriefing (Nguyen & Spall, 2008) was used to review screening and extraction decisions, and to provide clarification and negotiate outcomes when required. A hybrid thematic approach (Fereday & Muir-Cochrane, 2006) was used to identify themes evident in the research findings that would then inform the development of the framework. Using a two-step approach, inductive coding of research findings established themes describing factors that are reported to support the effective use of GenAI before deductive coding was used to map these findings onto the three domains identified in the research question (i.e., knowledge, skills, dispositions).

Review Findings

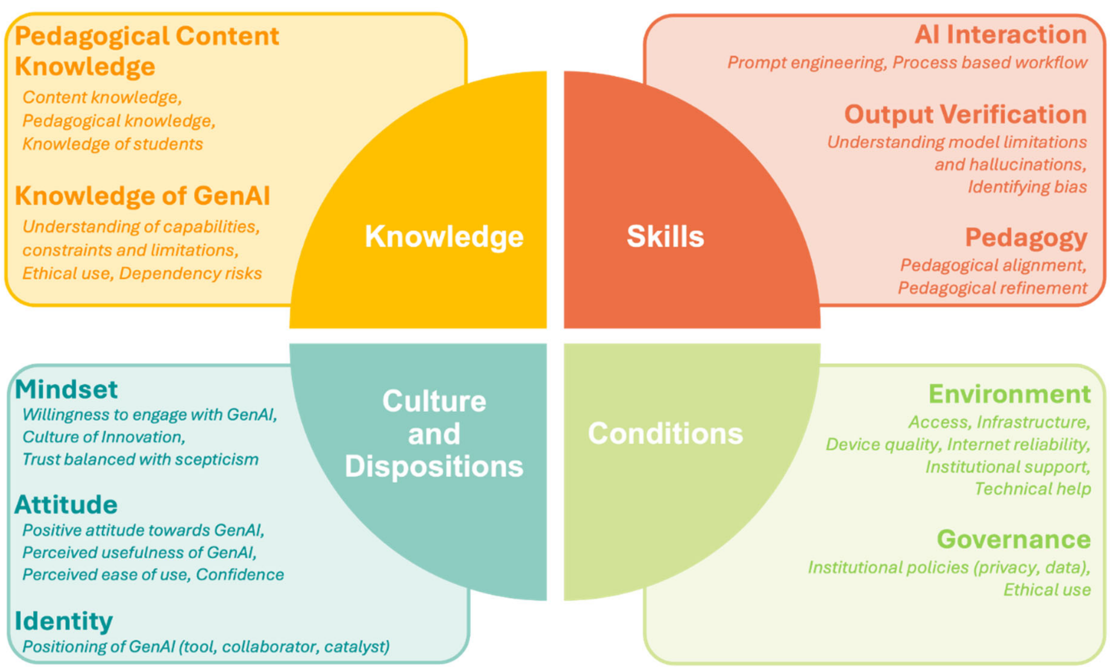
The rapid review identified 72 articles that provide insights into the skills, knowledge and dispositions that mathematics teachers need to make effective use of GenAI. Articles are roughly spread across in-service and pre-service teachers (43 cf. 39). Questionnaires are the primary data collection tool (36), although a significant number of studies (33) used questionnaires in conjunction with other data collection tools such as interviews, observations, review of chat logs, etcetera. Consequently, it is unsurprising that quantitative studies (33) were more common than qualitative (18) or mixed methods studies (11). A notable finding in the literature was the diverse range of countries included in the sample, with 20 countries featured in the 72 articles. This diversity indicates that the included articles provide a diverse data set in terms of participants, methods, and contexts, thus reducing bias in the research and improving the generalisability of findings across populations and contexts (Polanin et al., 2017).

The Effective Use of GenAI for Mathematics Teaching Framework

The preliminary framework consists of four domains (*Knowledge; Skills; Culture and Dispositions; Conditions)* that support mathematics teachers to make effective use of GenAI (see Figure 2). Each domain consists of several elements (e.g., *Pedagogical Content Knowledge* and *Knowledge of GenAI*) and sub-elements (e.g., *Content Knowledge, Pedagogical Knowledge, Knowledge of Students*) that describe the specific aspects of the domain that support the effective use of GenAI. Of note is the inclusion of the domain *Conditions*, which was not an initial focus of the research question and literature review. Upon conducting the inductive analysis of research findings, it was evident that this fourth domain was required to describe how external conditions support the effective use of GenAI. The following sections provide a description of elements and sub-elements within each domain.

Figure 2

The Preliminary Effective Use of GenAI for Mathematics Teaching Framework



Knowledge

The *Knowledge* domain describes the essential knowledge needed for mathematics teachers to work effectively with GenAI and highlights the importance of both *Pedagogical Content*

Knowledge (e.g., Shulman, 1986) and *Knowledge of GenAI*. Although Technological Pedagogical Content Knowledge (TPACK; Mishra & Koehler, 2006) has increasingly been used to investigate the knowledge required by teachers to work with GenAI given its affordance to combine PCK and technology specific skills (e.g., Li, 2025; Segal et al., 2025), in developing this framework we chose to separate *Pedagogical Content Knowledge* (PCK) and *Knowledge of GenAI* into two elements rather than applying the TPACK model. First, the PCK that supports effective GenAI use can be developed, and exists, without reference to technology and thus serves a broader purpose in supporting effective teaching. Second, studies in the review predominantly position AI as a tool to support mathematics teachers in their planning tasks rather than as a tool that teachers use in class to support mathematics learning. Consequently, the affordances of the TPACK model in being able to describe the knowledge needed to use technology to teach using specific pedagogies does not currently apply to this framework.

Pedagogical Content Knowledge (PCK) is essential when working with GenAI as it provides a lens through which users can critically engage with and evaluate GenAI outputs. Such evaluation is particularly important for recognising hallucinations within GenAI outputs and for planning adaptations that overcome these (Aga et al., 2024; Cameron et al., 2025; Copur-Gencturk et al., 2024). PCK also serves to inform how teachers adapt GenAI outputs for their own class contexts, with pre-service teachers with strong PCK reported as being more acute in their evaluation of GenAI outputs (Aga et al., 2024). PCK also enables teachers to adapt GenAI lesson plans to cater for diverse student needs, with pre-service teachers recognising that GenAI lesson plans are often teacher directed, repetitive and do not provide accessible learning opportunities for all students (Gurl et al., 2024).

Knowledge of GenAI incorporates understanding the capabilities, constraints and limitations of GenAI along with ethical considerations and knowledge of dependency risks is essential in supporting mathematics teachers to become critical users of GenAI. We opted not to refer to this element as AI literacy (e.g., Ng et al., 2021) given the specific focus on the implementation of GenAI in mathematics education compared to the broader focus on AI literacy.

The presence of hallucinations and mathematical errors in GenAI outputs are key limitations of Large Language Model technologies, and thus understanding the constraints and limitations of the technology help to prime teachers to be critical users of GenAI (e.g., Bernardi et al., 2025). Similarly, understanding the capabilities of GenAI to generate text and other outputs supports teachers to utilise GenAI whilst mitigating the aforementioned risks associated with their limitations (e.g., Bui et al., 2025). In mathematics, this includes understanding that GenAI tools are primarily text generators, not calculators, and that this presents unique challenges when using GenAI in mathematics contexts (e.g., Cameron et al., 2025).

Malik et al. (2025) detail the importance of understanding ethical use of GenAI, noting the potential risks to student privacy and teacher autonomy from unintended unethical use. They explain that the development of ethical understanding of GenAI, including understanding bias and cultural relevance, may act as safeguard to support the ethical use of GenAI. Further, knowledge of the risks of dependency of overuse of GenAI (e.g., Wijaya, Yu, et al., 2024) may enable teachers to develop and maintain ownership of their expertise and ensure they are using GenAI in a manner that supports, rather than replaces, their expertise.

Skills

The *Skills* domain, incorporating the key elements of *AI Interaction*, *Output Verification,* and *Pedagogy*, encapsulates the key skills that mathematics teachers require to make effective use of GenAI. The *AI Interaction* domain includes skills related to prompt engineering, which describes the skills needed to craft precise prompts to generate relevant, accurate, and pedagogically appropriate outputs. Grover et al. (2025) reported teachers' experiences of exploring prompt engineering, noting the steep learning curve associated with writing clear and specific prompts. However, research also notes the need for iterative processes when working with GenAI (e.g., Yu et al., 2025), noting that outputs are unlikely to directly align with the teachers' needs. Key to this iterative process are skills related to *Pedagogy,* including the ability to review and identify when GenAI outputs do or do not align with the intended aims and preferred practices of the teachers (i.e., *pedagogial alignment*; e.g., Oh, 2025) and the ability to then refine outputs into a usable form that supports the aims of the teacher (i.e., *pedagogical refinement;* e.g., Oh, 2025). The ability to identify hallucinations and bias (i.e., *output verification*), also forms an important part of iterative processes for working with GenAI. Critical thinking skills, combined with a critical view of GenAI (see *Culture and Dispositions)* and a strong understanding of student learning needs, underpin a teachers' ability to identify mathematical and pedagogical errors (e.g., Şimşek, 2025).

Overall, the skills required for working effectively with GenAI are underpinned by the *Knowledge* domain. For example, the ability to assess a GenAI output for its pedagogical alignment, and to then refine the output prior to classroom use, needs to be supported by strong pedagogical content knowledge. This example highlights the interconnected nature of the elements and domains, and thus the need for holistic professional learning opportunities that aim to address multiple elements concurrently.

Culture and Dispositions

This domain describes the key *Cultures and Dispositions* (i.e., *Mindset, Attitude, Identity)* that support mathematics teachers to make effective use of GenAI. Overall, research indicates that a critical view of GenAI is necessary for supporting effective use as it positions teachers to be critical of outputs, thus supporting them to identify hallucinations and bias, and to engage in the processes of pedagogical alignment and refinement. Busuttil and Calleja (2025) reported that contemporary views about the teaching and learning of mathematics, underpinned by discovery and connectionist educational philosophies view ChatGPT positively for supporting both teaching and learning. The importance of belief structures is further emphasised by Lin and colleagues (2025) who note a tension between technology acceptance and teacher beliefs, observing that teachers' beliefs about mathematics teaching may sometimes conflict with the practices embedded within GenAI systems; a tension that has been identified through the analysis of GenAI created lesson plans (e.g., Cameron & Mesiti, 2024). This example again highlights the relationships between elements in the domain, with such conflicts between beliefs and GenAI potentially contributing to pedagogical misalignment.

Attitude has been shown to play a crucial role in supporting the effective use of GenAI (e.g., Li, 2025; Wijaya, Su, et al., 2024). Fostering positive attitudes towards GenAI can therefore enhance teachers' ability to use it effectively. Key factors in shaping these attitudes are perceived usefulness and ease of use (Börekci & Uyangör, 2025), suggesting that teachers need both the skills to operate GenAI tools easily and efficiently, and the ability to recognise and demonstrate how GenAI can enhance their mathematics teaching.

A recurring theme in the literature was the need for teachers to position themselves as critical users of GenAI. Several studies with pre-service teachers highlight the importance of being critical of GenAI due to its current limitations (e.g., Aga et al., 2024; Bernardi et al., 2025). Aga et al. expand upon this, advocating for GenAI to be seen as a "mere tool" (p. 74) that can support the expertise of teachers. Similar metaphors highlight the potential to view GenAI as an assistant, thought-partner or compass, where users can offload routine tasks so they can focus on higher-order tasks like scaffolding and differentiation through the process of pedagogical refinement (Oh, 2025).

The sub-elements reported here demonstrate the potential for teachers' attitudes, beliefs and identity to impact their use of GenAI. Notably, implementation of GenAI appears dependant on both affective engagement with GenAI and with mathematics more broadly, thus highlighting the need for professional learning to consider how to support affective engagement with GenAI while encouraging reflection on what it means to teach and learn mathematics in the age of AI.

Conditions

Although not an initial focus of the research question, the review shows that external *Conditions,* including those related to the user's external *Environment* and relevant *Governance* frameworks, impact teachers' capacity to make effective use of GenAI. For example, Li (2025) reported a correlation between educational policies, technology availability, standardised assessments, curriculum, and parental and community engagement and the implementation of AI. Examples provides included the need for device and internet access, but also the support of stakeholders in creating an environment that supports AI use. A similar study using structural equation modelling also highlighted a link between educational systems and cultural norms, teachers' attitudes, and perceived behavioural control and their use of GenAI (Wijaya, Su, et al., 2024). The potential influence of the external domain is further highlighted by Albalawi (2025), who, based on data collected from teachers about their intentions to incorporate AI into their teaching, calls for policy makers to develop instructional frameworks that align AI tools with pedagogical practices and to provide "financial and moral incentives" (p. 896) to encourage AI integration. Various other models have also been proposed to support teachers in using GenAI, offering insights into the conditions that facilitate effective use of GenAI. Suggested strategies include pairing experienced GenAI teachers with novice teachers, implementing long-term professional learning programs, and establishing teacher support forums for teachers to discuss AI applications and troubleshoot challenges (Trung et al., 2025).

The *Conditions* domain demonstrates that the effective implementation of GenAI requires a broad range of support structures and is not only dependent on the knowledge, skills, culture and dispositions of individual teachers. This suggests that supporting effective use of GenAI may benefit from established support structures such as mentoring, communities of practices, and other whole school approaches to supporting innovation in teaching and learning.

Conclusions, Implications, and Further Research

This paper reports a framework for the effective use of GenAI that will be expanded and validated through future research with practising mathematics teachers. The framework, informed by a rapid literature review, describes the key domains (*Knowledge; Skills; Culture and Dispositions; Conditions)* that support mathematics teachers to make effective use of GenAI, with each domain illustrated through corresponding elements and sub-elements. While many sub-elements are specific to GenAI (e.g., *Knowledge of GenAI*; *AI Interaction*), the framework reinforces the importance of classroom teachers and the need for human oversight when working with GenAI (e.g., *Pedagogical Content Knowledge*; *Pedagogy*; *Identity*). This review highlights the continuing importance of the human element in mathematics teaching in the age of AI, with teachers acting as mediators between GenAI-generated outputs and the realities of daily classroom interactions.

The framework provides an organised evidence base for the development of pre-service and in-service professional learning about GenAI and provides several implications for the design and delivery of such programs. The complexity of the framework highlights that professional learning that only focusses on sub-elements are unlikely to be effective in supporting teachers to make effective use of GenAI. In many cases, GenAI professional learning will need to be grounded in discussions of pedagogy. For example, professional learning should extend beyond prompting techniques to include strategies for identifying pedagogical (mis)alignments between teachers' intentions and GenAI-generated outputs, as well as approaches for refining these outputs before classroom use (either online or offline).

As a preliminary framework derived from the literature, our future research will focus on validating and refining the framework across different local contexts. The framework will also benefit from the development of illustrations of practice for each sub-element. This additional detail, to be developed in collaboration with mathematics teachers who are experienced GenAI users, will provide an additional layer of evidence to inform the design of pre-service and in-service teacher education programs that aim to develop mathematics teachers' capacity to use GenAI effectively.

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