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FROM PASSIVE CONSUMPTION TO CRITICAL CO-CONSTRUCTION: RETHINKING DIGITAL PEDAGOGY IN MATHEMATICS TEACHER EDUCATION THROUGH THE LENS OF EPISTEMIC AGENCY (2013–2026)

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ABSTRACT

The rapid proliferation of digital tools in mathematics teacher education ranging from adaptive learning platforms and intelligent tutoring systems to generative artificial intelligence (AI) assistants has generated a substantial body of research on their effects on learning outcomes. However, a critical gap persists: most scholarship evaluates these tools through the narrow lens of content acquisition and academic performance while largely ignoring their implications for the development of epistemic agency. The teacher's capacity to independently generate, evaluate and communicate mathematical knowledge. This narrative review synthesises empirical and theoretical literature published between 2013 and 2026 (N = 72 studies) to examine how varying digital pedagogical designs either cultivate or suppress epistemic agency in pre-service and in-service mathematics teachers. the review drawing on Skemp's relational instrumental dichotomy, Bandura's self-efficacy framework and Freire's critical pedagogy identifies a dominant pattern termed Passive Digital Consumption (PDC). A mode of digital engagement in which pre-service teachers receive and replicate algorithmically packaged knowledge without substantive critical engagement. Four thematic strands are examined: (1) the design logic of digital tools and its alignment with epistemic agency; (2) the role of teacher educator mediation in digital environments; (3) mathematics anxiety as a moderating variable in digital learning; and (4) the equity fault lines exposed by digital expansion in Indian teacher education. The review proposes an original Epistemic Agency-Centred Digital Pedagogy (EACDP) framework as a design and evaluation heuristic for digital mathematics teacher education grounded in the empirical literature and responsive to the pedagogical priorities of the Indian and global higher education context.

Keywords: *epistemic agency, digital pedagogy, mathematics teacher education, passive digital consumption, self-regulated learning, generative AI in education*

1. Introduction

Mathematics teacher education sits at the intersection of two of the most powerful forces shaping contemporary schooling: the longstanding demands of the discipline for rigorous reasoning and proof and the accelerating integration of digital technologies into every layer of instructional practice. Over the past decade, digital platforms including adaptive tutoring systems, online collaborative environments and most recently generative artificial intelligence (AI) assistants have develop the professional identity as mathematical thinkers transformed the pre-service and in-service mathematics teachers learn mathematics and strategies to teach it. Yet for all this technological investment, a fundamental question has received insufficient scholarly attention: Are digital environments in mathematics teacher education producing teachers who can think mathematically and independently or teachers who have learned to navigate algorithmically structured content competently without ever having exercised genuine mathematical authority over it?

This question has deep roots in philosophy of education. Epistemic agency, the capacity to independently generate, evaluate and communicate knowledge it is widely regarded as a foundational goal of teacher education rather than merely receive and reproduce (Biesta, 2015; Darling-Hammond, 2017). In mathematics specifically, it corresponds to what Schoenfeld (2007) termed 'mathematical disposition': the orientation toward mathematics as a discipline in which claims are made, tested and justified not a set of procedures to be memorised and applied. The development of this disposition in mathematics teachers is not merely desirable it is structurally necessary for effective classroom practice since teachers who lack epistemic agency in mathematics are ill-equipped to respond to the unpredictable, divergent and often surprising reasoning of their students.

The digital turn in teacher education has produced an extensive literature but that literature has a characteristic blind spot. Meta-analyses and systematic reviews (Cheung & Slavin, 2013; Ran et al., 2022; Li & Ma, 2010) consistently report modest positive effects of digital tools on mathematics content learning measured through standardised assessments. What these analyses cannot capture and largely do not attempt to capture is whether digital environments are producing teachers with the epistemic courage and confidence to generate their own mathematical meaning, challenge incorrect ideas and design instruction that invites students to do the same. This review addresses that gap directly.

The review introduces the construct of Passive Digital Consumption (PDC) a mode of digital learning in which the learner's primary epistemic activity is the reception, navigation and replication of algorithmically structured content, rather than the generation, critique and reconstruction of mathematical knowledge. PDC is analytically distinct from surface learning (Marton & Säljö, 1976) and from cognitive offloading (Risko & Gilbert, 2016) though it shares features with both: it describes not just a learning strategy but a pedagogical relationship between the learner and the digital environment that is structurally constituted by the design of the tool. The conditions for PDC are maximised when digital tools provide immediate, authoritative feedback; present knowledge as fixed and convergent and reward speed and accuracy over reflection

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and argumentation. The conditions for epistemic agency, by contrast, require uncertainty, dialogue and the genuine possibility of creative error.

The review is anchored in three theoretical pillars: Skemp's (1976) relational instrumental framework which provides a language for distinguishing productive from superficial mathematical understanding; Bandura's (1997) social cognitive theory of self-efficacy which illuminates the motivational and affective dimensions of epistemic agency and Freire's (1970) critical pedagogy which insists that genuine education must position the learner as a subject of knowledge not an object of instruction. Together, these frameworks generate the evaluative lens through which the reviewed literature is read and assessed.

2. Theoretical Framework

2.1 Epistemic Agency and Skemp's Relational–Instrumental Distinction

Richard Skemp's (1976) distinction between relational and instrumental understanding provides the most powerful available diagnostic for evaluating digital mathematics education. Instrumental understanding knowing how to execute a procedure can be achieved without any genuine grasp of why the procedure works; relational understanding requires the learner to construct and maintain a conceptual map in which mathematical objects and relationships are meaningfully connected. Skemp observed that instrumental teaching is faster, easier to assess and produces more immediate performance gains which is precisely why it dominates algorithmically designed digital environments that reward correct answers and penalise procedural deviation.

Epistemic agency as operationalised in this review is the functional expression of relational understanding at the level of knowledge production: it is the capacity to ask mathematical questions, evaluate competing approaches, construct arguments and revise understanding in light of new evidence. A teacher who possesses epistemic agency treats mathematics as a living intellectual practice; one who has only instrumental understanding treats it as a fixed code. The distinction matters enormously for digital design: an environment that trains instrumental mastery without cultivating relational understanding may produce measurable performance gains while systematically undermining the epistemic agency that effective teaching requires.

2.2 Bandura's Self-Efficacy and Mathematical Identity

Bandura's (1997) construct of self-efficacy the belief in one's capacity to organise and execute actions required to produce a specific outcome provides the motivational counterpart to Skemp's cognitive framework. In mathematics teacher education, self-efficacy operates at two levels: content self-efficacy (the belief that one can do the mathematics) and pedagogical self-efficacy (the belief that one can teach it). Research consistently shows that these two forms of efficacy are correlated but distinguishable and that digital learning environments affect them differentially (Pajares & Miller, 1994; Thurm & Barzel, 2022).

Critically for the purposes of this review, Bandura identified four sources of self-efficacy: mastery experiences, vicarious learning, social persuasion and physiological states. Digital environments that restrict learners to algorithmically scaffolded mastery experiences the most common design paradigm in contemporary educational technology systematically deprive learners of the other three sources and in doing so may produce a thin, brittle form of mathematical self-efficacy that is performance-contingent rather than dispositional robust. When the algorithmic scaffolding is removed as it will be in the classroom this brittle efficacy may collapse precisely when it is most needed.

2.3 Freire's Critical Pedagogy and the Banking Model

Paulo Freire's (1970) critique of the banking model of education in which knowledge is deposited into passive learners by authoritative teachers acquires particular urgency in the digital age. The structural logic of most adaptive digital platforms is a technological instantiation of the banking model: knowledge is pre-packaged, algorithmically sequenced and delivered to learners whose primary task is to receive, process and return it in the correct form. The learner is not invited to question the knowledge to interrogate its assumptions or to contribute to its construction. In Freire's terms, they are objects of instruction rather than subjects of inquiry.

Freire's alternative dialogic, problem-posing education demands that learners be positioned as generators of questions and constructors of knowledge. In digital mathematics teacher education, this implies platforms that present mathematical problems as genuinely open that require learners to formulate as well as solve and that value justification and argumentation as highly as correct answers. The reviewed literature reveals that this Freirean design ideal is rarely instantiated in practice and that its absence is structurally connected to the suppression of epistemic agency documented across multiple empirical traditions.

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3. Methodology

This narrative review followed a structured literature search and thematic synthesis approach (Popay et al., 2006). A systematic search of five electronic databases Scopus, Web of Science, ERIC, PsycINFO and Google Scholar was conducted in February 2026 using the following search terms: (digital education OR educational technology OR artificial intelligence OR adaptive learning OR generative AI) AND (mathematics teacher education OR pre-service mathematics teacher OR in-service mathematics teacher OR mathematics teacher preparation) AND (epistemic agency OR mathematical reasoning OR self-efficacy OR critical thinking OR pedagogical reasoning). The search was bounded to peer-reviewed publications in English between January 2013 and December 2025. Initial screening returned 3,841 records; after deduplication and title/abstract review, 198 full texts were assessed; 72 studies met inclusion criteria and are synthesised in this review. Inclusion required that studies address the intersection of digital learning and teacher epistemology in mathematics education specifically studies focusing on school pupils without attention to teacher development were excluded.

The thematic synthesis proceeded through three stages: free coding of each key findings of the study, clustering of codes into descriptive themes and development of analytical themes that generated new conceptual insights beyond the content of individual studies (Thomas & Harden, 2008). Studies published between 2023 and 2025 those addressing generative AI specifically were coded separately in a second pass to identify whether the emergence of large language models (LLMs) had introduced qualitatively new patterns relative to the earlier literature. Quality assessment used the Mixed Methods Appraisal Tool (Hong et al., 2018); findings from higher-quality studies were weighted more prominently in the synthesis.

Table 1: Literature Search and Inclusion Summary

Stage	n
Initial records retrieved (all databases)	3,841
Records removed (duplicates)	981
Excluded at title / abstract screening	2,662
Full-text articles assessed	198
Excluded at full-text stage	126
Studies included in synthesis	72
Pre-LLM era (2013–2022)	51
Generative AI era (2023–2025)	21

Note. Inclusion required peer-reviewed, English-language studies addressing digital pedagogy in mathematics teacher education, published 2013–2025.

4. The Design Logic of Digital Tools and Epistemic Agency

The most fundamental finding of this review is that the epistemic outcomes of digital mathematics teacher education are overwhelmingly determined by the pedagogical logic embedded in the design of the tools used not by the mere presence or absence of technology. Across the reviewed literature two contrasting design logics emerge with notable consistency which this review terms convergent-authoritative and divergent-agentic design.

Convergent-authoritative tools the dominant paradigm are structured around predetermined correct answers immediate feedback that resolves cognitive uncertainty and incentive systems that reward speed and accuracy. Adaptive platforms such as Khan Academy, IXL and Carnegie Learning exemplify this paradigm. Their value for building procedural fluency is well documented (Ran et al., 2022; Steenbergen-Hu & Cooper, 2014) but multiple studies raise serious concerns about their effects on mathematical reasoning. Bokosmaty et al. (2017) found that pre-service teachers who completed a semester-long adaptive mathematics course showed statistically significant gains on procedural tests but no improvement and in some domains, modest decline on measures of mathematical explanation and justification. Crucially, they reported that the immediate feedback design of the platform had 'removed the need to think about why' a verbatim description of PDC that is strikingly consistent across studies, contexts and years.

By contrast, divergent-agentic tools present mathematical tasks as genuinely open require learners to generate and justify their own approaches and withhold authoritative feedback until the learner has committed to a direction. Dynamic mathematics software such as GeoGebra and Desmos exemplifies this paradigm when used appropriately. Cusi et al. (2022) demonstrated that pre-service teachers who used GeoGebra to generate and test their own geometric conjectures showed

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significantly higher scores on measures of mathematical argumentation and epistemic self-confidence than those who used static digital resources even when the groups showed equivalent content knowledge gains. The critical factor was not the software itself but its deployment in tasks that demanded conjecture, testing and justification rather than procedural navigation.

The 2023–2025 literature on generative AI introduces a new and particularly complex instance of the convergent-authoritative paradigm. Unlike earlier ITS platforms, LLMs such as ChatGPT-4o and Claude can generate mathematically coherent, contextually responsive and explanatorily fluent responses to virtually any mathematical question. This creates a design problem that has no precedent in the history of educational technology: learners can now receive what appears to be relational explanation rich, multi-step, contextually sensitive mathematical reasoning without having engaged in any of the cognitive work that relational understanding requires. Bastani et al. (2024) demonstrated through a large quasi-experimental study that mathematics students who used GPT-4 assistance showed strong gains during assisted learning but significantly weaker performance on unassisted assessments than a non-AI control group providing the sharpest empirical evidence to date for the PDC dynamic.

For pre-service mathematics teachers, the implications are acute. Luo et al. (2024) found that student teachers who routinely used generative AI to assist with mathematical lesson planning produced plans that were mathematically accurate and pedagogically fluent but significantly less creative less responsive to anticipated student difficulties and less reflective of the teacher's own mathematical reasoning than plans produced without AI assistance. In effect, the AI had replaced the teacher's epistemic agency with algorithmically packaged pedagogical decisions. As one participant stated, 'It does the thinking you don't want to do' a description that should trouble anyone committed to the professional preparation of mathematics teachers.

5. Teacher Educator Mediation in Digital Environments

A second and critically important theme across the reviewed literature concerns the role of the human teacher educator in shaping the epistemic outcomes of digital learning. The most consistent finding in this domain is that the same digital tool can produce radically different epistemic outcomes depending on the quality and orientation of the human pedagogical framing that surrounds it. Digital environments do not operate in a vacuum; they are embedded in institutional, relational and pedagogical contexts that substantially determine whether their affordances are activated toward epistemic agency or toward PDC.

Goos and Bennison (2018) documented this dynamic through a multi-case study of pre-service mathematics teacher education programmes across Australian universities. They found that identical digital platforms produced markedly different patterns of mathematical reasoning in different programme contexts contexts that differed primarily in the extent to which teacher educators modelled relational mathematical reasoning, required justification and argumentation in response to digital outputs and treated digital tools as objects of critical reflection rather than transparent instructional delivery systems. In programmes where teacher educators used digital tools without critical comment, pre-service teachers adopted a similarly unreflective stance; in programmes where educators routinely asked 'Why does the software give this output? Is it mathematically justified? What does it obscure?', students developed considerably more robust mathematical epistemologies.

This finding has particular urgency in the Indian context. Singh (2022) documented that many teacher educators in Indian B.Ed. programmes have limited prior experience with digital mathematics tools and uncertain confidence in their own mathematical reasoning, creating a risk that the adoption of digital technology in these contexts will default to the convergent-authoritative paradigm not by deliberate design, but by the absence of the critical pedagogical mediation that divergent-agentic deployment requires. The National Education Policy (Government of India, 2020) mandates the expansion of digital teacher education without specifying the faculty development requirements in mathematics content knowledge, educational technology and critical digital pedagogy necessary to ensure that expansion produces epistemic agency rather than PDC.

A related strand of evidence concerns the design of assessment in digital mathematics teacher education. Multiple studies found that even teacher educators committed to relational understanding tended to assess digital learning through convergent, performance-based instruments MCQ tests, procedural problem sets, automated quiz platforms that signalled to pre-service teachers that instrumental mastery was the authentic priority of the programme regardless of the relational rhetoric in lectures and discussions (Sullivan et al., 2015; Thurm & Barzel, 2022). The assessment tail wagged the pedagogical dog: the epistemic values instantiated in assessment overrode those espoused in instruction. This alignment problem between the epistemic values stated in programme philosophy and those enacted in digital assessment is identified in this review as a structural obstacle to epistemic agency that cannot be resolved by tool design alone.

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6. Mathematics Anxiety as a Moderating Variable

Mathematics anxiety the negative affective response to mathematical situations characterised by apprehension, avoidance and reduced working memory capacity (Ashcraft, 2002; Hembree, 1990) emerges in the reviewed literature as a critical moderating variable in the relationship between digital environments and epistemic agency. The relationship is complex and bidirectional: mathematics anxiety shapes the ways pre-service teachers engage with digital tools and digital tools depending on their design can either exacerbate or ameliorate the anxiety that shapes that engagement.

Peker (2009) established that mathematics anxiety is prevalent among pre-service teachers in South Asian and Middle Eastern contexts and Singh's (2022) recent replication in the Indian context confirmed that a substantial proportion of B.Ed. mathematics students enter teacher preparation programmes with significant levels of mathematics anxiety. Critically, anxious pre-service teachers have been found to adopt PDC strategies most intensively: they prefer convergent-authoritative digital environments because the immediate authoritative feedback these environments provide resolves the epistemic uncertainty that anxiety makes aversive (Ramirez et al., 2018). In other words, the design features of convergent-authoritative platforms that most powerfully suppress epistemic agency are precisely those that anxious learners find most reinforcing.

This creates a pedagogical dilemma with serious equity implications. The pre-service teachers who most need to develop epistemic agency those whose mathematics anxiety has historically been compensated by instrumental mastery are the most likely to resist the divergent-agentic digital designs that would develop it. Kalder and Lesik (2011) found that requiring anxious pre-service teachers to engage with open-ended digital mathematical tasks produced short-term increases in anxiety and negative attitudes toward technology unless the transition was carefully scaffolded with explicit acknowledgement of productive discomfort and structured metacognitive support. Without such scaffolding, the move to divergent-agentic design may reproduce rather than disrupt the epistemic inequities it is intended to address.

The generative AI literature adds a further dimension. Wardat et al. (2023) and Luo et al. (2024) both documented that mathematically anxious pre-service teachers were the heaviest and most dependent users of AI assistance in mathematics tasks and that they were the least likely to critically evaluate AI-generated mathematical explanations. The conversational reassurance of LLM interfaces their capacity to respond with apparent confidence and fluency to any mathematical question appears to function as a powerful anxiety-reduction mechanism but one that achieves its effect by bypassing rather than resolving the epistemic uncertainty through which genuine mathematical understanding is built. Addressing this dynamic requires not only careful digital design but deliberate affectively sensitive pedagogical scaffolding of the kind that the reviewed literature consistently identifies as present in the most effective digital mathematics teacher education programmes.

7. Equity Fault Lines in Digital Mathematics Teacher Education

The fourth and most structurally significant theme concerns the relationship between digital expansion in mathematics teacher education and educational equity. The promise of digital technology as a democratising force expanding access to high-quality mathematical instruction across geographic, socioeconomic and cultural barriers is regularly invoked in Indian educational policy and in international development discourse. The reviewed evidence complicates this promise in several important ways.

First, access to digital tools is not evenly distributed. Kumar and Sharma (2021) documented that pre-service teacher in rural and government-funded Indian B.Ed. programmes had substantially lower access to reliable internet connectivity, personal computing devices and institutionally supported digital learning platforms than their urban private-college counterparts with the access gap widening rather than narrowing during the COVID-19 pandemic period. The enforced digitalisation of teacher education in the pandemic thus produced, in many contexts, a de facto exclusion of precisely those pre-service teachers whose preparation it was intended to support.

Second, the emergence of LLM-based tools has introduced what this review terms a quality-access gap. The gap between the capabilities of the most powerful AI tools and those accessible to resource-constrained institutions. Holmes et al. (2023) documented that high-capacity AI tutoring systems those with the largest models most sophisticated mathematical reasoning capabilities and most robust pedagogical scaffolding were disproportionately available to well-resourced institutions in high-income countries while under-resourced institutions had access only to older less capable versions that produced higher rates of mathematical error and less nuanced pedagogical feedback. In the Indian context, Sharma and Gupta (2024) found that the generative AI tools most widely used by pre-service teachers in government B.Ed. programmes were free, publicly available models whose mathematical accuracy and pedagogical quality were significantly lower than the premium tools their private-college counterparts accessed through institutional subscriptions. Digital equity cannot be achieved by ensuring that all learners have access to some digital tool; it requires ensuring that they have access to pedagogically adequate ones.

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Third, and most critically, the reviewed literature suggests that digital tools produce their strongest epistemic gains in learners who already possess the mathematical confidence, SRL capacity and critical digital literacy to use them independently and their weakest or most negative epistemic effects in learners who lack these prerequisites. Warschauer and Tate (2022) described this as pedagogical complementarity: digital tools amplify the pedagogical strengths and weaknesses of the environments into which they are introduced. A programme with strong human pedagogical quality, clear epistemic values and well-prepared teacher educators will see digital tools strengthen those qualities; a programme without them will see digital tools accelerate the PDC dynamic that is already present in conventional instruction. The equity implication is sharp: digital expansion in underprepared teacher education contexts may without deliberate intervention produce more PDC for more pre-service teachers more efficiently.

Table 2: Thematic Summary: Conditions Promoting versus Suppressing Epistemic Agency in Digital Mathematics Teacher Education

Theme	Conditions Promoting Epistemic Agency	Conditions Suppressing Epistemic Agency (PDC)
Tool Design	Open tasks; delayed feedback; conjecture-based design; argumentation demands	Immediate authoritative feedback; convergent tasks; gamified accuracy rewards
Educator Mediation	Critical framing of digital outputs; relational assessment; explicit justification demands	Unreflective tool adoption; convergent digital assessment; instrumental rhetoric
Mathematics Anxiety	Scaffolded productive discomfort; metacognitive support; growth-oriented framing	Anxiety-driven PDC; AI-assisted uncertainty avoidance; performance contingency
Equity and Access	Quality tool access; SRL development; faculty digital pedagogy preparation	Quality-access gap; second-order digital divide; PDC amplification in under-resourced contexts

Note. PDC = Passive Digital Consumption. Synthesis based on 72 reviewed studies (2013–2025).

8. The Epistemic Agency-Centred Digital Pedagogy (EACDP) Framework

Drawing on the four thematic findings, this review proposes the Epistemic Agency-Centred Digital Pedagogy (EACDP) framework as an integrative design and evaluation heuristic for digital mathematics teacher education. The framework is organised around five interconnected principles each grounded in the empirical literature and theoretically anchored in the Skemp–Bandura–Freire triad outlined in Section 2.

Principle 1: Open-Ended Task Design. Digital environments in mathematics teacher education must privilege divergent over convergent task structures: tasks that admit multiple solution approaches, require mathematical justification and present the learner with genuine epistemic uncertainty. Assessment instruments including those embedded in digital platforms must measure mathematical reasoning and argumentative quality not merely procedural accuracy. In the LLM era, this implies tasks that cannot be satisfactorily completed by an AI system without the teacher's genuine mathematical engagement tasks that ask 'Why?', 'What if?' and 'How would you convince someone?' rather than 'What is the answer?'

Principle 2: Delayed and Transparent Feedback. Feedback in digital mathematics teacher education should be contingent on the learner's prior reasoning attempt not anticipatory of it. Platforms should require learners to articulate their mathematical thinking before receiving corrective or confirmatory feedback and should present that feedback with explicit transparency about its sources and limitations particularly in AI-mediated contexts where the provenance of feedback is systematically opaque. Pre-service teachers should be taught to interrogate digital feedback not merely to receive it.

Principle 3: Pedagogical Mediation as Programme Architecture. Human teacher educator mediation must be treated as a non-negotiable programme component not an optional supplement to digital instruction. Teacher educators must be prepared through ongoing professional development in both mathematics content and digital pedagogy to critically frame digital outputs, model relational mathematical reasoning in response to digital tools and design assessment that enacts the epistemic values the programme espouses. Digital tools cannot substitute for this mediation; they can only extend its reach when it is already present.

Principle 4: Anxiety-Sensitive Epistemic Scaffolding. Digital mathematics teacher education programmes must include systematic assessment of mathematics anxiety and SRL capacity at programme entry and must design scaffolded transitions to divergent-agentic digital engagement that acknowledge and work through rather than bypass the productive discomfort that epistemic development requires. This scaffolding is not a concession to low standards but a condition of genuine

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epistemic development: the research base is unequivocal that bypassing epistemic discomfort through immediate authoritative feedback produces instrumental performance without relational understanding.

Principle 5: Structural Equity by Design. Programme designers and policymakers must explicitly account for the quality-access gap the differential between the pedagogical capacities of digital tools available to differently resourced institutions and must not equate access to some digital tool with access to pedagogically adequate digital education. Equity requires not just that all pre-service teachers have a device and connectivity but that all have access to tools of sufficient quality with teacher educators of sufficient preparation to make epistemic agency a realistic programme outcome.

The EACDP framework is intended as both a design guide and an evaluation instrument. As a design guide, it provides programme developers with a set of evidence-grounded principles against which tool selection, curriculum design and assessment can be evaluated. As an evaluation instrument, it provides researchers and quality assurance bodies with a principled framework for assessing whether digital mathematics teacher education programmes are producing the epistemic agency their broader goals require. The framework does not prescribe specific tools or platforms the digital landscape changes too rapidly for such prescription to remain useful but provides a durable set of pedagogical commitments against which any tool or platform can be evaluated.

9. Discussion, Limitations and Future Directions

The central argument of this review that digital environments in mathematics teacher education are predominantly structured to produce Passive Digital Consumption rather than epistemic agency and that this structural tendency has become more intense rather than less with the emergence of generative AI has several implications that deserve explicit discussion.

For mathematics teacher educators, the most immediate implication is that the selection of digital tools is an act of pedagogical commitment not merely a logistical decision. Choosing a convergent-authoritative platform because it is widely available, user-friendly or aligned with institutional assessment conventions is choosing to prioritise instrumental performance over epistemic agency. A choice with consequences that will manifest not in the data collected during the course, but in the classrooms that pre-service teachers will inhabit for the next three decades. The EACDP framework is intended to make these implicit choices explicit and accountable.

For educational psychologists and researchers, the PDC construct offers a theoretically grounded research programme that has not yet been systematically pursued. Validated instruments for measuring PDC as distinct from surface learning, cognitive offloading or technology dependence do not yet exist. The development of such instruments would substantially advance both theoretical understanding and practical evaluation in digital mathematics teacher education. Similarly, longitudinal studies tracking the relationship between PDC in pre-service digital learning and instructional quality in early-career teaching are needed urgently; the review literature offers no study of this kind, despite its obvious relevance.

For policymakers in India and beyond, the findings underscore the need for a fundamental reorientation of digital education policy from an input focus device, platforms, connectivity to an epistemic outcomes focus. The digital education mandate of NEP 2020 is an important structural commitment but it requires complementary policy development in at least three areas: faculty preparation standards for digital mathematics teacher education; quality assurance frameworks that include epistemic agency as a measurable programme outcome; and equity frameworks that distinguish access from adequacy in digital tool provision.

Several limitations of this review must be acknowledged. First, the search was restricted to English-language publications which may underrepresent scholarship from non-Anglophone contexts including the substantial regional-language literature on mathematics teacher education in India. Second, the narrative review methodology, while appropriate for a theoretically generative review of this kind does not support quantitative synthesis or the computation of effect sizes; readers seeking meta-analytic precision should consult Ran et al. (2022) and Steenbergen-Hu and Cooper (2014) for complementary quantitative analyses. Third, the PDC construct and the EACDP framework are theoretical products of this review that require direct empirical testing; the review identifies the patterns from which they are derived but does not itself test their predictive validity. Fourth, the 21 generative AI studies in this corpus are preliminary many were published in 2023–2024 and address first-generation LLM deployments that have since been superseded by more capable systems. The epistemic implications of frontier AI models in teacher education remain substantially open as empirical questions.

10. Conclusion

This review has synthesised 72 studies published between 2013 and 2025 to examine the relationship between digital pedagogical design and the development of epistemic agency in pre-service and in-service mathematics teachers. It has demonstrated that the dominant paradigm of digital mathematics teacher education convergent-authoritative, algorithmically

scaffolded, immediately feedback-rich is structurally oriented toward the production of Passive Digital Consumption rather than the epistemic agency that effective mathematics teaching requires. It has traced this dynamic through four analytical themes tool design logic, teacher educator mediation, mathematics anxiety and structural equity. It has shown that the emergence of generative AI has intensified rather than resolved the fundamental tension.

The Epistemic Agency-Centred Digital Pedagogy (EACDP) framework proposed here is not a rejection of digital education but a demand for its deepening. Digital tools have genuine affordances for mathematical learning that no educator committed to quality mathematics teacher preparation can afford to ignore the visualisation power of dynamic geometry software, the personalisation capacity of adaptive platforms, the dialogic potential of collaborative digital spaces. But these affordances are realised only when digital tools are embedded in pedagogical contexts that position pre-service teachers as generators of mathematical meaning, not repositories of algorithmically packaged knowledge.

Mathematics, as Lakatos (1976) famously argued grows through conjecture and refutation through the messy, uncertain, creative process of making claims, testing them against counterexamples and revising them in light of argument. A teacher who has experienced this process is equipped to invite their students into it. A teacher who has only navigated algorithmically structured content efficiently is not. The central task of digital mathematics teacher education in India and globally in 2026 and beyond is to ensure that the digital environments we design are equal to the mathematical humanity we seek to cultivate.

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