

Artificial intelligence-supported development of teaching and learning materials by primary school teachers

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Abstract: Artificial intelligence (AI) is increasingly being incorporated into teachers' instructional planning and development of teaching and learning materials. This qualitative international review synthesizes evidence on how primary school teachers use AI to develop, adapt, and evaluate instructional materials, with particular attention to pedagogical opportunities, teacher competencies, differentiated instruction, and responsible implementation. A structured literature search was conducted across Scopus and Google Scholar for studies published between 2020 and 2026, yielding 191 records. Following the removal of duplicates and a rigorous screening process, 14 studies were retained for qualitative thematic synthesis. The synthesis examined AI-supported material development, differentiated and inclusive instructional practices, AI literacy and AI-TPACK, teacher verification, and institutional and ethical conditions. The findings suggest that AI can facilitate the generation, adaptation, and organization of instructional resources, but the pedagogical value of AI-supported materials depends substantially on teachers' ability to formulate purposeful prompts, critically evaluate outputs, verify accuracy, and align materials with curriculum and learners' developmental needs. The review identifies recurring concerns related to misinformation, privacy, copyright, bias, technological dependence, and uneven institutional support. Based on the synthesized evidence, a three-phase, 10-stage teacher-centered framework is proposed to structure AI-supported instructional material development. The framework positions AI as an assistive resource within a teacher-mediated design process and provides an evidence-informed basis for future empirical validation.

Keywords: Artificial intelligence; Primary education; Instructional materials; AI literacy; AI-TPACK; Teacher competence

1. INTRODUCTION

Artificial Intelligence (AI) is rapidly transforming educational practice by expanding opportunities for teachers in lesson planning, instructional material design, information synthesis, feedback generation, and instructional personalization. Generative AI and Large Language Models (LLMs) have made it increasingly accessible for educators to produce lesson plans, assessment items, expository texts, visual prompts, narratives, worksheets, and other supplementary instructional resources. This technological advancement is particularly pertinent to primary education, where learning materials must be comprehensible, engaging, developmentally appropriate, visually rich, and responsive to diverse student needs. Primary school teachers operate under constrained time and resource allocations while managing multifaceted professional responsibilities. Designing worksheets, classroom activities, graphic organizers, assessment rubrics, presentations, instructional narratives, audio materials, and supplementary aids accounts for a substantial portion of their daily preparation workload. Recent empirical evidence

demonstrates that AI can effectively scaffold teachers in developing instructional resources and streamlining access to information. For instance, in an empirical study of 231 primary school teachers in West Java, Sunaengsih et al.[1] documented the growing adoption of AI-based instructional materials while highlighting both its pedagogical efficacy and the persistent necessity for structured training and robust infrastructure. Similarly, Rachmadtullah et al.[2] found that elementary educators highly value AI for resource retrieval and instructional content creation, while underscoring that AI integration must remain closely aligned with core curriculum objectives.

Nevertheless, the pedagogical value of AI cannot be defined solely by operational efficiency or production speed. Educational materials should be scientifically sound, appropriate to students' age and cognitive development, and consistent with curriculum content [3]. Accordingly, AI-generated materials have educational value only when they are factually accurate, aligned with curricular standards, attuned to learners' developmental needs, accessible, and pedagogically meaningful. Consequently, the professional responsibility for evaluating, refining, contextualizing, and deploying AI-generated resources in classroom settings remains with the teacher. Consequently, the ultimate professional responsibility for evaluating, refining, contextualizing, and deploying AI-generated resources in classroom settings resides firmly with the teacher. This consideration is especially acute in primary education, where young learners are in the foundational stages of acquiring literacy, numeracy, critical thinking, social-emotional skills, and self-regulation.

Furthermore, AI can facilitate differentiated and inclusive education by enabling educators to generate multiple variations of a single concept, simplify linguistic complexity, adjust scaffolding levels, or transform materials across multimodal formats. For example, Basaruddin and Mustafa [4] investigated AI-supported analysis of English instructional materials in Malaysian primary special education classrooms, reporting measurable enhancements in material quality and accessibility. However, differentiated instruction is not an automated artifact of technology: meaningful customization requires teachers to deeply understand their students' individualized profiles and make deliberate pedagogical judgements regarding the contextual relevance and validity of generated content.

At the same time, AI integration entails salient risks, including algorithmic hallucinations, fabricated citations, data privacy breaches, intellectual property issues, algorithmic biases, and cognitive over-reliance. Educators must understand not only the generative capabilities of AI tools but also their operational limitations. Studies examining teachers' AI literacy and Technological Pedagogical Content Knowledge (TPACK/AI-TPACK) reveal that positive attitudes toward AI do not automatically translate into effective, integrated instructional practice. For instance, Yim and Su [5] observed that while primary school teachers recognized the perceived usefulness and ease of use of AI educational tools, significant deficits remained regarding their AI-specific content knowledge, TPACK proficiency, technical support, and institutional infrastructure.

Although international literature on educational AI is expanding exponentially, current scholarship remains fragmented across disconnected domains—namely teacher perceptions, AI literacy frameworks, resource design, professional development, TPACK integration, ethics, and institutional readiness. Existing reviews have largely examined these dimensions in isolation. Comparatively little attention has been directed toward the comprehensive, teacher-mediated workflow through which raw AI outputs are transformed into developmentally appropriate, standards-aligned, differentiated, and ethically sound instructional resources for primary classrooms. This review addresses this critical gap by synthesizing empirical evidence across these dimensions and proposing a teacher-centered, 10-stage conceptual framework for responsible AI-supported instructional material development.

1.1. Research purpose and questions

The purpose of this review is to synthesize international empirical research on primary school teachers' utilization of AI for instructional material design, identify recurring benefits, requisite teacher competencies, operational risks, and institutional conditions, and derive actionable principles for responsible implementation.

To achieve this purpose, the review addresses three central research questions:

- RQ1: How are primary school teachers currently utilizing AI in the development of teaching and learning materials?

- RQ2: What pedagogical benefits, instructional opportunities, professional competencies, and implementation challenges are associated with this utilization?
- RQ3: What evidence-based principles can be formulated to guide the responsible and effective development of AI-supported instructional materials in primary education?
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2. CONCEPTUAL AND THEORETICAL FRAMEWORK

2.1. AI-supported materials

AI-supported teaching and learning materials refer to educational resources whose generation, adaptation, analysis, or formatting processes are scaffolded by artificial intelligence systems. These resources include:

- Text-based materials and structured worksheets;
- Assessment items, problem sets, narrative texts, and explanatory passages;
- Visual aids, graphical illustrations, and multimedia scripts;
- Differentiated task variants and teacher-authored customized aids.

This review explicitly distinguishes the utilization of AI as a pedagogical design tool for educators from teaching AI as a direct subject of student instruction. This conceptual demarcation is vital, as the present synthesis concentrates on how teachers leverage AI systems to engineer instructional resources rather than curriculum development for teaching AI literacies to children.

Rachmadtullah et al.[2] demonstrated that primary school teachers utilize AI primarily for information retrieval and instructional media design, emphasizing that tool deployment must align systematically with learning objectives and pedagogical intent. Furthermore, Sunaengsih et al.[1] reported that AI-based materials are becoming increasingly embedded in primary classroom routines, while pointing out that adequate training and technological infrastructure remain indispensable prerequisites for sustained adoption.

Collectively, these findings indicate that AI can support established lesson planning and instructional design workflows, particularly in information retrieval, instructional media development, and resource preparation.

2.2. AI literacy

AI literacy extends beyond mere operational proficiency with specific software applications or interfaces. In a systematic review of 25 empirical investigations on primary school AI literacy, Yim and Su[5] delineated its multidimensional structure, identifying four key dimensions:

- Human-AI interaction and collaborative capability;
- Computational thinking;
- Critical data literacy;
- AI ethics and responsible use.

For classroom teachers, these competencies are fundamental for evaluating whether AI-generated instructional outputs are scientifically accurate, developmentally sound, and ethically defensible.

Moreover, essential teacher competencies encompass goal-oriented prompt engineering, identifying algorithmic hallucinations and limitations, verifying empirical facts, contextualizing linguistic nuance and localized examples, and making rigorous pedagogical decisions. While Du et al. [6] highlighted the positive role of AI literacy in facilitating teacher learning and professional development, Mazi and Yıldırım [7] identified substantial gaps in teachers' AI-specific knowledge and pedagogical integration skills, underscoring the critical need for structured professional learning programs.

2.3. AI-TPACK

Primary school classrooms are characterized by pronounced diversity in students' prior knowledge, cognitive pacing, language proficiency, personal interests, and scaffolding requirements. AI tools empower teachers to adapt textual complexity, vocabulary load, instructional examples, and representation modes dynamically. Theoretically, this

enables educators to articulate a single curricular objective across multiple tiered variations without manually authoring each iteration from scratch.

Basaruddin and Mustafa [4] investigated AI-assisted analysis and material generation in Malaysian primary special education contexts, reporting improvements in resource quality and accessibility. Although these findings illustrate AI's potential in designing materials for diverse learning needs, technology cannot independently diagnose idiosyncratic student deficits or tailor interventions autonomously.

Similarly, Sunaengsih et al.[1] showed that AI-supported instructional media was reported to support student comprehension and classroom engagement in primary settings. The broader pedagogical value lies in transitioning from standardized "one-size-fits-all" worksheets to multi-tiered, multimodal resource packages. Realizing this potential, however, necessitates deep teacher knowledge of student profiles and well-developed AI literacy to enact meaningful pedagogical adaptations.

2.4. Differentiated instruction

Effective AI adoption depends on far more than technical system access. Teachers must comprehend tool constraints, engineer robust instructional prompts, critically appraise generated outputs, and align materials with curricular standards and subject-matter didactics.

As established by Yim and Su[5], AI literacy represents an integrated composite of knowledge, application, critical evaluation, and ethical judgment, which cannot be reduced to procedural software training.

The Technological Pedagogical Content Knowledge (TPACK) framework provides an established theoretical lens for conceptualizing this integration. Originally formulated by Mishra and Koehler [8] to explain the complex intersections of technological, pedagogical, and content knowledge, it has recently been extended to address intelligent technologies[9]. In primary mathematics education, Li and Manzari [10] established that teachers' internal attitudes and external environmental factors interact reciprocally to shape AI implementation behaviors, demonstrating that individual competencies and institutional environments must be examined synchronously.

Furthermore, Polak et al.[11] highlighted a documented divergence between educators' general interest in AI tools and their applied competency to deploy them effectively in instructional settings. Even when teachers demonstrate high receptivity, they often struggle with prompt formulation, error identification, linguistic calibration for young learners, and evaluating whether an AI-suggested task truly achieves target learning outcomes.

Based on these studies, primary school teachers' AI competence can be understood as the following process: defining learning objectives → selecting appropriate AI tools → designing purposeful prompts → evaluating outputs → verifying information → adapting materials for students → implementing and observing → reflecting on the impact. This process integrates AI educational competence, digital competence, pedagogical competence, and subject matter knowledge.

2.5. Risks

AI-generated instructional content frequently exhibits factual inaccuracies, fabricated citations, culturally misaligned examples, and linguistically inappropriate register for young learners. Consequently, mandatory teacher verification remains indispensable. Rather than accepting AI outputs as authoritative truths, educators must treat them strictly as initial drafts and brainstorming substrates.

Data privacy and child protection present equally serious considerations. Teachers must refrain from inputting identifiable student data into third-party AI platforms and adhere strictly to institutional data governance standards and legal compliance mandates. Furthermore, intellectual property rights, proper attribution, algorithmic bias, and cognitive over-reliance demand rigorous vigilance.

Excessive technological reliance presents a significant cognitive vulnerability: if educators and learners outsource deep conceptual planning, critical synthesis, and problem-solving to AI tools, the technology risks diminishing rather than scaffolding intellectual agency. Yumbul and Sulak[12] uncovered this duality in primary teachers' perspectives, identifying enthusiasm alongside profound concerns regarding deskilling and ethical exposure. Likewise, Mazi and

Yıldırım[7] documented that high teacher interest is frequently compromised by pronounced disparities in empirical skills and practical training.

Finally, institutional ecologies critically govern sustainable implementation. Technological infrastructure, broadband connectivity, hardware availability, school policies, leadership vision, and practical professional development collectively determine adoption outcomes. AI integration must therefore be addressed as a systemic institutional capacity rather than the isolated responsibility of individual teachers.

3. RESEARCH METHODOLOGY

3.1. Research design

This study adopts a qualitative scoping review and thematic evidence synthesis design. This study employed a scoping review design with qualitative thematic synthesis, guided by the methodological framework of Arksey and O'Malley[13] and refined by Levac et al.[14], adhering to the core reporting principles of the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews) guidelines. Given that the empirical integration of Generative AI in primary education is an emerging, rapidly evolving field, a scoping synthesis is the most methodologically sound approach to map existing literature, clarify conceptual boundaries, identify knowledge gaps, and construct a process-oriented instructional framework.

Rather than calculating statistical effect sizes through a quantitative meta-analysis, the analytical priority was placed on qualitative documentary analysis and comparative thematic synthesis. This approach enables the systematic examination of heterogeneous research designs (qualitative case studies, mixed-methods designs, quasi-experiments, and surveys) to identify operational trajectories, pedagogical affordances, teacher competencies, and institutional constraints across diverse international contexts.

3.2. Search strategy and study identification

A structured literature search was conducted using Scopus and Google Scholar to identify international studies examining the use of artificial intelligence (AI) in the development of teaching and learning materials in primary education. The search covered publications from 2020 to 2026 to capture the development of AI-supported educational practices and the recent emergence of generative AI applications in primary education.

The search strategy incorporated terms related to four conceptual dimensions: (1) artificial intelligence, (2) primary education, (3) teaching and learning materials, and (4) teacher competence and AI-related pedagogical knowledge. The educational-level terms “primary school,” “elementary school,” and “K–6” were used to refine the retrieved literature to studies relevant to the target educational context.

The initial search identified 41 records in Scopus and 150 records in Google Scholar, yielding 191 records in total. After removing 7 duplicate records, 184 unique records remained for screening. Titles and abstracts were then screened for relevance to the review topic and research questions. Following this screening process, 170 records were excluded because their content did not sufficiently correspond to the scope and focus of the present review. The remaining 14 studies met the relevance and eligibility requirements and were included in the final qualitative thematic synthesis.

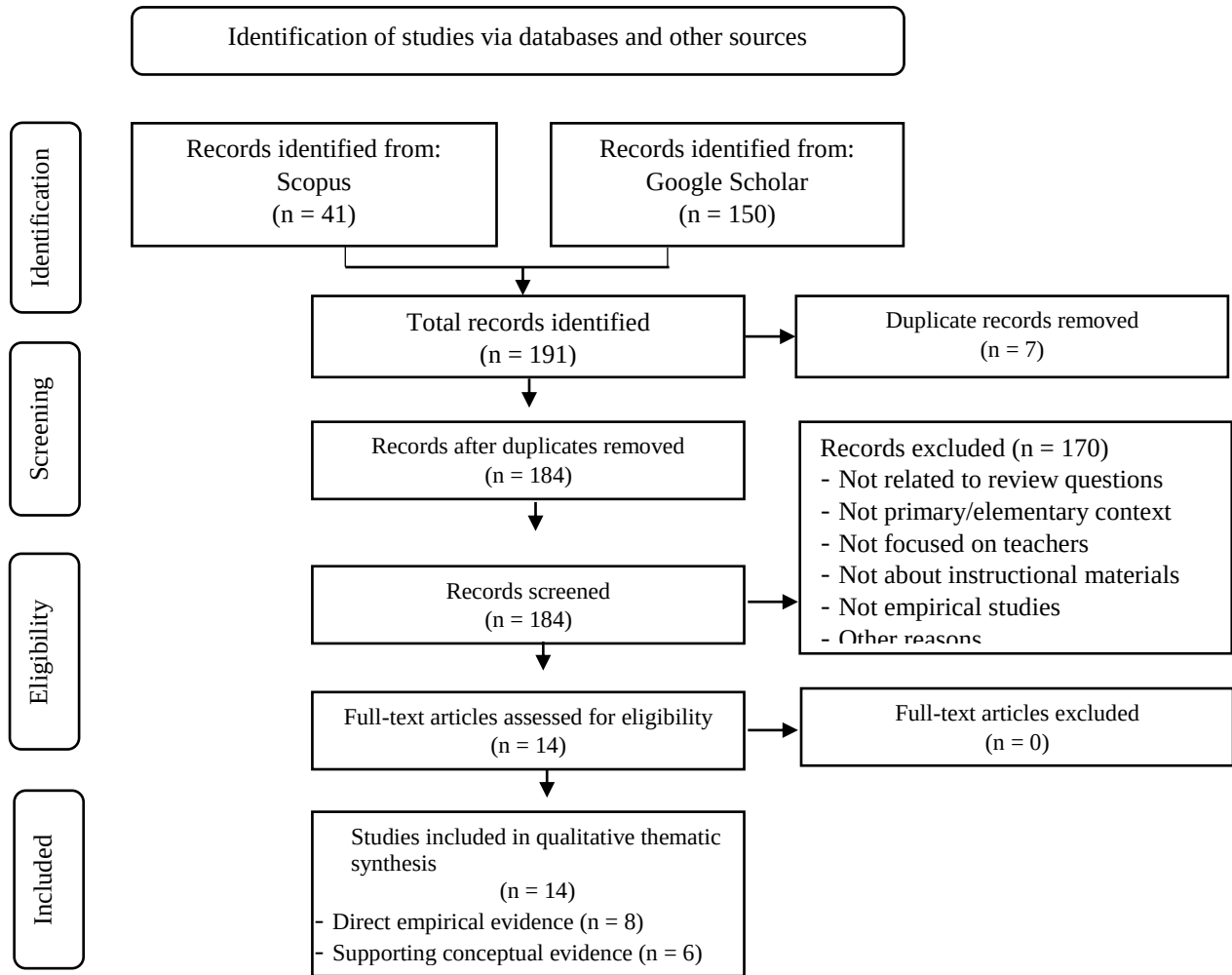


Figure 1. PRISMA-ScR flow diagram of the study identification, screening, eligibility, and inclusion process.

The selection process was therefore based on the relevance of the retrieved studies to primary/elementary education, AI-supported instructional material development, teacher competencies, and the pedagogical, ethical, and institutional dimensions addressed by the research questions.

3.3. Inclusion and exclusion criteria

To ensure consistency in study selection, predefined inclusion and exclusion criteria were applied during the screening process.

Studies were included when they met the following criteria:

- ① The study focused on primary/elementary education or primary school teachers, including K–6 contexts.
- ② The study examined the use, development, adaptation, evaluation, or application of AI-supported teaching and learning materials or instructional resources.
- ③ The study addressed at least one of the review questions concerning AI utilization, pedagogical benefits and challenges, teacher competencies, AI literacy, AI-TPACK, differentiated instruction, or responsible implementation.
- ④ The study was published between 2020 and 2026.
- ⑤ The publication was a peer-reviewed academic article or rigorously reviewed conference paper available in English.
- ⑥ Sufficient methodological and bibliographic information was available to assess the relevance of the study.

Studies were excluded when they:

- ① Focused exclusively on higher education or secondary education without clear relevance to primary education;
- ② Focused exclusively on student-facing AI systems without relevance to teacher-mediated instructional material development;
- ③ Addressed AI from a purely technical or computational perspective without an educational or pedagogical focus;
- ④ Did not sufficiently address the review questions or the central topic of AI-supported instructional material development in primary education;
- ⑤ Were editorials, opinion papers, non-peer-reviewed reports, or publications without sufficient methodological information.

3.4. Study selection and evidence hierarchy

The retrieved citations were subjected to a two-stage screening process: title/abstract screening followed by a comprehensive full-text review against the eligibility criteria.

Because empirical inquiry into generative AI utilization specifically within primary school material development is an emerging field, the final synthesized corpus of $N = 14$ key studies was categorized into a two-tiered evidence hierarchy:

- Tier 1: Direct empirical evidence ($n = 8$): Studies conducted directly with primary/elementary educators or within authentic primary school environments, explicitly analyzing instructional media, material generation, differentiated task design, or primary classroom AI integration [4; 15; 16; 10; 7; 2; 1; 7].
- Tier 2: Supporting conceptual evidence ($n = 6$): Empirical and systematic review studies across broader K–12 and teacher education ecologies that provide essential theoretical foundations regarding AI-TPACK transformation, baseline AI literacy dimensions, prompt mechanics, and institutional ethics that are directly transferable to the primary level [18; 19; 11; 5; 20].

The final evidence base comprised 14 studies, consisting of eight direct empirical studies focused on primary/elementary education and six supporting studies from broader K–12 or teacher-education contexts. The supporting studies were not treated as direct evidence of primary teachers' instructional-material development; rather, they were used to contextualize AI literacy, AI-TPACK, teacher readiness, and institutional conditions relevant to the review questions.

Table 1. Summary of included international studies on AI-supported instructional material development

No.	Study / context	Participants / methodological design	Key contribution to instructional material development	Relevant RQ(s)	Evidence classification
1	Erol & Erol (2024), Turkey	Primary school teachers; Empirical qualitative	Analyzed opportunities and necessity for human-in-the-loop teacher mediation in AI adoption.	RQ2, RQ3	Direct
2	Rachmadtullah et al. (2024), Indonesia	Elementary teachers; Qualitative inquiry	Evaluated teacher perceptions on utilizing AI for instructional media and content generation.	RQ1, RQ2	Direct
3	Sunaengsih et al. (2025), Indonesia	231 primary school teachers; Survey-based quantitative	Documented AI material usage for deep learning alongside infrastructure and training needs.	RQ1, RQ2	Direct
4	Basaruddin & Mustafa (2025), Malaysia	54 special education teachers; Quasi-experimental	Evaluated AI-assisted analysis and differentiation of English instructional resources.	RQ1, RQ2	Direct
5	Yim & Su (2025), International	25 empirical studies; Systematic review	Delineated core dimensions and competency frameworks of primary AI literacy.	RQ2, RQ3	Supporting
6	Li & Manzari	516 primary math	Modeled internal and external	RQ2, RQ3	Direct

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	(2025), China	teachers; Equation (SEM)	Structural Modeling	environmental determinants governing AI implementation.		
7	Mazi & Yıldırım (2025), Turkey	20 primary teachers; Phenomenological case study		Documented applied competency deficits and professional development requirements.	RQ2, RQ3	Direct
8	Polak et al. (2022), International	Secondary/K–12 teachers; Exploratory qualitative		Identified discrepancies between teacher interest and applied pedagogical AI readiness.	RQ2, RQ3	Supporting
9	Hava & Babayiğit (2024), Turkey	401 teachers; Survey / SEM		Empirically established the predictive relationship between digital proficiency and AI-TPACK.	RQ2, RQ3	Supporting
10	Yue et al. (2024), China / K–12	1,664 K–12 teachers; Large-scale quantitative		Assessed baseline AI-TPACK readiness profiles and attitudinal distributions.	RQ2, RQ3	Supporting
11	Yim & Wegerif (2024), China	60 primary educators; Mixed-methods		Explored teachers' perceptions and acceptance of AI educational tools, identifying AI knowledge, TPACK, technical, and institutional support needs.	RQ2, RQ3	Supporting
12	Kosmas et al. (2025), Cyprus	25 teachers, 62 students; Co-design framework		Validated the efficacy of collaborative co-design for age-appropriate AI literacy materials.	RQ1, RQ2	Direct
13	Du et al. (2024), International	Practicing educators; Empirical study		Highlighted the role of AI literacy in scaffolding continuous teacher learning workflows.	RQ2, RQ3	Supporting
14	Jiang et al. (2026), China	500+ primary school teachers; Mixed-methods		Investigated structural TPACK transformation barriers within primary school ecologies.	RQ2, RQ3	Direct

Source: Developed by the researcher

3.5. Data extraction and thematic synthesis

A standardized data extraction matrix was developed to systematically code each included study across the following parameters:

1. Bibliographic metadata (authors, year, publication outlet, geographic context);
2. Participant demographics and sample size (N);
3. Methodological design and analytical approach;
4. Target AI modalities and instructional material types (textual, visual, differentiated, assessment);
5. Key findings regarding teacher competencies (prompting, verification, AI-TPACK);
6. Pedagogical affordances, operational risks, and institutional mediating conditions.

Extracted data underwent a six-phase thematic synthesis following Braun and Clarke's (2006) qualitative analysis protocol: familiarization with the data, initial code generation, searching for themes, reviewing themes across the direct/supporting tiers, defining and naming thematic constructs, and producing the integrative narrative synthesis.

The thematic analysis yielded six core analytical categories: (a) Instructional Material Design & Productivity, (b) Differentiated and Inclusive Customization, (c) AI Literacy and Prompt Competence, (d) AI-TPACK Integration, (e) Teacher Oversight and Verification, and (f) Institutional Infrastructure and Ethical Governance.

3.6. Methodological rigor and limitations

Methodological rigor was maintained through peer debriefing and continuous comparative coding to ensure Thematic consistency was strengthened through iterative coding, comparison of themes across the direct and supporting

evidence groups, and repeated review of extracted data against the original studies. Evidence directness was explicitly weighted, ensuring that pedagogical recommendations directly reflect primary classroom realities.

Methodological limitations:

- ① **Corpus size:** Reflecting the emerging status of generative AI research in primary education, the corpus comprises 14 primary studies. Although the corpus was relatively small, it provided sufficient thematic coverage to address the review questions; however, the findings should not be interpreted as statistically generalizable.
- ② **Perceptual measures:** Several included studies relied on self-reported teacher surveys and case studies rather than direct experimental measurement of pupil learning gains.
- ③ **Linguistic and contextual diversity:** While spanning diverse geographic jurisdictions (Asia, Europe, Middle East), the findings are primarily derived from early adopters in specific educational ecosystems, necessitating contextual adaptation for non-English and developing educational environments.
- ④ **Review period:** The review covers a relatively short period from 2020 to 2026, which may limit the temporal breadth of the evidence base.
- ⑤ **Rapid technological development:** The rapid evolution of generative AI technologies and tools during the review period may affect the stability and comparability of findings across studies.
- ⑥ **Variation in tools, contexts, and outcome measures:** The included studies examined different AI tools, instructional contexts, participant groups, and outcome measures, which limits direct comparison and broad generalization across settings.
- ⑦ **Limited longitudinal evidence:** Most included studies focused on teacher perceptions, implementation experiences, or short-term applications, while longitudinal evidence concerning sustained AI use and its effects on teaching and learning remains limited.

4. FINDINGS

As evidenced by the synthesized literature, research across different national contexts consistently identified instructional material design, differentiated customization, teacher competence, and institutional infrastructure as key dimensions of AI integration in primary education. These recurring themes indicate that AI-supported material development is closely connected to teachers' instructional planning, pedagogical decision-making, and contextual adaptation. This confirms that AI integration cannot be conceptualized merely as isolated tool usage, but rather as an intersection of teacher pedagogical decision-making, instructional design, and institutional ecologies.

4.1. Characteristics of included studies

Eight studies provided direct evidence, while six studies provided supporting evidence. Direct evidence comprises empirical investigations focusing explicitly on primary school teachers, elementary learning materials, or authentic primary classroom implementations. Supporting evidence encompasses broader K–12 teacher cohorts, theoretical AI literacy dimensions, or TPACK readiness studies. This distinction is critical because not all included studies measured primary teachers' material development workflows directly.

Geographically, the evidence base spans Turkey, Indonesia, Malaysia, China, Cyprus, and broader international cohorts, employing qualitative inquiries, quantitative surveys, mixed methods, quasi-experimental designs, case studies, and systematic reviews. Additional sources [11, 12] provide broader primary education context and were utilized as foundational background rather than within the core 14-study comparative matrix.

4.2. AI-supported material development

Generative AI expands instructional resource development beyond traditional text-based formats. Teachers utilize AI platforms to engineer visual prompts, alternative conceptual explanations, narrative passages, differentiated question banks, audio scripts, and multimodal representations of core curricular concepts.

In primary education, this multimodal flexibility scaffolds diverse visual, auditory, and interactive learning modalities. However, the proliferation of varied formats does not inherently guarantee pedagogical quality. Every generated

resource requires rigorous teacher verification regarding factual accuracy, developmental appropriateness, accessibility, cognitive load, and curriculum alignment.

4.3. Differentiation and inclusion

Empirical evidence indicates that AI facilitates the adaptation of instructional materials to accommodate learners' prior knowledge, linguistic proficiency, cognitive pacing, personal interests, and scaffolding requirements. For example, Basaruddin and Mustafa[4] demonstrated these affordances in primary special education settings, while Kosmas et al.[16] highlighted the value of co-designing adaptable, age-appropriate literacy resources. Furthermore, Jiang et al.[15] reported evidence suggesting that AI can support differentiated instructional practices in primary classrooms. Nevertheless, differentiated instruction remains fundamentally a pedagogical, human-mediated process. While AI can generate multiple tiered iterations of instructional content, it cannot independently diagnose individual cognitive deficits or formulate optimal pedagogical interventions. Effective differentiation requires deep teacher knowledge of student profiles, curriculum requirements, subject-matter didactics, and real-time classroom dynamics.

4.4. Teacher competence and AI literacy

The reviewed literature uniformly establishes that teacher competence in educational AI is multidimensional. Educators require technical fluency, AI-specific content knowledge, pedagogical knowledge, critical evaluation capabilities, factual verification skills, and ethical judgment. [5] established that AI literacy extends well beyond basic tool operation, while Hava and Babayiğit [19] demonstrated the predictive relationship between general digital proficiency and AI-TPACK. Additionally, Yue et al. [20] and Yim and Wegerif [22] showed that teachers' readiness and technology acceptance are significantly moderated by domain knowledge, prior experience, and institutional support.

Based on these findings, the teacher competencies required for AI-supported instructional material design are operationalized through a sequential workflow:

1. Defining learning objectives;
2. Diagnosing learner needs;
3. Selecting appropriate AI tools;
4. Engineering targeted instructional prompts;
5. Generating initial drafts;
6. Verifying factual integrity and pedagogical alignment;
7. Contextualizing materials for target learners;
8. Implementing materials in classroom instruction;
9. Evaluating empirical learning outcomes;
10. Iteratively refining and adapting materials.

This iterative workflow unifies AI literacy, digital proficiency, pedagogical content knowledge, and reflective teaching practice.

4.5. Ethical and institutional conditions

Ethical considerations are prominent across the empirical literature. AI-generated outputs often contain hallucinations, factual inaccuracies, and age-inappropriate phrasing, necessitating that teachers treat raw outputs strictly as provisional drafts rather than finalized instructional content.

Data privacy and child safeguarding are paramount: educators must not input identifiable student records into public AI systems and must comply with institutional data governance protocols. Furthermore, copyright compliance, source attribution, algorithmic bias mitigation, and preventing cognitive over-reliance require proactive pedagogical vigilance. Institutional ecologies govern the long-term sustainability of AI integration. The synthesis highlights three decisive institutional factors:

- Digital infrastructure, robust broadband connectivity, and hardware access;
- Clear institutional AI policies and responsive technical support;

- Transformational leadership, dedicated budget allocation, and continuous professional development.
- Consequently, educational AI adoption must be approached as an institutional capacity-building initiative rather than an isolated teacher responsibility.

4.6. Integrated synthesis

Synthesizing the comparative evidence matrix reveals seven core dimensions governing AI utilization in primary instructional material design:

Table 2. Integrated synthesis matrix of AI utilization evidence in primary education

Core dimension	Synthesized evidence and pedagogical findings
Instructional material development	Scaffolds ideation, information structuring, lesson drafting, and multi-tier task design.
Teacher productivity	Reduces repetitive administrative preparation time and accelerates instructional resource generation.
Differentiated instruction	Facilitates the generation of tiered variants aligned with diverse proficiency levels and learning needs.
AI literacy	Demands critical competencies in prompt engineering, output evaluation, verification, and ethical reasoning.
AI-TPACK / TPACK	Requires the systematic integration of technological affordances, pedagogical strategies, and subject content knowledge.
Teacher professional oversight	Mandates human-in-the-loop verification, contextual calibration, classroom implementation, and iterative refinement.
Institutional readiness	Depends on broadband infrastructure, device availability, institutional governance, and sustained professional development.

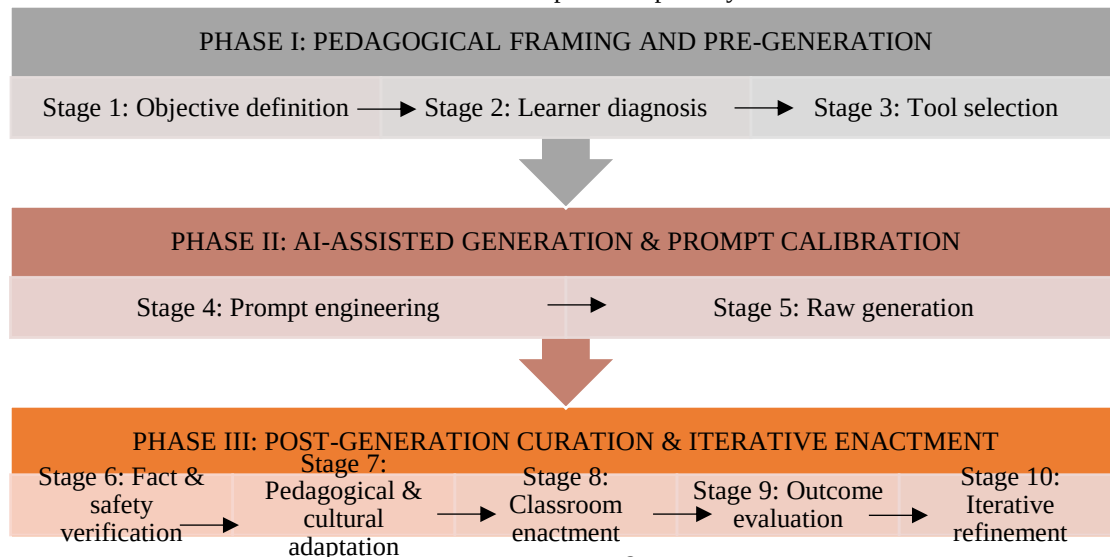
Source: Developed by the researcher

4.7. Proposed framework

Based on the thematic synthesis of international empirical evidence, this study proposes a teacher-centered, 10-stage conceptual framework for developing AI-supported teaching and learning materials in primary education. The framework re-anchors generative AI within the TPACK/AI-TPACK paradigm, establishing that AI functions strictly as an assistive drafting and ideation substrate, while human pedagogical judgment (Human-in-the-Loop) governs curriculum alignment, developmental calibration, factual verification, and classroom enactment.

The framework is structured into three sequential yet recursively linked phases: Phase I: Pedagogical framing & pre-generation, Phase II: AI-assisted generation & prompt calibration, and Phase III: Post-generation pedagogical curation & iterative enactment.

Figure 2. The three-phase, 10-stage teacher-centered framework for AI-supported instructional material development in primary education.



The proposed framework is conceptual and evidence-informed; it should not be interpreted as an empirically validated instructional intervention model.

4.7.1. Phase I: Pedagogical framing and pre-generation

This foundational phase ensures that technology deployment is driven by pedagogical intent and curriculum imperatives rather than tool availability.

Stage 1: Curricular and objective definition

- Teacher action: Defines precise, standards-aligned learning objectives, determines the required cognitive depth (e.g., Bloom's revised taxonomy for primary level), and outlines specific concept mastery indicators.
- AI functional role: None (*strictly human-led to prevent technology-driven curriculum drift*).

Stage 2: Learner profiling and needs diagnosis

- Teacher action: Analyzes the target classroom ecology, including learners' developmental stages, baseline reading proficiencies, prior knowledge, special educational needs (SEN), and necessary scaffolding tiers for differentiated instruction.
- AI Functional role: None (*preserves student data privacy by keeping individual diagnostic profiling firmly with the educator*).

Stage 3: Pedagogical modality and tool selection

- Teacher action: Selects the appropriate generative AI tool (textual LLM, visual generator, or multi-modal converter) based on the target material format (e.g., decodable reader, differentiated math worksheet, graphic organizer) and institutional compliance policies.
- AI functional role: Provides technical capabilities and processing modalities corresponding to the teacher's design intent.
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4.7.2. Phase II: AI-assisted generation and prompt calibration

In this operational phase, pedagogical intentions are translated into algorithmic instructions, and provisional material drafts are generated.

Stage 4: Goal-oriented prompt engineering

- Teacher action: Formulates multi-layered, pedagogically constrained prompts that explicitly incorporate target age, reading level, text complexity, and grade-appropriate language, vocabulary limits, structural formats, scaffolding instructions, and tone.
- AI functional role: Interprets input parameters, contextual prompts, and structural constraints.

Stage 5: Iterative raw output generation

- Teacher action: Evaluates the initial outputs in real-time and conducts multi-turn prompt adjustments (e.g., asking for alternative examples, simplifying sentence structures, or varying problem difficulty).
- AI functional role: Generates diverse textual variations, multi-tiered problem sets, visual prompts, narratives, or audio scripts based on calibrated prompts.
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4.7.3. Phase III: Post-generation pedagogical curation and iterative enactment

The final phase operationalizes the critical human-in-the-loop oversight required before, during, and after classroom delivery.

Stage 6: Factual integrity, ethics, and safety verification

- Teacher action: Rigorously audits raw outputs to detect algorithmic hallucinations, scientific or mathematical inaccuracies, algorithmic bias, copyright infringements, and inappropriate content.
- AI functional role: Acts as a provisional, unverified drafting substrate.

Stage 7: Pedagogical and cultural contextualization

- Teacher action: Adapts generated materials to local cultural context, school curriculum nuances, native language idioms, visual layout standards, and classroom-specific cognitive pacing.

- AI functional role: Can be optionally re-prompted to modify specific phrasing, formatting, or localized references under teacher guidance.

Stage 8: Classroom enactment and observation

- Teacher action: Deploys the curated materials within authentic primary classroom instruction and observes student cognitive engagement, task completion pacing, comprehension hurdles, and interaction dynamics.
- AI functional role: Passive (*instructional material deployed in physical or digital classroom environments*).

Stage 9: Empirical learning outcome evaluation

- Teacher action: Assesses formative student performance, analyzes assessment data, evaluates whether target differentiation was achieved, and identifies pedagogical gaps in the material.
- AI functional role: Can optionally assist in synthesizing aggregated, anonymized student response trends or rubric scoring criteria.

Stage 10: Iterative refinement and archive

- Teacher action: Modifies the instructional resource based on classroom data, logs prompt effectiveness for future reuse, updates the school's shared resource repository, and feeds reflections back into future lesson planning cycles (recursive feedback loop).
- AI functional role: Executes targeted revisions, reformulations, or layout adjustments based on empirical teacher feedback.

Table 3. Structural matrix of the 10-stage AI-supported material development framework

Phase	Stage	Primary teacher action (Pedagogical agency)	AI functional role (Algorithmic scaffolding)	Core AI-TPACK dimension
Phase I: Pedagogical framing	1. Objective definition	Formulate curriculum-aligned learning goals and cognitive benchmarks.	None (<i>Human agency only</i>)	Pedagogical content knowledge (PCK)
	2. Learner diagnosis	Profile cognitive pacing, reading levels, and differentiation needs.	None (<i>Data privacy preservation</i>)	Pedagogical knowledge (PK)
	3. Tool selection	Select compliant AI platforms suitable for target multi-modal formats.	System capability provider	Technological knowledge (TK)
Phase II: AI-assisted generation	4. Prompt engineering	Author constrained prompts with age, linguistic, and structural rules.	Parameter interpretation	Technological pedagogical knowledge (TPK)
	5. Raw generation	Execute multi-turn iterative prompting to produce candidate drafts.	Multi-tier generation content	Technological content knowledge (TCK)
	6. Fact & safety verification	Audit outputs for hallucinations, factual errors, bias, and ethics.	Provisional substrate drafting	Technological pedagogical content knowledge (TPACK)
Phase III: Post-generation curation	7. Contextual adaptation	Calibrate language register, cultural resonance, and visual layout.	Assistive re-formatting	Pedagogical content knowledge (PCK)
	8. Classroom enactment	Deliver materials and observe pupil engagement and comprehension.	Deployed artifact	Applied didactics / PK
	9. Outcome evaluation	Assess pupil learning gains and differentiation efficacy.	Optional anonymized analytics	Assessment literacy / PK
	10. Iterative refinement	Refine materials, archive effective prompts, and close feedback loop.	Re-prompted revision	Reflective practice / AI-TPACK

Source: Developed by the researcher.

5. DISCUSSION

5.1. Theoretical implications

The primary theoretical contribution of this review lies in moving beyond the descriptive assessment of teachers' AI literacy toward a process-oriented, pedagogical workflow model. While earlier scholarship largely conceptualized AI integration as a generalized technological competency (e.g., general AI literacy or passive tool adoption), our synthesis re-anchors AI within the Technological Pedagogical Content Knowledge (TPACK) framework. Specifically, the findings suggest that AI-supported material development is most meaningful when integrated into teachers' existing instructional design processes, particularly in planning, content generation, adaptation, and differentiation. By delineating the 10-stage framework, this study demonstrates that AI integration in primary education is fundamentally an epistemological and instructional design challenge rather than a mere technical operation. The framework bridges the theoretical gap between static AI-TPACK constructs and the dynamic, stage-by-stage cognitive judgments teachers make—ranging from objective alignment to prompt calibration and factual verification.

5.2. Practical implications

From a practical perspective, this review addresses the unique instructional constraints of primary classrooms. Unlike higher educational tiers where students engage with generative AI directly, primary education requires intensive teacher mediation. The synthesis underscores that primary instructional materials demand high linguistic simplicity, developmental appropriateness, and multi-modal scaffolding. The practical value of the proposed workflow is that it equips primary educators with a structured heuristic to mitigate key operational risks—such as algorithmic hallucinations, cultural biases, and cognitive over-complexity. Consequently, AI material generation shifts from trial-and-error prompting to a principled, quality-assured instructional design routine that directly supports differentiated learning in mixed-ability elementary classrooms.

5.3. Teacher education implications

These insights necessitate a paradigm shift in teacher professional development (PD) programs. Current PD initiatives often overemphasize technical prompt mechanics at the expense of pedagogical reasoning. Our findings suggest that teacher training should explicitly focus on:

1. Pedagogical prompt formulation: Training teachers to embed pedagogical constraints, developmental benchmarks, and differentiation criteria into AI prompts.
2. Critical verification competence: Developing robust content-auditing skills to detect factual errors, subtle misconceptions, and developmental misalignments in AI outputs.
3. Ethical and algorithmic literacy: Fostering awareness of algorithmic bias, student data privacy, and intellectual property considerations in primary education contexts.

5.4. Contextual implications

While AI tools offer marked efficiency gains in material design, their integration introduces non-trivial ethical and institutional dilemmas. The review highlights that educational inequities may widen if AI-supported workflows remain contingent on institutional access to premium tools or reliable digital infrastructure. Furthermore, without clear institutional governance, the risk of uncritical material adoption increases. Educational policymakers must therefore establish clear guidelines regarding content integrity, copyright boundaries, and ethical AI deployment in primary curricula.

5.5. Limitations and future research

Although the synthesized evidence strongly supports the conceptual feasibility of the proposed 10-stage model, empirical validation remains nascent. Most reviewed studies focused on initial material design and teacher perceptions, leaving classroom enactment and long-term student learning gains underexplored. Future empirical investigations

should employ longitudinal and quasi-experimental designs to evaluate how materials developed through this structured framework impact actual learner engagement and achievement across diverse primary school settings.

5.6. Cross-contextual critical analysis

The synthesized literature highlights contextual variations that caution against adopting a universal implementation model:

- Studies from Indonesia and Turkey: Focused predominantly on teacher perceptions, applied classroom practices, and professional development needs;
- Studies from China: Emphasized AI-TPACK readiness structures, environmental determinants, and systemic instructional transformations;
- Malaysian Special Education Research: Foregrounded accessibility, inclusion, and tailored scaffolding;
- Research from Cyprus: Highlighted age-appropriate design and collaborative co-design methodologies.

These variations confirm that the instructional value of AI is mediated by national curricula, student demographics, teacher competencies, digital infrastructure, and institutional policies. Effective integration relies not on finding a single universal AI tool, but on the teacher's adaptive mediating capacity within a specific educational ecosystem.

5.7. Implications for Non-English and developing educational contexts

While international findings provide critical insights, they cannot be transferred uncritically to non-English-speaking and developing educational settings. Primary education across diverse linguistic and developing contexts is characterized by distinct grammatical structures, culturally localized curricula, unique pedagogical traditions, and varying levels of digital infrastructure. Because prevailing generative AI models are predominantly trained on English corpora, deploying them in non-English primary classrooms necessitates heightened pedagogical vigilance regarding linguistic accuracy, cultural resonance, and curricular compliance. Consequently, the conceptual framework proposed in this review establishes an adaptable baseline to guide instructional design and future empirical inquiry across resource-constrained and multilingual educational ecosystems.

6. CONCLUSION

This international review synthesized emerging evidence on artificial intelligence-supported instructional material development by primary school teachers. The central finding indicates that while generative AI is frequently associated with increased efficiency in instructional material preparation and offers potential tools for targeted differentiation, its actual pedagogical value is strictly bounded by teacher agency, critical verification, and developmental contextualization.

Theoretically, this study extends the AI-TPACK construct from a static technological competency into an actionable, process-oriented workflow. Practically, it translates broad pedagogical principles into a structured three-phase, 10-stage conceptual framework tailored to the unique developmental and linguistic constraints of elementary classrooms. A primary methodological limitation of this review is its reliance on a relatively small, heterogeneous corpus of 14 studies, which reflects the nascent state of empirical inquiry regarding primary school teachers. Crucially, the proposed 10-stage framework is an evidence-informed conceptual model rather than an empirically validated instrument. Because existing empirical research largely captures teachers' perceptions, short-term implementation experiences, or self-reported usage rather than direct longitudinal measurements of student learning outcomes, claims regarding AI's direct impact on learning must be interpreted with caution. Future research should prioritize rigorous quasi-experimental and longitudinal investigations to empirically test, refine, and validate the framework's stages against measurable student progress and long-term teacher practice across diverse educational contexts.

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AUTHOR'S INTRODUCTION

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