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Ethnomathematics in the Age of Artificial Intelligence: Navigating Cultural Preservation and Technological Advancement

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ABSTRACT

This study maps and synthesises two adjacent bodies of literature—research on ethnomathematics and culturally responsive mathematics instruction focused on Akan cultural practices, and research on artificial intelligence (AI) in mathematics education—to propose a culturally responsive, AI-supported instructional framework for Ghanaian classrooms. A systematic scoping review was conducted following the PRISMA Extension for Scoping Reviews (PRISMA-ScR) and PRISMA 2020 flow conventions. Six databases were searched for records published between 2005 and 2025, supplemented by hand-searching. AI was operationalised broadly, from intelligent tutoring and adaptive learning systems to generative AI from late 2022 onwards. Of 612 records, 25 studies were retained for qualitative thematic synthesis. The synthesis indicates that kente weaving, Adinkra symbolism, market transactions, and drumming patterns encode mathematical ideas such as symmetry, proportion, sequence, and logical reasoning. The AI-focused studies, most of which predate generative AI, suggest that these tools can support personalised, interactive, and contextualised learning. No included study combines the two strands in the Akan context; this absence is a central finding and motivates the proposed framework. Blending ethnomathematics with AI is associated with greater cultural relevance, engagement, and conceptual clarity, although digitising Indigenous knowledge raises ethical questions of ownership, representation, and community consent.

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1. INTRODUCTION

Mathematics educators have long sought ways to provide realistic mathematics instruction for all learners [1]. This effort stems from a growing recognition of the importance of mathematics for society and from new insights into how mathematics is

taught and learned. One pedagogy gaining currency is ethnomathematics, the study of the relationship between culture and mathematics [2]. Ethnomathematics may also be understood as a form of mathematics practised within specific cultural groups; it aims to foster an appreciation of both culture and mathematics [3]. The term entered education around 1977 through the Brazilian educator and mathematician Ubiratan D'Ambrosio. As later elaborated, *ethno* refers to members of a cultural group identified by their traditions, codes, symbols, myths, and distinctive ways of reasoning; *mathema* means to explain and understand the world; and *tics* refers to processes such as counting, ordering, measuring, ciphering, categorising, inferring, and modelling [4], [5].

When ethnomathematics first emerged, it was a reaction to the conscious devaluing of mathematics produced by non-European civilisations [6]. During that era, many believed that mathematical understanding flowed solely from Western civilisation. Scholars in ethnomathematics hold that recognising the cultural context of mathematics, and teaching culturally relevant mathematics, is essential [7], [8]. For mathematics education to shape the political and social dynamics of culture, instruction must be founded on cultural relevance and on personal experiences that deepen learners' understanding of reality, culture, society, and themselves [4].

Artificial intelligence, whose conceptual foundations are commonly traced to Alan Turing's test of machine intelligence [9] and to John McCarthy's coining of the term at the Dartmouth workshop [10], has since developed into a family of educational technologies rather than a single tool. In education, AI encompasses computer-assisted instruction, intelligent tutoring systems, adaptive and personalised learning platforms, learning analytics, automated assessment, and—most recently—generative conversational systems [11], [12]. AI-driven platforms adapt to each learner's pace and style, automate assessment, deliver real-time feedback, and support collaborative environments, thereby improving engagement, motivation, and outcomes while relieving educators of routine administrative tasks [12].

The use of AI in education also raises ethical issues, including student autonomy, consent, and the prospect of AI displacing human teachers. It is therefore prudent to adapt the technology to learners' cultural backgrounds and to develop ethical guidelines that protect students' rights and support educators [13]. Globally, AI is transforming teaching and learning; in Africa, however, integration remains nascent. The continent faces limited technological infrastructure, a shortage of skilled educators, and socio-economic barriers to quality education [14]. Despite these constraints, pockets of innovation exist, such as mobile learning platforms and AI-driven tutoring [15]. Unreliable internet connectivity hampers tools that require continuous online access, and substantial investment in teacher training is needed [16].

In West Africa, disparities in access to quality education and technology persist. Ghana, Nigeria, and Senegal face inadequate infrastructure, limited digital literacy, and financial constraints [17]. In Nigeria, AI integration is hampered by inconsistent power supply and limited internet access; in Senegal, the high cost of technology and the need for localised content constrain deployment [18]. In Ghana, limited awareness and training

restrict AI use; most teachers in colleges of education have not been adequately trained in AI and digital tools, sustaining a reliance on traditional methods [19], [20].

Traditional, teacher-centred methods that prioritise rote learning over the critical thinking and problem-solving prescribed by the curriculum remain prevalent in Ghana [21]. At the same time, learners are increasingly exposed to technology and familiar with platforms such as WhatsApp, Facebook, and TikTok, and more recently with ChatGPT and similar tools, which they use and sometimes misuse. Because mathematics is a core subject at all pre-tertiary levels, it can serve as a medium for engaging young learners through the combined lens of culture and technology.

1.1. Research Problem and Gap

Although ethnomathematics and AI have each attracted considerable attention, the literature offers limited conceptual or empirical work on how Akan ethnomathematics specifically can be combined with AI-supported pedagogy in Ghanaian mathematics education. Existing ethnomathematics studies rarely incorporate intelligent technologies, while studies of AI in African education seldom engage Indigenous mathematical knowledge. Indeed, of the 25 studies retained in this review (Table 1), 12 address culture and mathematics pedagogy and 13 address AI or educational technology, but none combines the two strands in the Akan—or any Ghanaian—context. This review addresses that gap by systematically mapping and synthesising both bodies of literature and proposing an integrative framework.

1.2. Research Objectives and Questions

The study pursues three objectives: (i) to identify the mathematical knowledge embedded in selected Akan cultural practices—kente weaving, adinkra symbols, market transactions, and drumming patterns; (ii) to examine how AI tools can support and extend ethnomathematics-based instruction; and (iii) to propose a culturally responsive, AI-supported framework for enhancing conceptual understanding in Ghanaian mathematics classrooms. Accordingly, the review is guided by the following research questions:

- RQ1. What mathematical concepts are embedded in Akan ethnomathematical practices, according to the reviewed literature?
- RQ2. What forms of AI have been examined in mathematics education between 2005 and 2025, and how can such tools enhance the teaching and learning of ethnomathematics-based content?
- RQ3. What conceptual framework can integrate Akan ethnomathematics and AI to improve conceptual understanding in mathematics?

1.3. Significance of the Study

Theoretically, the study extends culturally responsive pedagogy and constructivism into the domain of AI-mediated mathematics learning. Practically, it offers teachers, teacher-training institutions, and EdTech developers a structured way to design culturally grounded, technology-enhanced lessons. For policy, it informs curriculum and AI-

integration decisions aimed at more inclusive and equitable mathematics education in Ghana and comparable contexts.

1.4. Scope and Rationale

Two deliberate scope decisions frame this review and should be stated at the outset. First, the cultural focus is confined to the Akan, the largest ethno-linguistic group in Ghana, whose weaving, symbolic, trading, and musical traditions are unusually well documented. The Akan case is treated as an instrumental case: the intention is not to claim that Akan practices are unique carriers of mathematics, but to develop, in depth for one well-documented culture, a mapping between cultural practice, curriculum, and technology that can subsequently be adapted to other Ghanaian and African cultural contexts. Depth in a single case was preferred over a shallow survey of many cultures, and the transferability of the resulting framework is examined in the Discussion.

Second, because virtually no published work sits at the direct intersection of Akan ethnomathematics and AI, the review necessarily synthesises two adjacent literatures—culturally grounded mathematics instruction on the one hand, and AI and intelligent technologies in mathematics education on the other—and reasons systematically across them. This mapping-and-integration purpose is characteristic of a scoping review rather than an effect-estimating systematic review; the study is therefore designed and reported as a systematic scoping review [22], while retaining the transparency devices of PRISMA 2020 for study identification and selection [23].

2. CONCEPTUAL FRAMEWORK

The study is underpinned by a conceptual framework that integrates Akan ethnomathematics, AI, and constructivist and culturally responsive pedagogies to enhance conceptual understanding. At its core, the framework recognises the mathematical richness embedded in Akan cultural practices—kente weaving, adinkra symbolism, market transactions, and drumming. These artefacts are not merely traditional expressions; they serve as concrete representations of abstract ideas such as symmetry, proportion, sequence, and logical reasoning, making mathematics more accessible and personally relevant.

Layered onto this cultural foundation is the amplifying potential of AI, which offers adaptive, interactive, and personalised support. Conversational agents can facilitate inquiry-based learning; pattern generators allow learners to simulate culturally relevant designs; virtual market simulators provide contextualised arithmetic practice; and adaptive platforms personalise instruction by identifying and addressing conceptual gaps. These technologies can transform static content into dynamic, learner-centred experiences.

The framework is anchored in Culturally Responsive Pedagogy (CRP) and Constructivist Learning Theory. CRP holds that learning is most effective when content reflects the learner's cultural identity and lived experience, while constructivism holds that learners construct meaning through active engagement and real-world application. Together they justify blending cultural content with AI-driven tools to create inclusive, meaningful, and engaging learning environments. These components are expected to produce enhanced conceptual understanding, deeper engagement, increased cultural

appreciation, and improved cognitive outcomes. Figure 1 captures this interaction, illustrating the flow from cultural input through AI mediation to learning outcomes within a culturally responsive and constructivist paradigm.

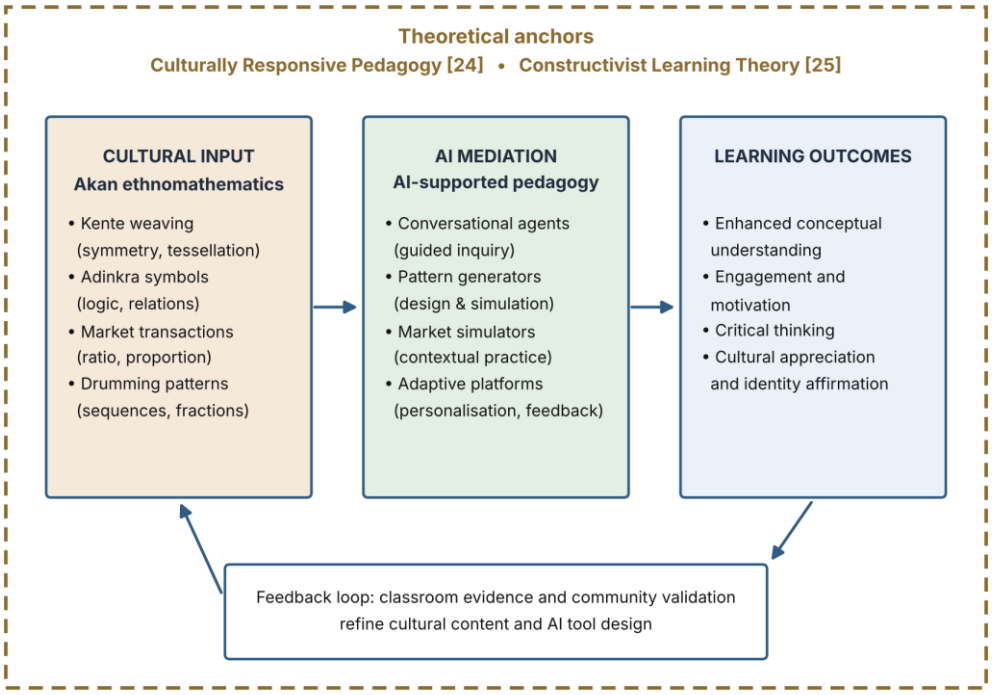


Figure 1. Conceptual framework of ethnomathematics–AI integration for conceptual understanding.

3. METHOD

This study employed a systematic scoping review to investigate the pedagogical potential of integrating Akan ethnomathematics and AI for enhancing conceptual understanding in mathematics. The review followed the PRISMA Extension for Scoping Reviews (PRISMA-ScR) [22] and adopted the PRISMA 2020 conventions for reporting study identification and selection [23] to ensure transparency and replicability. Because no human participants or field-based primary data were involved, the synthesis draws exclusively on previously published scholarship and reputable institutional reports. In direct response to the requirement that a review of this kind be reproducible, the complete corpus of included studies—with bibliographic details, source type, context, primary focus, design, and the contribution of each study to the research questions—is reported in full in Table 1.

3.1. Research Design

A qualitative, interpretive scoping review design was adopted to map and synthesise the interaction between traditional cultural knowledge systems and emerging educational technologies. A scoping design was chosen deliberately: the evidence base is heterogeneous, spans two literatures that rarely intersect, and is largely conceptual rather than experimental, so the appropriate synthesis goal is to map concepts, evidence types, and gaps rather than to estimate pooled effects. The design enabled the analysis of patterns,

connections, and educational possibilities within Akan ethnomathematics and their potential operationalisation through AI platforms. The study is non-empirical: it derives insights through structured literature synthesis and conceptual modelling rather than experimentation.

3.2. Review Protocol and Search Strategy

A review protocol was defined *a priori*, specifying the research questions, databases, search strings, and selection criteria. Six databases were searched for records published between 2005 and 2025: Scopus, Web of Science, ERIC, IEEE Xplore, ScienceDirect, and Google Scholar. The search combined three concept blocks using Boolean operators:

- ("ethnomathematics" OR "culturally responsive mathematics" OR "Indigenous mathematics" OR "Akan")
- AND ("artificial intelligence" OR "AI" OR "intelligent tutoring" OR "adaptive learning" OR "computer-assisted instruction" OR "learning analytics" OR "ChatGPT")
- AND ("mathematics education" OR "conceptual understanding" OR "teaching" OR "learning").

The two topical blocks were also run separately (each in combination with the mathematics-education block) so that studies addressing either strand in depth could be captured, given the near absence of studies addressing both. The database searches returned 610 records. Reference lists of key studies were additionally hand-searched; this citation searching contributed two seminal works that predate the search window but are foundational to the field [26], [27] and are flagged accordingly in Table 1.

3.3. Operational Definition of Artificial Intelligence and the 2005–2025 Window

Because widely accessible generative AI tools such as ChatGPT only became publicly available in late 2022, it is essential to be explicit about what "artificial intelligence" means in a review whose search window opens in 2005. In this review, AI was operationalised broadly, following the taxonomy of Zawacki-Richter *et al.* [12] and Holmes *et al.* [11], to encompass: (i) intelligent tutoring systems; (ii) adaptive and personalised learning platforms; (iii) profiling, prediction, and learning analytics; (iv) automated assessment and feedback systems; and (v) generative conversational AI, the most recent addition to the family. The year 2005 was selected as the lower bound because it marks the period in which research on intelligent tutoring and adaptive learning matured into a substantial empirical literature (e.g., [28]) and in which ethnomathematics consolidated as an international research programme [5], [8].

Accordingly, studies published between 2005 and 2022 met the technology-related inclusion criterion by examining these earlier, pre-generative forms of AI and intelligent educational technology—not generative chatbots, which did not yet exist. Studies published from late 2022 onwards could additionally address generative AI. Table 1 identifies the specific technological focus of each AI-related study so that readers can verify this stratification directly. Two consequences of this definition are acknowledged

openly: first, references in this review to conversational agents such as ChatGPT as candidate instructional tools are conceptual extrapolations from the evidence on earlier AI systems, not summaries of empirical trials of generative AI; second, no included study empirically evaluates generative AI in combination with ethnomathematics. Both points are revisited in the Limitations (Section 4.2.8).

3.4. Inclusion and Exclusion Criteria

Studies were included if they (i) addressed ethnomathematics or culturally grounded mathematics instruction, or the use of AI as defined in Section 3.3 (or closely allied digital educational technology) in mathematics education or in African education systems; (ii) were peer-reviewed journal articles, conference papers, scholarly books, or authoritative institutional reports; (iii) were published in English, in principle between 2005 and 2025; and (iv) provided conceptual, empirical, or methodological insight relevant to at least one research question. Seminal works published before 2005 that were identified through citation searching and are foundational to either strand were eligible for retention and are explicitly flagged in Table 1. Studies were excluded if they were off-topic or non-educational, lacked any link between culture and mathematics or between AI/technology and mathematics education, were not peer-reviewed (e.g., blog posts, opinion pieces, or preprints), or were unavailable in full text or in English. On this basis, one otherwise relevant candidate source [1] was excluded from the corpus because it is a preprint; it is cited in this manuscript only as background context.

3.5. Study Selection and PRISMA Flow

The selection proceeded in four phases—identification, screening, eligibility, and inclusion. Of the 610 database records identified, 70 duplicates were removed, leaving 540 records, to which 2 hand-searched records were added (542 in total). Title and abstract screening excluded 125 off-topic or non-educational records, yielding 417 records for full-text assessment. A further 392 records were excluded at the full-text stage because they lacked a substantive link between culture and/or AI and mathematics education, were not peer-reviewed, or were unavailable in full text or in English, leaving 25 studies that met all criteria and formed the corpus for qualitative synthesis. The selection process is depicted in the PRISMA flow diagram (Figure 2), and the complete corpus is itemised in Table 1. Screening at the title/abstract and full-text stages was performed by the researchers using the predefined criteria, with uncertain cases resolved by discussion; the screening log, including per-reason exclusion counts at the full-text stage, is available from the corresponding author on request.

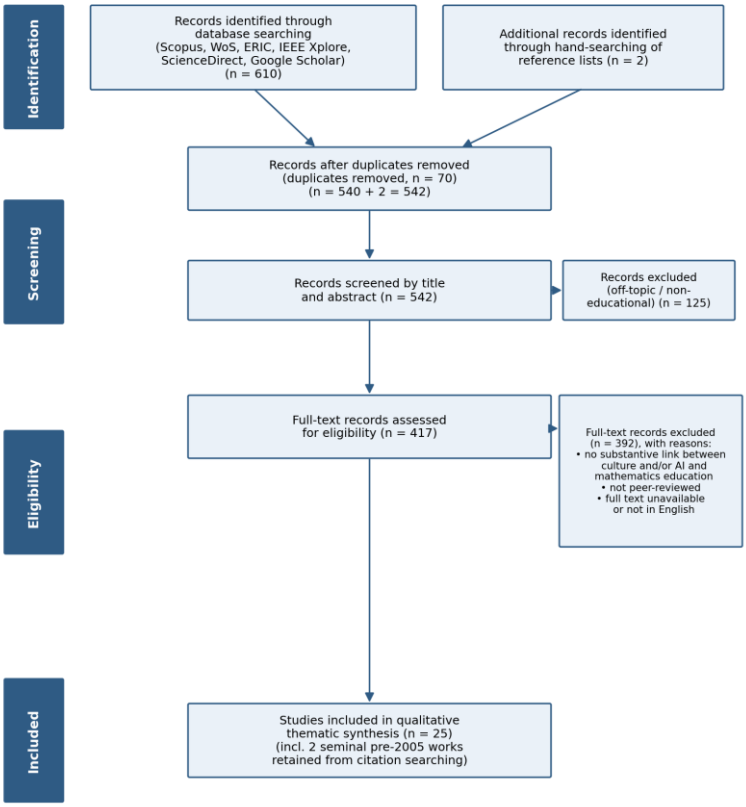


Figure 2. PRISMA 2020 flow diagram of the study selection process.

3.6. Data Extraction and Thematic Analysis

Data were extracted from the 25 included studies using a structured extraction sheet capturing bibliographic details, source type, study aim, context, methodology, cultural or technological focus, and key findings; the resulting study-characteristics matrix is reported as Table 1. The corpus was analysed using Braun and Clarke's six-phase thematic analysis [29]: familiarisation with the data; generation of initial codes; searching for themes; reviewing themes; defining and naming themes; and reporting. Coding was conducted independently by the researchers and then reconciled through discussion to enhance dependability; disagreements were resolved by consensus, and a coding audit trail was maintained. Three major analytical domains emerged from this process: (i) cultural mathematical knowledge (ethnomathematics); (ii) AI technologies in education; and (iii) conceptual learning and cognitive engagement. These domains were triangulated to identify intersections where AI could amplify ethnomathematical instruction.

3.7. Theoretical Framework

Two theories underpinned the analysis and were applied analytically rather than merely descriptively, serving as lenses for coding and interpreting the corpus.

Culturally Responsive Pedagogy (CRP). CRP emphasises aligning content, methods, and interactions with learners' cultural identities and experiences [24]. In coding, CRP was used to flag instances where cultural practices (e.g., Indigenous counting systems, symbolic reasoning, or trade-based calculation) were positioned as legitimate mathematical knowledge. CRP frames Akan ethnomathematical concepts as a basis for curricula that are both academically rigorous and culturally affirming, challenging Eurocentric paradigms.

Constructivist Learning Theory. Constructivism posits that learners actively build knowledge through interaction with their environment [25]. It was used analytically to identify how ethnomathematical contexts (e.g., symmetry in kente or proportion in market transactions) and AI tools could create experiential, inquiry-driven learning. Together, CRP and constructivism provided the interpretive scaffold for synthesising findings into the proposed framework.

3.8. Technological Tools Considered

Several AI tools and platforms were examined conceptually for their educational relevance, including conversational agents (e.g., ChatGPT) for inquiry and problem-solving; adaptive learning systems (e.g., DreamBox, Squirrel AI) for personalised instruction; and simulation tools for cultural pattern exploration (e.g., kente-weaving simulators and symmetry applications). Consistent with Section 3.3, the evidence base for adaptive and tutoring systems is drawn from the pre-generative AI literature, whereas conversational agents are treated as conceptual candidates. None of these tools was tested with students in this review; empirical evaluation is reserved for the pilot study proposed in Appendix A.

3.9. Contextual Focus and Cultural Mapping

The Akan ethnic group was selected for the reasons set out in Section 1.4. Four ethnomathematical elements were mapped onto core competencies in Ghana's Common Core Programme (Basic Education) curriculum: kente weaving (geometric patterns and symmetry), adinkra symbols (logical relationships and symbolism), traditional markets (arithmetic and proportion), and drumming patterns (sequences and time intervals). The explicit mapping of each practice to curriculum strands and candidate AI tools is presented in the Results (Table 3).

3.10. Ethical Considerations

Although no empirical data were collected, the review acknowledges the ethical implications of AI in education and of digitising Indigenous knowledge, including student data privacy and digital-footprint management, cultural sensitivity in AI content development, the question of who owns and validates cultural datasets, and the preservation of the integrity and authenticity of Indigenous knowledge systems. Future empirical research based on this framework would require ethical clearance from the Ghana Education Service and the relevant Institutional Review Boards.

4. RESULTS AND DISCUSSION

4.1. Results

4.1.1. Characteristics of the Included Studies

This section presents the findings of the systematic synthesis of the 25 included studies. To make the review process fully transparent and reproducible, Table 1 itemises every study in the corpus, giving its bibliographic identity, source type, context, primary focus, design or method, and its specific contribution to the research questions. Two seminal works identified through citation searching and published before 2005 are marked with an asterisk (see Section 3.4).

Table 1. Characteristics of the 25 studies included in the review.

No.	Author(s) (year)	Source type	Context	Primary focus	Design / method	Contribution to review (RQ)
1	D'Ambrosio (1985)* [26]	Journal article	Global	Ethnomathematics as a field; culture–mathematics link	Conceptual / position paper	Foundational definition of ethnomathematics (RQ1)
2	Ladson-Billings (1995)* [27]	Journal article	United States	Culturally relevant pedagogy	Theoretical article	Grounds culturally responsive framing (RQ1, RQ3)
3	Rosa & Orey (2007) [5]	Journal article	Global	Ethnomathematics as a research field	Conceptual review	Culture–mathematics linkage (RQ1)
4	VanLehn (2011) [28]	Journal article	Global	Intelligent tutoring systems (pre-generative AI)	Comparative review of tutoring effectiveness	Evidence on AI tutoring effectiveness (RQ2)
5	Chahine (2013) [6]	Journal article	Non-Western contexts	Ethnomathematics of non-Western civilisations	Conceptual analysis	Decolonial rationale for ethnomathematics (RQ1)
6	Boaler (2016) [30]	Book	United States / global	Mathematical mindsets; conceptual teaching	Research-based synthesis	Conceptual-understanding outcomes (RQ3)
7	Civil (2016) [31]	Conference paper	United States	Home–school mathematical practices	Empirical synthesis	Cultural funds of knowledge (RQ1)
8	Rosa *et al.* (2016) [8]	Book	Global	Ethnomathematics as a programme	Edited research volume	State of the field (RQ1)
9	Williamson (2016) [13]	Journal article	Global	Promise and peril of educational AI	Critical conceptual analysis	Ethics of AI in education (RQ2)
10	Popenici & Kerr (2017) [32]	Journal article	Higher education	AI impact on teaching and learning (pre-generative AI)	Exploratory review	AI affordances and risks (RQ2)
11	Asare *et al.* (2019) [21]	Journal article	Ghana	Traditional teacher-centred pedagogy	Descriptive overview	Problem context in Ghana (RQ1, RQ3)
12	Holmes *et al.* (2019) [11]	Book	Global	AI in education: promises and implications	Research synthesis	Taxonomy of AI tools (RQ2)
13	Zawacki-Richter *et al.* (2019) [12]	Journal article	Higher education	AI applications: profiling, assessment, adaptive systems, ITS	Systematic review	Typology of pre-generative AI applications (RQ2)
14	Ajayi *et al.* (2020) [17]	Journal article	West Africa	AI integration: challenges and prospects	Analytical / policy paper	Regional implementation constraints (RQ2)

No.	Author(s) (year)	Source type	Context	Primary focus	Design / method	Contribution to review (RQ)
15	Mhlanga & Moloi (2020) [15]	Journal article	South Africa / Africa	COVID-19 digital transformation of education	Case analysis	Digital readiness and innovation (RQ2)
16	Rosa (2020) [7]	Journal article	Global	Ethnomathematics and curriculum development	Conceptual paper	Curriculum contextualisation (RQ1, RQ3)
17	World Bank (2020) [14]	Institutional report	Global / Africa	Digital technologies in education	Policy report	Infrastructure evidence (RQ2)
18	Albanese (2021) [2]	Journal article	Global	Ethnomathematics and cultural relevance	Conceptual paper	Contemporary relevance of ethnomathematics (RQ1)
19	Dzandu & Dadzie (2021) [20]	Journal article	Ghana	Digital pedagogy and AI in teacher education	Contextual study	Teacher readiness in Ghana (RQ2)
20	Meaney *et al.* (2021) [3]	Journal article	Indigenous contexts (Aotearoa NZ)	Indigenous mathematics education	Empirical synthesis	Indigenous knowledge in instruction (RQ1)
21	Nwankwo *et al.* (2021) [18]	Journal article	West Africa	AI and education reform	Analytical paper	Localisation needs for AI content (RQ2)
22	Ouyang & Jiao (2021) [33]	Journal article	Global	Paradigms of AI in education	Conceptual review	Learner-centred AI paradigm (RQ2, RQ3)
23	Tambo *et al.* (2021) [16]	Journal article	Africa	Teacher preparation for AI	Policy analysis	Professional-development requirements (RQ2)
24	Amankwah-Amoah (2022) [19]	Journal article	Ghana	Technology integration in education	Analytical paper	Adoption barriers in Ghana (RQ2)
25	Atta & Bonyah (2023b) [4]	Journal article	Ghana (Akan)	Mathematics teaching for social justice; Akan cultural practices	Qualitative empirical study	Akan cultural practices in mathematics teaching (RQ1, RQ3)

*Note. * Seminal work published before the 2005 search window, identified through hand-searching of reference lists and retained as a foundational source (Section 3.4). ITS = intelligent tutoring systems; RQ = research question.*

Corpus profile. Of the 25 studies, 2 predate 2005 (retained seminal works), 3 were published between 2005 and 2015, 18 between 2016 and 2021, and 2 between 2022 and 2025. Twelve studies address culture, ethnomathematics, or culturally responsive mathematics pedagogy, and 13 address AI, educational technology, or the African implementation context. Consistent with the operational definition in Section 3.3, every AI-focused study published before late 2022 concerns pre-generative forms of AI—intelligent tutoring systems, adaptive and personalised learning, learning analytics, and automated assessment—or the enabling digital infrastructure; none of the included studies empirically evaluates generative AI, and none combines AI with ethnomathematics in the Akan context. The findings are organised around three domains derived from the thematic analysis: Akan ethnomathematical practices, AI integration in education, and conceptual understanding in mathematics. To maintain the appropriate epistemic status of a literature-based study, the synthesis uses formulations such as “the literature indicates” and “the analysis suggests” rather than implying primary empirical results.

4.1.2. Akan Ethnomathematical Practices as Foundations for Instruction

The analysis indicates that Akan cultural practices encode a range of mathematical concepts reported across the reviewed studies [3], [4], [26]:

- **Kente weaving patterns** exemplify symmetry, reflection, tessellation, and geometric sequences.
- **Adinkra symbols** exhibit bilateral and radial symmetry and convey abstract logical structures that align with set theory and algebraic thinking.
- **Market transactions** offer intuitive pathways for teaching arithmetic, unit pricing, ratios, and proportions.
- **Drumming patterns** can be deconstructed into sequences and time intervals, useful for teaching fractions and series.

The literature suggests that the cultural familiarity of these elements creates a cognitive bridge, supporting learners' internalisation of mathematical concepts by situating them within familiar frameworks [27], [31].

4.1.3. Relevance and Potential of AI Tools in Ethnomathematics-Based Instruction

Across the corpus, AI tools emerge as promising means of supporting and expanding cultural mathematics instruction [11], [12], [32]. The strongest empirical support concerns pre-generative systems: comparative evidence indicates that intelligent tutoring systems can approach the effectiveness of human tutoring [28], and systematic mapping shows adaptive learning, profiling, and automated assessment to be the most studied applications [12]. Building on this base, four tool families are relevant to ethnomathematics-based instruction:

- **Conversational AI assistants** facilitate exploratory dialogue, allowing learners to ask questions about symbols, values, or computational processes; as generative tools, these are conceptual candidates whose classroom effectiveness remains to be tested (Section 3.3).
- **Pattern-generator applications** help simulate symmetrical and repeating patterns that can be customised to reflect traditional kente layouts.
- **AI simulations of market scenarios** enable learners to manipulate data in culturally familiar trade settings, developing arithmetic fluency and economic reasoning.
- **Adaptive quizzing platforms** personalise learning by identifying conceptual gaps and adjusting difficulty to suit each learner, the application family with the most established evidence base.

The analysis suggests that, when paired with ethnomathematical content, these tools do not merely replicate rote processes but can stimulate inquiry, visualisation, and conceptual abstraction [28], [32].

4.1.4. Conceptual Understanding through Dual Anchoring (Culture and AI)

The dual-anchoring strategy—cultural relevance combined with technological interactivity—emerges from the literature as a promising pedagogical model. Reported

potential benefits include the following, which the reviewed studies associate with culturally grounded and AI-supported instruction [27], [30], [33]:

- **Enhanced conceptual understanding.** Learners appear better able to grasp abstract ideas when these are tied to real-life and cultural experiences.
- **Improved engagement and motivation.** Culturally relevant tasks and interactive tools are reported to increase interest, especially among underperforming groups.
- **Development of critical thinking.** Ethnomathematical tasks often require logical reasoning, pattern recognition, and synthesis, which AI-facilitated inquiry can further encourage.
- **Reduction of cognitive disconnection.** Learners may no longer perceive mathematics as foreign or detached from their lives, which the literature links to improved retention.

4.1.5. Summary Table of Domains, Tools, and Implications

Table 2. Illustrative summary of domains, observed features, and educational implications.

Domain	Observed feature / tool	Educational implication
Akan ethnomathematics	Kente, adinkra, markets, drums	Concrete representation of abstract concepts (symmetry, proportion, sequence)
AI educational tools	Conversational agents, pattern simulators, market simulations, adaptive quizzes	Scalable, personalised, interactive instruction
Cognitive and affective impact	Improved understanding, engagement, cultural pride	Enhances motivation; bridges theory and lived experience

4.1.6. Mapping Akan Practices to Curriculum Topics and AI Tools

In response to the need for an explicit linkage between cultural practice, curriculum, and technology, Table 3 maps each Akan ethnomathematical practice onto specific strands of Ghana's Basic Education mathematics curriculum and identifies candidate AI tools for instruction. This matrix operationalises the framework and provides teachers with a concrete starting point for lesson design.

Table 3. Mapping of Akan ethnomathematical practices to curriculum topics and candidate AI tools.

Akan practice	Embedded mathematics	Curriculum strand (Basic Education)	Candidate AI tool
Kente weaving	Symmetry, reflection, tessellation, geometric sequences	Geometry and measurement; patterns and relations	Pattern-generator / symmetry apps (e.g., GeoGebra)
Adinkra symbols	Bilateral/radial symmetry, logic, set relations	Geometry; algebra (reasoning with sets and relations)	Conversational AI for symbol–concept inquiry
Market transactions	Arithmetic, unit pricing, ratio, proportion, percentage	Number; proportional reasoning	AI market simulators; adaptive practice
Drumming patterns	Sequences, intervals, fractions, series	Number; patterns and relations	Rhythm/sequence generators; adaptive quizzing

Collectively, these results support the integration of culturally embedded mathematics and AI-driven pedagogy to promote inclusive, relevant, and effective learning, particularly in Ghanaian junior high schools, while underscoring that the evidence base remains predominantly conceptual and warrants empirical testing.

4.2. Discussion

This review set out to map and synthesise the literature on integrating Akan ethnomathematics with AI and to propose a culturally responsive, AI-supported framework. The findings affirm that Akan culture is rich in embedded mathematical knowledge and that AI tools can plausibly amplify its pedagogical value. The following discussion interprets these findings, links them explicitly to theory, compares them with existing studies, and addresses ethical and practical considerations raised in the literature.

4.2.1. Cultural Context as a Foundation for Mathematical Cognition

Learners frequently encounter abstract mathematics in isolation, which hinders understanding. The synthesis suggests that contextualising learning through familiar cultural practices—weaving, trading, and symbolic representation—facilitates meaningful connections. Understanding symmetry through kente or proportion through market transactions renders learning more intuitive and relatable, consistent with broader evidence that contextualised instruction supports transfer [27], [31].

4.2.2. Artificial Intelligence as a Cultural Mediator

A central theoretical contribution of this study is the conceptualisation of AI as a cultural mediator. Rather than delivering decontextualised content, AI can personalise, simulate, and visualise mathematical problems derived from cultural contexts. AI-driven kente-pattern platforms can help learners explore geometry through real-time manipulation of shapes and transformations, while conversational agents can generate adaptive assessments anchored in adinkra symbols. When embedded with curated cultural datasets, such systems act as bridges between tradition and innovation [12], [32]. This mediating role positions AI not as a replacement for cultural knowledge but as an amplifier of it. It bears repeating that, for generative conversational agents specifically, this mediating role is a design proposition grounded in evidence on earlier AI systems (Section 3.3), not yet a demonstrated classroom result.

4.2.3. Operationalising the Theoretical Framework

The proposed model operationalises Culturally Responsive Pedagogy by treating Akan cultural artefacts as legitimate mathematical content rather than mere illustration, thereby validating learners' identities and challenging Eurocentric framings [24]. It operationalises constructivism by using AI tools to create inquiry-driven, experiential tasks—designing kente symmetries, simulating market exchanges—in which learners actively construct meaning and engage in dialogue and collaboration [25]. AI supports constructivist learning specifically by providing adaptive scaffolding, immediate feedback, and opportunities for iterative exploration that a single teacher cannot offer at scale. The

two theories are thus complementary: CRP determines what content is meaningful, while constructivism determines how learners engage with it.

4.2.4. Comparison with Existing Studies

The proposed model both extends and contrasts with prior work. Earlier ethnomathematics studies in Ghana and elsewhere demonstrate the cultural and cognitive value of Indigenous mathematics but generally stop short of integrating digital technologies [3], [4], [26]. Conversely, studies of AI in African education emphasise personalisation and access but rarely engage Indigenous knowledge [12], [14], [15]. By explicitly coupling Akan ethnomathematics with AI mediation, this review advances an integrative position that neither literature has fully articulated. Where some technology-in-education studies caution that AI may flatten local context, the present framework deliberately centres cultural authenticity as a design constraint, aligning with calls for decolonised and locally relevant EdTech [17], [18].

4.2.5. Ethical Considerations in Digitising Indigenous Knowledge

Digitising Indigenous knowledge raises questions that extend beyond conventional data privacy. The literature highlights issues of ownership—who holds the rights to cultural datasets derived from kente or adinkra—and of representation, since AI systems trained on incomplete or decontextualised samples risk misrepresenting Akan symbols and their meanings. Community participation is therefore essential: cultural custodians and educators should be involved in curating, validating, and approving content, and benefit-sharing arrangements should be considered so that communities are partners rather than passive data sources [13]. Embedding these safeguards is a precondition for ethical implementation, not an afterthought.

4.2.6. The Risk of Cultural Simplification

A further caution concerns cultural simplification. Kente, adinkra, markets, and drumming are living cultural practices with deep historical and symbolic meaning; they are not merely teaching aids. Reducing them to convenient vehicles for mathematical content risks stripping away the very significance that makes them powerful for learners. The framework therefore advocates teaching the cultural meaning alongside the mathematics, so that learners appreciate, for example, both the symmetry and the symbolism of an adinkra sign. Maintaining this dual fidelity—mathematical and cultural—guards against tokenism.

4.2.7. Practical Classroom Challenges

Implementation faces concrete barriers. Many Ghanaian schools, particularly in rural areas, have limited or unreliable internet access and few devices, constraining tools that require continuous connectivity [14], [16]. Teacher readiness is uneven, with gaps in both ethnomathematical methods and AI literacy [19], [20]. Language is a further consideration, since AI tools predominantly operate in English while many learners are more comfortable in local languages. The cost of AI subscriptions and devices may also be

prohibitive. These realities point to the need for offline-capable tools, sustained teacher professional development, localised and multilingual content, and phased, low-cost pilots.

4.2.8. Limitations of the Study

Several limitations should be acknowledged. First, the review is conceptual and literature-based; its conclusions are propositions to be tested, not empirical outcomes. Second, the corpus is modest in size (25 studies) and heterogeneous in design, which is why a scoping approach—mapping concepts, evidence types, and gaps—was adopted rather than an effect-estimating synthesis; the corpus is fully itemised in Table 1 so that readers can audit its composition. Third, and directly related to the temporal scope of the review, no included study empirically evaluates generative AI, and none tests any form of AI in combination with ethnomathematics: the AI evidence in the corpus concerns intelligent tutoring, adaptive learning, and related pre-generative systems, so all statements in this review about conversational agents such as ChatGPT are conceptual extrapolations (Sections 3.3 and 4.1.1). Fourth, the restriction to English-language, peer-reviewed sources may have excluded relevant work published in other languages or in grey literature, introducing potential selection bias. Fifth, the rapidly evolving nature of AI means that some tools cited may be superseded. Finally, the focus on Akan culture, while purposeful (Section 1.4), limits direct generalisation to other cultural contexts, though the framework is designed to be transferable.

4.2.9. Suggestions for Future Research

Future work should empirically test the framework through classroom interventions that measure conceptual understanding, engagement, and retention, ideally using quasi-experimental or design-based research. Studies should evaluate specific AI tools—including, now that they are widely available, generative conversational agents—with learners, assess scalability in large classes, examine multilingual and offline implementations, and develop community-governed protocols for curating cultural datasets. Comparative studies across different Ghanaian ethnic groups and other African contexts would further test transferability.

5. CONCLUSION

This study systematically mapped and synthesised the literature on integrating Akan ethnomathematics with artificial intelligence to enhance conceptual understanding in mathematics education. The synthesis of 25 studies—itemised in full in Table 1—indicates that Akan cultural practices—kente weaving, adinkra symbolism, market transactions, and drumming—encode mathematical knowledge that is accessible and meaningful to learners, and that AI tools, on the evidence of the pre-generative AI literature, can plausibly transform this knowledge into interactive, personalised learning experiences. The study's principal contributions are a transparent map of two literatures that have hitherto developed in isolation, a culturally responsive, AI-supported framework for mathematics learning in Ghana, and an explicit mapping of cultural practices to curriculum strands and candidate technologies.

Because the evidence base is conceptual, these findings are best understood as well-grounded propositions rather than demonstrated outcomes; the framework awaits empirical validation, an agenda partly specified in the appendices. The aspiration of a more decolonised, learner-centred mathematics curriculum is supported by the reviewed literature but must be pursued with attention to the ethical governance of Indigenous knowledge and to the practical realities of Ghanaian classrooms—infrastructure, teacher readiness, language, and cost. Pursued responsibly, the blending of tradition and technology offers a credible pathway toward more inclusive, relevant, and effective mathematics education in Ghana and beyond.

Several recommendations follow directly from the framework and synthesis. Educational policymakers should incorporate ethnomathematics into national curricula, developing culturally responsive content that reflects Ghanaian ethnic mathematical practices and is linked to existing curriculum strands as in Table 3, and should support AI-integration policies through guidelines and funding for AI tools designed with local cultural relevance and offline capability in mind. Teacher-training institutions should introduce modules on ethnomathematics and AI pedagogy grounded in CRP and constructivism, and provide continuous professional development on using conversational AI, adaptive platforms, and mobile simulations in culturally meaningful ways. EdTech developers and AI researchers should develop localised, community-validated AI content in collaboration with cultural custodians and educators, with explicit data-governance arrangements, and build frameworks that address data privacy, accurate cultural representation, and the preservation of Indigenous knowledge. Finally, schools and educational institutions should pilot ethno-AI learning labs in which the framework can be implemented and evaluated, and promote culturally grounded STEM clubs that combine cultural knowledge with AI experimentation and mathematics.

APPENDICES

Appendix A. Proposed Pilot Study Framework

To empirically validate the conceptual findings of this review, the following pilot research design is proposed to test the effectiveness of combining Akan ethnomathematical practices with AI-driven instruction. The pilot would provide preliminary data on learning outcomes, engagement, and cognitive development among junior high school students in Ghana.

Table A1. Proposed pilot study design

Component	Details
Title	Evaluating the impact of ethnomathematics–AI integration on conceptual understanding in junior high mathematics in Ghana
Objective	To empirically assess the effect of integrating Akan ethnomathematics with AI tools on students' conceptual understanding
Design	Quasi-experimental design with a pre-test–post-test control group
Sample	60 junior high school students (30 control, 30 experimental) from the Sunyani Municipality
Intervention	Experimental group receives AI-based, culturally contextualised instruction; control group receives traditional instruction

Component	Details
Data-collection tools	Conceptual Understanding Test; Student Engagement Survey; Teacher Observation Checklist
Data analysis	Paired-samples t-test for pre–post comparisons; descriptive statistics for engagement
Duration	6–8 weeks of instruction
Ethical approval	To be obtained from the Ghana Education Service and the relevant Institutional Review Board

Appendix B. Sample Lesson Plan: Symmetry through Kente Cloth Patterns

Topic: Exploring symmetry through kente cloth patterns. **Level:** Junior High School (JHS 2). **Duration:** 80 minutes (double period).

Objectives:

- Identify types of symmetry (reflectional and rotational) in kente cloth patterns.
- Create symmetrical designs using AI pattern-generation tools.
- Explain the cultural significance of kente designs and relate it to mathematical concepts.

Materials: projector or interactive whiteboard; an AI symmetry tool or kente-pattern simulator (e.g., GeoGebra); printed images of traditional kente patterns; graph paper, rulers, and coloured pencils.

Activities:

- **Introduction (10 min).** Show kente images and discuss their cultural significance and where learners have seen them.
- **Concept development (15 min).** Introduce vertical, horizontal, and rotational symmetry; analyse lines of symmetry in printed and digital kente.
- **Guided practice with AI (25 min).** Learners design symmetrical patterns using an AI tool, exploring rotational and reflectional symmetry.
- **Group reflection (10 min).** Groups present their patterns and relate them to cultural designs.
- **Assessment (20 min).** A short worksheet on symmetry types followed by peer assessment using a rubric.

Assessment tools: observation checklist; symmetry-identification worksheet; student-created pattern rubric (symmetry accuracy, creativity, cultural alignment).

Appendix C. Sample Assessment Instrument: Conceptual Understanding Test

Title: Post-Instruction Assessment – Ethnomathematics and Symmetry. **Level:** JHS 2. **Duration:** 30 minutes. **Instructions:** Answer all questions; show all working where necessary.

Section A: Multiple Choice (1 mark each).

- What type of symmetry is most often found in traditional kente patterns? (A) Translational (B) Reflectional (C) Circular (D) None
- An adinkra symbol is flipped over a vertical axis. What type of symmetry is this? (A) Rotational (B) Reflectional (C) Translational (D) None of the above

Section B: Short Answer (4 marks each).

- Explain how a market transaction in your community can be used to teach ratios.

- Draw a simple symmetrical pattern and show its lines of symmetry.

Section C: Application (8 marks).

- Design a mini market price list with three items. Create two word problems involving proportion or percentage using this list, and solve them.

Appendix D. Sample Lesson Plan: Proportion through Akan Market Practices

Topic: Understanding ratios and proportions through market scenarios. **Level:** JHS 2. **Duration:** 70 minutes.

Objectives:

- Define and calculate ratios and proportions.
- Apply ratios to solve real-life problems using Akan market settings.
- Use an AI chatbot to simulate market transactions and problem-solving.

Materials: a chart of common market items and prices (e.g., plantain, gari, tomatoes); smartphones or tablets with AI chatbot access; market-transaction worksheets; calculators and pencils.

Activities:

- **Warm-up discussion (10 min).** Learners describe recent market trips and how pricing, measurement, and comparison feature in shopping.
- **Concept development (15 min).** Introduce ratios and proportions; demonstrate converting price quantities (e.g., 2 cups of rice for ¢10 → 1 cup for ¢5).
- **AI chat simulation (20 min).** Groups use AI to simulate buying and selling in a virtual market, with the AI providing price-based proportion tasks.
- **Hands-on application (15 min).** Learners calculate best buys and fair prices using real and AI-generated pricing scenarios.
- **Review and reflection (10 min).** Groups share a solved problem and relate it to real-life shopping and mathematics.

Assessment tools: worksheet graded on correctness and reasoning; group observation notes; exit slip ("One thing I learned about using mathematics in the market").

Appendix E. Rubric: Student-Created Ethnomathematics Projects

Table E1. Rubric for student-created ethnomathematics projects

Criteria	Excellent (4)	Good (3)	Fair (2)	Needs improvement (1)
Mathematical accuracy	Concepts clearly applied; calculations correct	Mostly accurate; minor errors	Several errors, but an attempt is made	Misunderstood concepts or incorrect application
Creativity and originality	Highly creative; integrates culture uniquely	Shows creativity and cultural relevance	Culturally inspired but lacks creativity	Limited effort or little cultural connection
Use of AI tools	Effectively used AI to enhance design and problem-solving	Used AI adequately with minimal guidance	Attempted to use AI with limited effect	AI not used or misused
Presentation and explanation	Clear, confident explanation of work and its mathematical basis	Good explanation with minor gaps	Limited clarity; basic explanation	Struggled to explain; unclear

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