



Pedagogical Fragmentation and Elementary Teachers' Perceived Readiness to Integrate AI into Ethnomathematics-Based Project Learning

Novia Frisda Eldiana*, Subanji, Ponimin, Aynin Mashfufah, Eddy Sutadji, Mardhatillah

Universitas Negeri Malang, Indonesia

*Corresponding author: novia.frisda.2521039@students.um.ac.id

Abstract

Elementary mathematics teachers are encouraged to combine artificial intelligence (AI), project-based learning, and culturally grounded instruction, yet how they negotiate these demands in everyday classrooms remains insufficiently understood. This study aims to examine teachers' perceived readiness and pedagogical challenges in integrating AI with ethnomathematics-based project learning in two elementary schools in Tulungagung, Indonesia. The study employed a preliminary qualitative descriptive case study involving four fifth-grade teachers, supplemented by questionnaire responses from 62 pupils. Data was collected through two weeks of classroom observations, semi-structured teacher interviews, and a nine-item pupil questionnaire. Interview and observation data were analyzed through iterative coding guided by the Miles–Huberman framework, while questionnaire responses were summarized descriptively. The findings revealed pedagogical fragmentation: project activities, digital applications, and cultural examples were generally implemented separately rather than integrated into mathematical inquiry. Teachers described difficulties coordinating AI-related guidance, project design, local cultural resources, and curricular expectations. Among pupils, 80% reported boredom in mathematics, 90% favored interactive digital challenges, and 75% expressed interest in local culture. These accounts do not establish measured AI competence, cognitive overload, or causal effects on pupil experiences. The study contributes context-specific evidence distinguishing technological access from pedagogical readiness, with implications for collaborative lesson design, responsible AI literacy, and culturally grounded mathematics instruction.

ARTICLE HISTORY

Received:

19 May 2026

Accepted:

10 September 2026

Published:

30 September 2026

KEYWORDS

Artificial intelligence;
Ethnomathematics;
Project-based
learning; Teacher
readiness;
Pedagogical
fragmentation



1. Introduction

The rapid development of artificial intelligence (AI) is creating new possibilities for elementary mathematics education, including the design and delivery of project-based learning (PjBL), but its classroom use also raises questions about teacher readiness (Batubara et al., 2025; Rachmadtullah et al.,



2024). Educational institutions are increasingly expected to equip students with digital literacy, creativity, and problem-solving skills while ensuring that technology supports meaningful mathematical learning. In Indonesia, these expectations intersect with the need to preserve local wisdom through ethnomathematics, which connects mathematical ideas with cultural practices (D'Ambrosio, 1985). Consequently, teachers face the challenge of coordinating digital tools, collaborative projects, and culturally meaningful content rather than treating them as separate activities. AI literacy and pedagogical judgment are particularly important because understanding a technology does not automatically imply the ability to use it creatively and responsibly in teaching (Rogers & Carbonaro, 2025; Sperling et al., 2024; Yim & Su, 2025).

The urgency of this issue is highlighted by preliminary needs-analysis data gathered from Public Elementary School 1 TS and Integrated Islamic Elementary School NF in Tulungagung Regency, Indonesia. Initial observations indicated that although PjBL had been implemented to encourage student collaboration, it often operated separately from the ethnocultural exploration that could provide meaningful contexts for mathematical concepts. Questionnaire responses from 62 fifth-grade students indicated that 80% reported feeling bored during mathematics lessons, while 55% disagreed with a positively worded item about wanting to express answers that differed from their peers'. At the same time, 90% expressed interest in interactive digital challenges, and 75% showed interest in activities involving local culture. These contrasting responses indicate a gap between students' reported preferences and observed learning practices, although they do not establish their causes. They also raise questions about pedagogical readiness beyond the availability of digital devices and applications (Batubara et al., 2025).

To understand this phenomenon, the study draws on Vygotsky's (1978) social constructivism and Sweller's (2011) cognitive load theory as complementary conceptual perspectives. Vygotsky emphasizes social interaction, mediation, and cultural resources in knowledge construction, providing a foundation for connecting ethnomathematics with collaborative PjBL. Within this perspective, AI may serve as a mediating tool when its instructional use is appropriately guided by teachers. However, simultaneously designing PjBL activities, selecting suitable AI tools, and incorporating local cultural practices into mathematical tasks may create competing demands on teachers' attention and planning. Cognitive load theory offers one perspective for interpreting these demands, particularly when unfamiliar instructional elements must be coordinated. In this study, teachers' cognitive load was not directly measured; the theory is used to interpret perceived workload and instructional difficulties rather than to establish psychometrically measured cognitive overload.

Recent studies have examined culturally situated learning and digital technologies in mathematics education. Apriandi et al. (2023) investigated STEAM learning integrated with cultural contexts, while Basri et al. (2026) developed digital ethnomathematics teaching materials. Syarifuddin et al. (2025) examined ethnomathematics-based PjBL supported by GeoGebra; in another approach, Noviyana et al. (2025) investigated AI-assisted problem-based learning (PBL) among elementary pupils. These approaches are related but distinct: GeoGebra-supported instruction is not necessarily AI-based, and PBL is not interchangeable with PjBL. Reviews of AI in mathematics education likewise emphasize distinctions among AI technologies, their instructional roles, and teachers' contributions (Schindler et al., 2026; Yoon & Kwon, 2024). Meanwhile, teachers' perspectives on AI reveal a recurring gap between favorable attitudes and practical competence in using AI pedagogically (Ayanwale et al., 2022; Rachmadtullah et al., 2024). These findings motivate an analysis of the conditions for integration rather than another general claim about technological benefits.

These differences in instructional aims matter for how research findings are transferred to elementary classrooms. Studies that teach children the concepts of AI may assess pupils' technical knowledge, while studies that use AI to teach mathematics must also evaluate the accuracy of mathematical explanations, developmental appropriateness, and the quality of teacher-mediated feedback. Reviews of K–12 AI learning-task design have identified resource and task-design challenges, but do not themselves establish that AI improves culturally contextualized mathematics projects (Li et al., 2024; Liu & Zhong, 2024). Likewise, research on generative AI in K–12 settings emphasizes teacher preparation and implementation safeguards rather than prescribing a single technology for every learning objective (Marzano, 2026). This distinction helps position the present study as an examination of instructional integration and teacher judgment rather than a test of pupils' AI competence.

However, a more specific question remains concerning how elementary teachers negotiate the overlapping demands of project design, AI-related instructional support, and the mathematical interpretation of local culture. Prior research addresses student outcomes, particular technology-supported approaches, or general teacher perceptions (Barus et al., 2025; Noviyana et al., 2025; Syarifuddin et al., 2025). International reviews likewise identify persistent gaps in teacher preparation and the design of effective learning tasks, but many examine teaching AI as curriculum content rather than using AI to mediate elementary mathematics instruction (Li et al., 2024; Liu & Zhong, 2024; Tan et al., 2025). Closer attention is therefore needed to teachers' decisions when these pedagogical elements remain disconnected in everyday instruction. Comparing experiences in public and private elementary school contexts may clarify the perceived demands involved without claiming that such challenges are universal.

This preliminary study addressed that gap by examining teachers' readiness and pedagogical dilemmas in relation to integrating AI into ethnomathematics-based PjBL. It involved four fifth-grade teachers and 62 students from two elementary schools in Tulungagung Regency, with student questionnaire responses providing contextual evidence alongside teacher interviews and classroom observations. The study asked: (1) How do elementary school teachers perceive their readiness and pedagogical challenges in integrating AI into ethnomathematics-based PjBL? (2) How do teachers describe the cognitive and pedagogical demands of balancing digital innovation, project design, and local cultural content in mathematics classrooms? It contributes context-specific evidence about pedagogical fragmentation and professional support needs rather than an evaluation of an implemented AI–PjBL intervention.

2. Methods

This study employed a qualitative descriptive case study design, supported by basic quantitative data. This design was selected because the core objective was to explore teachers' experiences, pedagogical challenges, and perceived instructional demands in natural classroom settings. At the same time, student questionnaires provided descriptive context regarding pupils' learning experiences and preferences. The approach allowed comparison of teacher interviews with classroom practices and student responses (Creswell & Poth, 2018). The questionnaire data were not intended to establish causal relationships or directly measure teachers' cognitive load.

Participants were selected using purposive sampling. School inclusion criteria required implementation of the independent curriculum (Kurikulum Merdeka) and variation in institutional type and technological infrastructure. Two schools in Tulungagung Regency, East Java, were selected: Public Elementary School 1 TS and Integrated Islamic Elementary School NF. Four teachers currently teaching fifth-grade mathematics and transitioning to digital or project-based learning participated, with teaching experience ranging from five to over 15 years. Sixty-two fifth-grade students (aged 10–11 years) taught by these teachers also participated in observations and the questionnaire. The sample was chosen for contextual contrast, not statistical representativeness.

Field data were collected using three main instruments aligned with the research objectives. First, a nine-item four-point Likert-scale questionnaire captured pupils' self-reported boredom, preferences for PjBL, interest in interactive digital activities and local culture, and willingness to express alternative answers. Before use, it underwent expert judgment review for readability among fifth-graders. Second, a semi-structured teacher interview protocol was used to examine perceived instructional demands. Informed by cognitive load theory (Sweller, 2011), its domains were technical demands in

operating AI tools, pedagogical design demands in structuring PjBL, cultural integration demands, and administrative demands. These domains organized teachers' accounts and did not constitute psychometric measures of cognitive load. Third, a participant observation guide and infrastructure checklist supported comparison of interview accounts with actual classroom activities and available resources.

The four-point questionnaire and the interview protocol provided different kinds of evidence. Questionnaire item percentages described pupils' agreement or disagreement with specific statements; they were not intended to diagnose motivation, creativity, or achievement. Interview domains, by contrast, encouraged teachers to describe practical situations in which technological, pedagogical, cultural, and administrative demands competed. The study was therefore organized around complementary descriptive evidence rather than a statistical test linking pupil perceptions with teacher readiness. This distinction is important because the respondent groups differed: the pupils provided survey responses, whereas four teachers described their professional experiences. No individual-level statistical matching between pupils and teachers was reported. The results should consequently be read as converging contextual observations, not as estimates of association or mediating effects.

Data collection comprised two consecutive weeks of direct classroom observations, followed by student questionnaires and in-depth audio-recorded teacher interviews. Student responses were summarized using frequencies and percentages in Microsoft Excel 365. Agreement percentages for positively worded interest items were distinguished from disagreement responses to the positively worded alternative-answer item. Therefore, the 55% reported for that item indicates disagreement with wanting to give a different answer, not a validated measure of creative confidence. Interview transcripts and field notes were interpreted using the interactive data condensation, data display, and conclusion-drawing framework of Miles et al. (2014), with assistance from computer-aided qualitative analysis software. Questionnaire findings provided descriptive context; interviews and observations supplied the primary evidence of teachers' pedagogical experiences.

Data condensation was organized into three reported coding cycles. Open coding identified meaning units from interview transcripts and field notes, producing 45 initial codes. Axial coding grouped them into three categories: technical and infrastructure anxiety, cultural integration disorientation, and curricular overload. Selective coding synthesized these categories into the interpretive theme Pedagogical Dilemmas and Educators' Cognitive Overload. A summary of interview findings and preliminary interpretations was returned to all four teachers for member checking, and cross-school comparisons were made between observations at SDN 1 Ts and SDIT NF. The theme reflects reported

and observed difficulties; without a validated cognitive-load scale, it cannot be treated as a clinical or psychometric finding.

The original study reports research permission from relevant education authorities in Tulungagung Regency and written informed consent from teachers and the parents or guardians of participating children. Names were replaced with alphanumeric codes (G1–G4 for teachers and S-codes for pupils) in transcription and reporting. Whether age-appropriate child assent was additionally obtained remains to be confirmed with the authors before submission. Similarly, the expert review documentation, software name, and original questionnaire response frequencies should be made available for methodological verification.

3. Results

3.1 Students' Perceptions of Mathematics Learning and Instructional Preferences

Responses from 62 fifth graders suggested contrasting patterns between current mathematics experiences and preferred classroom activities. 80% agreed that they often felt bored when studying mathematics. Fifty-five percent disagreed with a positively worded statement about wanting to offer answers different from their friends (Item 8). The latter response indicates reluctance to offer alternative answers, rather than a direct measure of creativity or confidence. 90% were interested in technology-supported interactive challenges, 80% preferred opportunities to create tasks or projects in their own way, and 75% expressed interest in local culture. Seventy-five percent also preferred doing projects rather than memorization. These perceptions alone cannot demonstrate that existing teaching practices caused boredom or reluctance.

Table 1.

Summary of Percentage of Student Perceptions and Needs Based on the Questionnaire

No	Statement	STS	TS	S	SS
1	The class lessons today were very enjoyable.	10	25	45	20
2	I often feel bored while studying mathematics.	5	15	50	30
3	I prefer learning by doing projects rather than memorization.	5	20	50	25
4	I like it when lessons use technology that provides interactive challenges.	0	10	55	35
5	I am interested in learning about the culture or local wisdom of my area.	5	20	50	25
6	I am accustomed to using applications or technology on smartphones and laptops.	0	5	40	55
7	I feel that teachers often give me opportunities to try out new ideas.	10	40	35	15
8	I would like to give a different answer from my friends.	15	40	30	15
9	I like being able to create assignments and projects in my own way.	5	15	55	25

Note. STS = strongly disagree; TS = disagree; S = agree; SS = strongly agree.

3.2 Observed Fragmentation of Project-Based, Digital, and Cultural Learning Activities

Interviews and cross-school observations indicated pedagogical fragmentation in both settings. Here, fragmentation means that PjBL, digital applications, and local cultural resources existed in school activities but were seldom coordinated into a coherent mathematics task. At Public Elementary School 1 Ts, pupils periodically produced models of geometric solids, whereas cultural content was more often addressed through Pancasila Student Profile Strengthening Project (P5) events. Digital applications such as Kahoot! and Quizizz were mainly used for short end-of-lesson quizzes. Thus, modeling, digital evaluation, and cultural exploration were present but generally separated.

At Integrated Islamic Elementary School NF, project activities were more thematic and collaborative. Cultural content was introduced through thematic work and occasional field trips, while digital technology was primarily available in the computer laboratory. Although the school had a more established infrastructure arrangement, AI-supported mathematical inquiry was not consistently integrated into the observed cultural projects. These are school-specific observations, not evidence that all public and private schools display the same pattern. The observation matrix retains the original five analytical aspects.

Table 2.

Observation matrix for PjBL, technology, and ethnocultural integration

Observed aspect	Indicator	Public Elementary School 1 Ts	Integrated Islamic Elementary School NF
PjBL implementation	Authentic projects and student collaboration	Stand-alone modeling activities; collaboration remained highly teacher-guided.	Thematic projects with collaboration; limited integration of digital and cultural resources.
Technology and scaffolding	Use of digital tools within core mathematics tasks	Digital tools mainly supported end-of-lesson quizzes.	Digital facilities were available but not consistently used in core mathematical inquiry.
Ethnocultural integration	Mathematical analysis of local culture	Culture was addressed primarily through P5 rather than through regular mathematics projects.	Culture was reflected in thematic activities and occasional field trips.
Opportunities for creativity	Divergent thinking and pupil autonomy	Some opportunities to explore ideas, constrained by prescribed product formats.	Creative projects occurred, but independence was limited in routine activities.
Instructional design needs	Coordinating project, culture, and digital support	Teachers reported difficulty connecting all three elements.	Teachers requested more structured guidance for integrated instruction.

Source: Authors' observation matrix; wording clarified to distinguish observed practices from teachers' reported difficulties.

The school comparison also shows why fragmentation should not be confused with technological deprivation. The public school made use of pupils' devices and short digital assessments, while the private school offered access to a computer laboratory and more thematic project work. Neither observed configuration consistently connected local artifacts with sustained digital mathematical inquiry. These differences matter because a single recommendation to purchase more devices would not address the instructional design problem identified in both settings. At the same time, the evidence does not justify describing the two institutions as representative of public and private schools more generally. Their usefulness lies in the contrast between two practical arrangements that encountered a comparable coordination challenge during the limited observation window.

The observation matrix is also useful for separating an observed activity from an inferred need. For example, the use of Kahoot! or Quizizz at the end of a lesson is directly observable. In contrast, the claim that a teacher needs additional support for AI scaffolding depends on the interview account. Similarly, noting that pupils completed a geometry model does not establish whether they developed conceptual understanding. The matrix should therefore be interpreted as a record of instructional organization rather than an assessment of pedagogical effectiveness. This distinction preserves the empirical value of Table 2 without converting descriptions of classroom routines into unsupported evaluations of teachers or students.

Across the two contexts, the recurring issue was not simply the presence of equipment but how digital tools, mathematical content, project work, and cultural materials were combined. However, two cases and a two-week observation period cannot establish the prevalence of this pattern beyond these schools.

3.3 Digital Infrastructure Availability and Teachers' Pedagogical Readiness

Infrastructure observations identified contrasting arrangements. Public Elementary School 1 Ts (SDN 1 Ts) used a Bring Your Own Device (BYOD) policy with mobile Internet, whereas SDIT NF had a computer laboratory and Wi-Fi access; both had projectors. Teachers were familiar with digital presentations and quiz applications. However, interviews indicated difficulties designing mathematics activities in which AI could act as guided instructional support within ethnomathematics-based PjBL. This infrastructure–pedagogy paradox concerns a difference between device use and integrated instructional design, not a formal competence score.

Figure 1 reproduces the original ordinal ratings for technology and teacher skill, from 0 (not available) to 2 (good). Projectors, electricity, and student devices

were rated 2; Internet, laboratory/device provision, and teacher skill were rated 1. Because the figure provides a combined set of component ratings rather than school-specific scores, it cannot independently verify comparative AI readiness or prove adequate hardware for sustained AI integration.

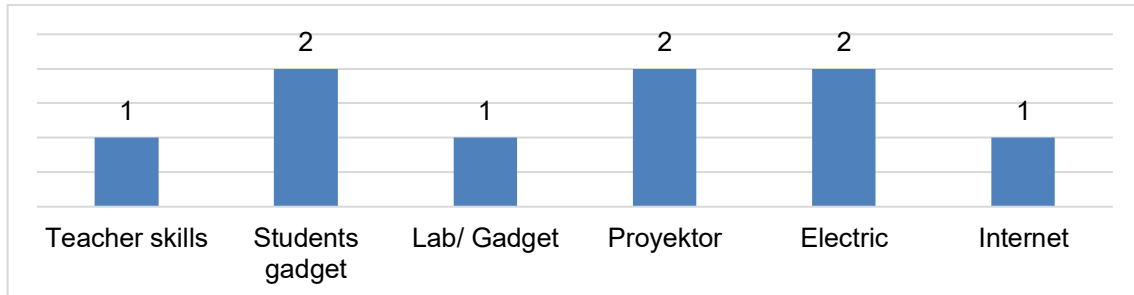


Fig. 1. Bar Chart of Technology Infrastructure Readiness and Teacher Competence

3.4 Teachers' Reported Challenges in Integrating AI, Projects, and Local Culture

Interviews with G1–G4 contextualized the observations. Their accounts suggest that the challenge was not simply resistance to new technology; it also involved planning mathematics projects, deciding how digital tools should support thinking, and managing curricular expectations. G1, a senior public-school teacher with more than 15 years' experience, described the following difficulty:

"I understand that AI is great and that kids love their phones. However, I wasted my time just trying to figure out how the app worked, not to mention racking my brain trying to find the connection between the volume formula for geometric shapes and the roof shape of the Tulungagung Pendopo. In the end, because I was afraid of not completing the material, I kept the project simple, as long as they submitted their work." (Interview Transcript G1, April 2026).

G1 described simplifying a mathematical project because coordinating a digital tool, cultural content, and curriculum completion seemed difficult. The account illustrates perceived instructional demands, not a measured working-memory limitation. Teachers also mentioned administrative constraints associated with conventional curricular reporting.

"The problem is not the Wi-Fi. The problem is that when I ask my children to come up with project ideas using an AI chatbot, they are confused about what to type (prompting). Because I myself have never received training in using AI for learning assistance, I struggle to provide the right scaffolding for them. In the end, AI is only used to find instant answers, not to develop ideas." (Interview Transcript G3, April 2026).

G3's account suggests that available Wi-Fi did not ensure effective prompting or project scaffolding. It also indicates that AI use had been attempted in at least one activity, while sustained integration was not established in the observations. In both schools, digital tools often served presentation or evaluation functions, and regional artifacts were more often illustrated than investigated

mathematically. The coding framework grouped the teacher accounts into technical and infrastructure anxiety, cultural integration disorientation, and curricular overload. These interpretive themes do not establish clinically significant cognitive overload or demonstrate a cause of pupil boredom. The original-language interviews and evidence from G2 and G4 should be checked before finalizing the cross-case claims.

4. Discussion

The questionnaire results should also be interpreted in light of item wording. Agreement with a preference for interactive technology does not necessarily indicate dissatisfaction with every existing activity. Likewise, disagreement with the wish to offer a different answer may reflect classroom norms or task-specific uncertainty, rather than a stable personality characteristic. The lack of respondent-level frequencies and validated scales prevents stronger psychometric interpretations. Nevertheless, taken alongside observed reliance on summative quizzes and teacher-guided projects, these responses help identify a practical problem worth investigating: how to create learning opportunities in which pupils can explore different mathematical ideas, receive meaningful feedback, and relate their work to local knowledge. The value of this triangulation is diagnostic, not causal.

4.1 Competing Pedagogical Demands Behind Instructional Simplification

The principal instructional paradox is that students reported strong interest in digital activities (90%) and local culture (75%), yet 80% reported boredom in mathematics. These descriptive responses do not identify the causes of boredom. Observations instead show a parallel pattern: PjBL, digital quizzes, and cultural examples were generally implemented separately. This occurred in both schools despite their different facility arrangements. The finding is therefore best interpreted as limited coordination of instruction in these particular contexts, rather than the complete absence of innovation or evidence of widespread pedagogical disruption.

Sweller's (2011) cognitive load theory offers an interpretive lens for the demands teachers described when managing project design, unfamiliar AI applications, cultural relevance, and curriculum time. G1's account suggests that technical uncertainty and difficulty connecting a local roof structure to geometry contributed to a simpler project plan. However, the study collected no validated cognitive-load measures or direct working-memory evidence. Therefore, the categories capture perceived instructional demands rather than causal mechanisms or clinical states. A more defensible implication is that reducing unnecessary complexity in lesson planning and offering usable exemplars may

support teachers' planning; the effectiveness of these measures remains untested in this study.

Prior research helps specify what teacher readiness requires. Rachmadtullah et al. (2024) and Batubara et al. (2025) documented teachers' positive attitudes toward AI alongside practical challenges. Celik (2023) emphasized technological-pedagogical and ethical knowledge, whereas Sperling et al. (2024) identified limitations in the preparation of teachers' practical and ethical AI literacy. Ayanwale et al. (2022), studying teachers' intentions to teach AI as a subject in Nigeria, likewise linked readiness to relevant beliefs, although teaching ABOUT AI differs from using AI in elementary mathematics. The present cases illustrate the additional task of coordinating AI with mathematical representations, projects, and cultural context. This interpretation extends beyond a binary distinction between having devices and not having them, without assuming generalizable effects.

The distinction between technological and pedagogical competence is more than a question of training length. A teacher may be comfortable operating an application but still needs support deciding whether a generated example is accurate, whether a prompt reveals pupil information, or whether an explanation is appropriate for ten- and eleven-year-olds. Sperling et al. (2024) argue for a broader conception of teacher AI literacy that includes practical and ethical professional knowledge; Celik (2023) similarly treats the integration of AI as a technological-pedagogical undertaking. In the present cases, this distinction is visible in teachers' comfort with presentation and quiz tools alongside uncertainty about AI-assisted reasoning tasks. Professional learning should therefore make instructional judgment observable through examples and collaborative analysis, rather than relying only on self-reported digital confidence.

4.2 The Need for Teacher-Guided Scaffolding in AI-Assisted Mathematical Learning

Within Vygotsky's (1978) social constructivism, AI may be considered a potential form of mediated support for students' reasoning. The expression virtual More Knowledgeable Other (MKO) is used as a design analogy, not as proof that AI can replace a teacher's social and cultural mediation. The empirical starting points are specific: 55% of pupils disagreed that they wanted to offer answers different from their friends', and G3 reported difficulties in guiding prompts for a chatbot. Neither observation establishes that AI scaffolding would solve the reluctance to participate. Instead, the accounts call for more explicit guidance in how pupils ask questions, examine suggestions, and justify their mathematical choices.

One possible design would use AI to pose graduated questions rather than supply immediate final answers, such as asking pupils to identify geometrical features of a local building, compare measurements, justify a calculation, and

verify its contextual plausibility. Zhang et al. (2024), reviewing pedagogical agents for K–12 learners, found that design features and pedagogical roles require attention to their actual educational value. Li et al. (2024), reviewing the design of tasks for teaching AI in K–12 contexts, also emphasized learning-task quality and resources. However, that literature focuses on AI as subject content rather than AI as a mathematics assistant. These studies strengthen the rationale for designing and evaluating scaffolds, not for claiming that such an approach worked in either observed school.

Noviyana et al. (2025) investigated AI-assisted problem-based learning in elementary mathematics, whereas this study concerns the possible integration of AI with project-based learning and ethnomathematics. The distinction matters. Reviews of AI in mathematics education note that educational functions vary from adaptive infrastructure to learning partnership and that teacher involvement remains important (Schindler et al., 2026; Yoon & Kwon, 2024). Kasneci et al. (2023) outlined opportunities and risks of large language models, while Wang et al. (2024) identified response errors, dependency, and privacy risks alongside interactivity and personalization. Therefore, AI may introduce new responsibilities for teachers, including verifying mathematical accuracy, moderating content, and protecting children's data. This study did not test whether any AI approach reduced teacher effort, so the reduced workload should remain a hypothesis for future research.

For elementary learners, the quality of scaffolding must also be evaluated against the mathematical and social purposes of the activity. An AI system might generate an apparently persuasive explanation of symmetry, but pupils still need opportunities to examine the actual pattern, test the proposed transformation, and explain their reasoning. The K–12 pedagogical-agent literature suggests that educational value depends on how a tool's role and design fit learner characteristics rather than on its apparent sophistication (Zhang et al., 2024). In the present context, the teacher would remain responsible for checking the cultural artifact, the mathematics, and the pupils' understanding. This caution is especially important when transferring claims from studies of general chatbots or AI instruction to a new, untested ethnomathematics project.

4.3 Mathematical Inquiry as the Foundation of Meaningful Ethnomathematics Integration

The second substantive challenge concerns transforming local artifacts into mathematical investigations. D'Ambrosio's (1985) ethnomathematics perspective suggests that cultural practices offer resources for mathematical thinking, but presenting an artifact visually is not itself sufficient. G1 referred to the roof of a Tulungagung pendopo as a potential geometry context but found it difficult to design a task around it. Similarly, Turonggo Yakso batik from Trenggalek offers a regional context for studying patterns and symmetry, though its cultural origin

should not be conflated with that of Tulungagung architectural heritage (Eldiana et al., 2023, 2025).

Prior studies provide useful but limited comparisons. Apriandi et al. (2023) explored culturally integrated STEAM learning; Basri et al. (2026) developed Madurese ethnomathematics-based digital materials; and Pratama and Afriani (2026) synthesized the effects of ethnomathematics-based learning on mathematical representation. Syarifuddin et al. (2025) examined PjBL using GeoGebra, a mathematics software environment that should not be automatically classified as an AI system. Kyeremeh et al. (2025) reported obstacles in integrating ethnomathematical perspectives into geometry teaching among mathematics teacher educators in Ghana. The different contexts and study designs prevent direct equivalence, but they reinforce the distinction between the mathematical interpretation of culture and mere illustration.

Pedagogical reflection could therefore involve checking whether a cultural artifact supports a valid grade-appropriate question, deciding if a digital tool genuinely improves reasoning, and reviewing representations generated by AI for mathematical and cultural inaccuracies. A recent meta-review distinguishes different AI technologies and roles in mathematics education (Schindler et al., 2026), supporting careful terminology. Digitalization of a resource, GeoGebra visualization, AI-generated explanation, and adaptive tutoring should be differentiated in both teacher training and research claims. This precision makes a stronger contribution than treating technological novelty as pedagogical success.

The local-cultural dimension also calls for careful content selection. Batik Turonggo Yakso and a Tulungagung pendopo should not be presented as interchangeable objects merely because both can support geometry instruction. Their distinct origins and meanings matter when creating explanatory prompts and project briefs. Teachers could invite pupils to identify recurring geometrical features of an authentic artifact, explain the limits of a simplified model, and compare mathematical properties without claiming that an AI-generated description accurately represents the original cultural practice. The earlier regional studies by Eldiana et al. (2023, 2025) offer starting points for content selection, not ready-made evidence that an AI intervention will succeed. This is why cultural review, local consultation, and mathematical verification belong within instructional design rather than being relegated to decoration.

4.4 Integrated Lesson Design as a Foundation for Teacher Readiness Beyond Technical Skills

Theoretically, the study shifts attention from device availability and student enthusiasm toward teachers' work of coordinating objectives, project stages, digital tools, and culturally meaningful mathematical content. In instructional design terms (Branch, 2009), these components require alignment rather than a

sequence of disconnected activities. This case-based contribution is contextual and interpretive: it does not establish teacher cognitive capacity as a measured causal determinant. Using student questionnaire data, observations, and interviews together clarifies why basic technological familiarity may coexist with uncertainty about integrated mathematics teaching.

Recent international evidence helps identify focused professional development priorities. Tan et al. (2025), reviewing AI in teaching and teacher professional development, found an imbalance between studies on classroom AI applications and those addressing professional learning. Marzano (2026), reviewing generative AI at the K–12 level, similarly noted a need for teacher preparation and practical guidance. Rogers and Carbonaro (2025) distinguished between understanding AI and using it fluently and creatively. These sources justify a shift from isolated application tutorials to guided co-design of culturally grounded tasks, transparent prompting practices, assessment of AI outputs, and reflection on student autonomy. Because they are reviews or conceptual comparisons rather than tests in the participating schools, the proposed sequence is an agenda for design, not an evaluated intervention.

A practical professional-development sequence might begin with choosing a local artifact, identifying mathematically defensible features, constructing a project question, deciding whether a digital representation or AI scaffold adds value, and then planning student explanations, verification, and safeguards. Teachers could jointly evaluate AI responses for accuracy, cultural appropriateness, and child privacy. The broader literature reports both opportunities and risks of generative AI for engagement and learning. Deng et al. (2025), in a meta-analysis of ChatGPT experiments across education, found improvements in several learning outcomes. However, those aggregated effects should not be transferred directly to Grade V ethnomathematics PjBL. The proposed pedagogical approach needs development and direct evaluation before claims about effectiveness or reduced workload can be justified.

At the school level, the results suggest that hardware provision may need to be accompanied by collaborative planning time, examples of verified mathematical tasks, and guidance for responsible AI use. Further research could compare public and private contexts with greater case diversity and examine whether structured planning actually changes teacher decisions and pupil inquiry. Professional support should recognize both the mathematical integrity of local cultural representation and the developmental needs of primary-school pupils.

For policymakers, this analysis suggests a narrower and more testable account of readiness than either enthusiasm for technology or a generic digital-skills checklist. Readiness may require teachers to plan a mathematically coherent project, choose culturally appropriate sources, use AI only where it adds instructional value, and recognize when generated guidance should be corrected

or withheld. Institutional support might include shared planning time, curated cultural resources, and opportunities to evaluate example lessons together. Tan et al. (2025) identified a relative shortage of research on teacher development compared with AI classroom applications; that imbalance supports evaluating these professional-learning arrangements systematically. The present study can inform the questions that such evaluations should ask, but cannot determine the best model of professional development on its own.

4.5 Limitations and the Need for Empirical Evaluation of AI Integration

This preliminary study included four teachers and 62 students from two selected schools over two weeks. Its findings cannot be broadly generalized to elementary schools. The questionnaire data reflect perceptions rather than verified causes of engagement or measures of AI literacy, and the percentages reported require verification. The study did not measure cognitive load, assess AI instructional competence with a validated scale, or implement a specific AI-ethnomathematics project-based learning (PjBL) intervention. Evidence is primarily from interviews with Groups 1 and 3; including accounts from Groups 2 and 4 would enhance the comparison. Additionally, member checking, child assent, and instrument validation require confirmation from the authors.

Future studies should involve longer observations, stimulated recall interviews, and validated assessments of teacher readiness to understand lesson planning and implementation better. Design-based research could develop and refine AI-supported ethnomathematics PjBL in collaboration with teachers, looking at factors such as mathematical understanding, cultural accuracy, student agency, workload, and child safety. Existing reviews highlight gaps in rigorous, longitudinal, and age-specific designs in K–12 AI education (Liu & Zhong, 2024; Marzano, 2026).

More research is needed to distinguish feasibility from effectiveness. Pilot studies may show operational capability without clarifying improvements in mathematical reasoning or teacher workload. Comparative designs could assess these outcomes, while qualitative follow-ups could explore why certain scaffolds aid in some activities and not others. The evidence on AI in K–12 education shows significant variation across system types, teacher roles, and task designs (Schindler et al., 2026; Yoon & Kwon, 2024). Addressing these design choices is crucial to avoid treating "AI integration" as a single intervention.

5. Conclusion

This study concludes that a clear gap exists between pupils' enthusiasm for digital learning and classroom implementation in the two participating elementary schools. Project-based learning, digital technology, and ethnomathematics were generally implemented separately rather than as one coherent mathematics-

learning approach. Project activities often emphasized product completion, and technology was mainly used for presentation or evaluation rather than adaptive support. Although 90% of respondents expressed interest in interactive technology and 75% in local culture, 80% reported boredom in mathematics, while 55% disagreed with wanting to present answers different from friends. Teachers described difficulties coordinating project design, technological tools, mathematical content, local culture, and curriculum expectations. The study does not establish that such fragmentation caused the student responses or that teachers experienced objectively measured cognitive overload.

The contribution is a context-specific comparison of student perceptions, classroom observations, and teacher accounts showing why access to basic digital resources should not be equated with readiness for AI-assisted ethnomathematics PjBL. In practice, professional development may need to integrate instructional planning, culturally grounded mathematical tasks, evaluation of AI-generated content, ethical safeguards, and adaptive scaffolding, rather than focusing solely on technical skills. Given the small number of teachers, two schools, and short observation period, longitudinal and design-based studies should investigate these possibilities in authentic elementary classrooms. Successful integration requires pedagogical judgment, cultural sensitivity, and sustained support in addition to appropriate infrastructure.

Declarations

All authors have reviewed and approved the final manuscript and declared no competing interests. The study was conducted in accordance with established ethical standards, with appropriate informed consent and safeguards for participant confidentiality. Grammarly was employed to enhance academic language and citation consistency. No research data was generated using artificial intelligence.

References

- Apriandi, D., Krisdiana, I., Suprpto, E., & Megantara, B. A. (2023). Development and effectiveness of STEAM-C integrated learning devices to improve students' creative thinking skills in a specific cultural context. *Journal of Learning for Development*, 10(3), 440–451. <https://doi.org/10.56059/jl4d.v10i3.813>
- Ayanwale, M. A., Sanusi, I. T., Adelana, O. P., Aruleba, K. D., & Oyelere, S. S. (2022). Teachers' readiness and intention to teach artificial intelligence in schools. *Computers and Education: Artificial Intelligence*, 3, Article 100099. <https://doi.org/10.1016/j.caeai.2022.100099>

- Barus, Y. K., Pangestu, W. T., Muzaki, F. I., & Ahdhianto, E. (2025). Unlocking potential: A teacher's lens on artificial intelligence towards students' problem-solving skills. *Journal of Integrated Elementary Education*, 5(1), 220–233. <https://doi.org/10.21580/jieed.v5i1.24974>
- Basri, H., Jannah, U. R., Hasanah, S. I., Dewi, N. P., Azzahra, F., Ubaidillah, & Yahya, F. H. (2026). Development of Madurese ethnomathematics-based digital teaching materials to enhance students' critical thinking skills and character. *Multidisciplinary Science Journal*, 8(7), Article e2026161. <https://doi.org/10.31893/multiscience.2026161>
- Batubara, H. H., Syukur, F., Junaedi, M., Purwanti, K. L., & Shanie, A. (2025). Teachers' perceptions and readiness for mobile artificial intelligence integration in elementary education. *International Journal of Interactive Mobile Technologies*, 19(16), 148–162. <https://doi.org/10.3991/ijim.v19i16.55711>
- Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer. <https://doi.org/10.1007/978-0-387-09506-6>
- Celik, I. (2023). Towards Intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior*, 138, Article 107468. <https://doi.org/10.1016/j.chb.2022.107468>
- Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publications.
- Deng, R., Jiang, M., Yu, X., Lu, Y., & Liu, S. (2025). Does ChatGPT enhance student learning? A systematic review and meta-analysis of experimental studies. *Computers & Education*, 227, Article 105224. <https://doi.org/10.1016/j.compedu.2024.105224>
- D'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the Learning of Mathematics*, 5(1), 44–48.
- Eldiana, N. F., Kusumaningrum, S. R., & Dewi, R. S. I. (2023). Ethnomathematics: Mathematics in Batik Turonggo Yakso from Trenggalek. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 12(1), 1515–1524. <https://doi.org/10.24127/ajpm.v12i1.6240>
- Eldiana, N. F., Supriyono, & Arifin, S. (2025). Etnomatematika Pendopo Kongas Arum Kusumaning Bongso (studi etnografi pada struktur arsitektur dan ornamen). *Indiktika: Jurnal Inovasi Pendidikan Matematika*, 8(1), 1–11. <https://doi.org/10.31851/indiktika.v8i1.20354>
- Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., . . . Kasneci, G. (2023). ChatGPT for good? On

- opportunities and challenges of large language models for education. *Learning and Individual Differences*, 103, Article 102274. <https://doi.org/10.1016/j.lindif.2023.102274>
- Kyeremeh, P., Awuah, F. K., & Orey, D. C. (2025). Challenges regarding the integration of ethnomathematical perspectives into geometry teaching: The faculty reflection. *Asian Journal for Mathematics Education*, 4(3), 416–430. <https://doi.org/10.1177/27527263251326330>
- Li, L., Yu, F., & Zhang, E. (2024). A systematic review of learning task design for K-12 AI education: Trends, challenges, and opportunities. *Computers and Education: Artificial Intelligence*, 6, Article 100217. <https://doi.org/10.1016/j.caeai.2024.100217>
- Liu, X., & Zhong, B. (2024). A systematic review of how educators teach AI in K-12 education. *Educational Research Review*, 45, Article 100642. <https://doi.org/10.1016/j.edurev.2024.100642>
- Marzano, D. (2026). Generative artificial intelligence (GAI) in teaching and learning processes at the K-12 level: A systematic review. *Technology, Knowledge and Learning*, 31, 789–829. <https://doi.org/10.1007/s10758-025-09853-7>
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications.
- Noviyana, H., Rahmawati, F., Kirana, A. R., & Tanod, M. J. (2025). Enhancing elementary students' mathematical problem-solving skills through AI-assisted problem-based learning. *Journal of Integrated Elementary Education*, 5(2), 254–268. <https://doi.org/10.21580/jieed.v5i2.27576>
- Pratama, R. A., & Afriani, R. (2026). The effectiveness of ethnomathematics-based learning on students' mathematical representation in Indonesia: A meta-analysis study. *Journal of Teaching and Learning*, 20(2), 97–118. <https://doi.org/10.22329/jtl.v20i2.8873>
- Rachmadtullah, R., Tanod, M. J., Rasmitadila, Irawan, N., McNeilly, A., & Suharni. (2024). Elementary school teachers' perspectives on the use of artificial intelligence to develop learning media. *Journal of Integrated Elementary Education*, 4(1), 71–82. <https://doi.org/10.21580/jieed.v4i1.21994>
- Rogers, T., & Carbonaro, M. (2025). From understanding to creating: Bridging AI literacy and AI fluency in K-12 education. *Journal of Teaching and Learning*, 19(4), 20–38. <https://doi.org/10.22329/jtl.v19i4.9420>
- Schindler, M., Cevikbas, M., & Lilienthal, A. J. (2026). Artificial intelligence in mathematics education: A two-dimensional conceptual framework and meta-review. *ZDM – Mathematics Education*, 58, 831–850. <https://doi.org/10.1007/s11858-026-01827-y>

- Sperling, K., Stenberg, C.-J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. *Computers and Education Open*, 6, Article 100169. <https://doi.org/10.1016/j.caeo.2024.100169>
- Sweller, J. (2011). Cognitive load theory. In J. P. Mestre & B. H. Ross (Eds.), *Psychology of learning and motivation* (Vol. 55, pp. 37–76). Academic Press. <https://doi.org/10.1016/B978-0-12-387691-1.00002-8>
- Syarifuddin, Adiansha, A. A., & Irfan. (2025). Ethnomathematics-based project-based learning with GeoGebra application support to optimize students' mathematical creativity. *International Journal of Information and Education Technology*, 15(10), 2095–2104. <https://doi.org/10.18178/ijiet.2025.15.10.2408>
- Tan, X., Cheng, K. S., & Ling, M. H. A. (2025). Artificial intelligence in teaching and teacher professional development: A systematic review. *Computers and Education: Artificial Intelligence*, 8, Article 100355. <https://doi.org/10.1016/j.caeai.2024.100355>
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press.
- Wang, N., Wang, X., & Su, Y.-S. (2024). Critical analysis of the technological affordances, challenges, and future directions of generative AI in education: A systematic review. *Asia Pacific Journal of Education*, 44(1), 139–155. <https://doi.org/10.1080/02188791.2024.2305156>
- Yim, I. H. Y., & Su, J. (2025). Artificial intelligence literacy education in primary schools: A review. *International Journal of Technology and Design Education*, 35, 2175–2204. <https://doi.org/10.1007/s10798-025-09979-w>
- Yoon, J., & Kwon, O. N. (2024). Systematic literature review on AI-based mathematics teaching and learning: Focusing on the role of AI and teachers. *Journal of Korean Mathematics Education*, 63(3), 573–591. <https://doi.org/10.7468/mathedu.2024.63.3.573>
- Zhang, S., Jaldi, C. D., Schroeder, N. L., López, A. A., Gladstone, J. R., & Heidig, S. (2024). Pedagogical agent design for K-12 education: A systematic review. *Computers & Education*, 223, Article 105165. <https://doi.org/10.1016/j.compedu.2024.105165>