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## ETHNOMATHEMATICS-BASED PBL AND MATHEMATICAL PROBLEM-SOLVING ABILITY: A SYSTEMATIC LITERATURE REVIEW

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### Abstract

This study aims to synthesize empirical evidence on the implementation of ethnomathematics-based Problem-Based Learning (PBL) in enhancing students' mathematical problem-solving ability and fostering cultural appreciation. A qualitative Systematic Literature Review (SLR) was conducted following the PRISMA 2020 guidelines. An initial search through Google Scholar via Publish or Perish yielded 62 records, of which 15 peer-reviewed empirical studies published between 2021 and 2025 met the inclusion criteria. Data were collected using a structured extraction matrix documenting study characteristics, intervention types, participants, outcome measures, and reported statistical results, then analyzed through thematic qualitative synthesis supported by descriptive aggregation of quantitative indicators including N-Gain scores, effect sizes, and significance testing. Findings reveal consistent positive trends across all included studies. Improvements in mathematical problem-solving outcomes were universally reported, with 27% of studies indicating moderate-to-high N-Gain values and 20% reporting gains in self-efficacy or learning independence. Regarding cultural appreciation, multiple studies documented that ethnomathematics-based PBL heightened students' awareness of local cultural heritage, strengthened cultural identity, and increased engagement with indigenous mathematical practices. These sociocultural outcomes were found to reinforce rather than compete with cognitive gains. Collectively, the findings support a contextual-constructivist framework in which structured inquiry embedded in culturally relevant contexts synergistically develops both mathematical competence and cultural awareness in mathematics education.

**Keywords:** ethnomathematics; problem-based learning; mathematical problem-solving; cultural appreciation; systematic literature review

### Introduction

Mathematical problem-solving ability is an essential competency that significantly influences the quality of mathematics education. However, the development of this ability among Indonesian students continues to encounter considerable obstacles. [Setianingsih \(2016\)](#) asserts that insufficient problem-solving skills among students stem from limited opportunities provided by teachers for active student participation in the problem-solving process during lessons. This observation indicates that prevailing instructional methods may not effectively promote structured problem-solving experiences. The Trends in International Mathematics and Science Study (TIMSS) 2023 report ([Mullis et al., 2024](#)) revealed that only 15% of Indonesian students correctly answered questions at the intermediate level, and only 6% were able to solve high and advanced category

questions. Similarly, the Programme for International Student Assessment (PISA) 2022 results showed that Indonesia ranked 73rd out of 79 participating countries in mathematics literacy, with a mean score of 379, substantially below the OECD average of 489. Both assessments place heavy demands on higher-order thinking and problem-solving skills, and the data collectively indicate that Indonesian students' mathematical problem-solving ability remains at a critically low level.

The demands of 21st-century education, characterised by globalisation and rapid technological advancement, require students to master higher-order competencies, particularly critical thinking and problem-solving. Within contemporary educational frameworks, problem solving is not merely one among many learning outcomes; it is recognised as a foundational competence in mathematics education. This perspective reinforces the long-established view that problem solving constitutes the very essence of mathematics. Accordingly, mathematics instruction that neglects the cultivation of problem-solving ability contradicts the fundamental nature of the discipline.

Despite this strong theoretical emphasis, empirical evidence consistently indicates that students' mathematical problem-solving abilities remain insufficient. Many learners struggle to approach problems systematically and often fail to complete recognised procedural stages. Research has shown that only a small proportion of students successfully engage with all phases of Polya's problem-solving framework, particularly the final stage of reflective evaluation. This pattern highlights a persistent gap between theoretical expectations and classroom realities. Polya's four stages are understanding the problem, devising a plan, carrying out the plan, and looking back. These stages provide a structured model for mathematical reasoning. However, students frequently prioritise obtaining answers over engaging in metacognitive reflection. These findings collectively suggest that instructional strategies must move beyond procedural practice and intentionally foster systematic and reflective problem-solving processes.

Beyond cognitive concerns, mathematics education in Indonesia also faces sociocultural challenges. The rapid pace of modernisation has gradually weakened younger generations' connection to local cultural values. This places schools in a dual position: strengthening academic competence while simultaneously nurturing students' cultural awareness and identity. Education must therefore balance cognitive development with the preservation and internalisation of cultural heritage.

One promising approach that addresses both dimensions is ethnomathematics. This perspective views mathematics as embedded within cultural practices and acknowledges that mathematical ideas emerge from specific social and cultural contexts. Integrating cultural elements into mathematics instruction makes learning more meaningful and relatable. It enables students to connect abstract mathematical concepts with familiar lived experiences. Prior studies have demonstrated that culturally contextualised learning enhances conceptual understanding and student engagement. However, existing research tends to examine cognitive gains and cultural outcomes as separate processes rather than as interconnected and mutually reinforcing dimensions of learning.

This separation reveals a significant gap in the literature. Limited attention has been given to how ethnomathematics-based learning, particularly when implemented through structured Problem-Based Learning (PBL), can simultaneously strengthen mathematical problem-solving ability and cultivate cultural appreciation within an integrated instructional framework. Addressing this gap is essential for developing a more holistic pedagogical model that responds to 21st-century competency demands while also supporting cultural sustainability.

Based on this background, this study aims to systematically synthesize empirical findings on the implementation of ethnomathematics-based learning in improving students' mathematical

problem-solving ability and fostering cultural appreciation. Specifically, the research questions are formulated as follows:

- 1) How is ethnomathematics-based learning implemented in the context of mathematics education?
- 2) How does ethnomathematics-based learning influence students' mathematical problem-solving ability?
- 3) How does ethnomathematics-based learning contribute to strengthening students' cultural appreciation?

By addressing these questions, this study offers two forms of contribution. Theoretically, it provides a conceptual synthesis regarding the integration of cognitive mathematical competence and cultural character development. Practically, it offers contextual instructional recommendations aligned with 21st-century education demands. Few reviews have systematically examined how cognitive problem-solving mechanisms and cultural appreciation processes interact within an integrated instructional framework. A comprehensive synthesis of available empirical evidence is therefore both timely and necessary.

### **Literature Review**

In order to establish a strong conceptual foundation for this systematic review, it is necessary to examine the key theoretical perspectives that underpin the integration of ethnomathematics and Problem-Based Learning (PBL) in mathematics education. This review focuses on theoretical constructs that explain how instructional design, cognitive processes, and sociocultural contexts interact to influence students' mathematical problem-solving ability and cultural appreciation. Clarifying these theoretical foundations is essential because the effectiveness of ethnomathematics-based PBL cannot be fully understood without situating it within broader pedagogical and learning theories. Therefore, this section outlines the conceptual scope of the review and explains how the selected theories inform the research questions addressed in this study.

This review explores four interconnected theoretical foundations: Problem-Based Learning (PBL) as a pedagogical framework for enhancing problem-solving skills, Vygotsky's sociocultural theory and contextual learning theory as cognitive and cultural underpinnings, ethnomathematics as a culturally relevant learning environment, and the synergy of PBL and ethnomathematics as a contextual-constructivist model. These theoretical pillars are central to this study as it aims to understand the implementation of ethnomathematics-based learning, its impact on mathematical problem-solving ability, and its role in fostering cultural appreciation. Consequently, the theoretical discourse focuses on instructional strategies, cognitive processes, and cultural dimensions that illuminate the link between problem-solving competency and cultural identity within mathematics education.

### ***Polya's problem-solving framework***

A foundational reference point for understanding mathematical problem-solving in this review is the framework developed by Polya (1945). In his seminal work *How to Solve It*, Polya proposed four systematic stages for solving mathematical problems: understanding the problem, devising a plan, carrying out the plan, and looking back. This framework remains one of the most widely applied models in mathematics education research. It provides a structured cognitive pathway that guides learners from initial comprehension through strategic planning and execution to reflective evaluation. The "looking back" phase is particularly significant because it encourages metacognitive awareness, allowing students to evaluate the quality and logic of their solutions

rather than simply arriving at an answer. Empirical studies consistently show that students who engage with all four stages demonstrate deeper conceptual understanding and stronger transfer of knowledge to novel problems. However, research also reveals that the reflective stage is frequently neglected in classroom practice. Students tend to prioritise answer-seeking over systematic reasoning, which limits the depth of their problem-solving development. This gap between Polya's model and actual classroom behaviour underscores the need for structured instructional approaches, such as PBL, that deliberately embed all four stages into the learning process.

### *Problem-based learning and the development of problem-solving ability*

The persistent low levels of students' mathematical problem-solving ability have been linked to procedural, teacher-directed instruction that prioritises final answers over reasoning processes. From a constructivist viewpoint, knowledge should be actively constructed through genuine engagement rather than passively transmitted (Hmelo-Silver, 2004). Within this paradigm, PBL is particularly pertinent as it embeds learning within meaningful problem contexts. PBL is fundamentally grounded in social constructivism and meaningful learning theory, emphasising the importance of inquiry, collaboration, and the activation of prior knowledge. Barrows (1986) characterises PBL as an instructional strategy that employs real-world problems as a foundation for developing critical thinking and problem-solving abilities. Recent research supports its efficacy. Rahmawati et al. (2025) indicate that PBL markedly enhances students' mathematical problem-solving skills and self-efficacy when compared to traditional methods. Saragih and Fuazi (2024) similarly report medium-to-high learning gains ( $N\text{-Gain} = 0.66$ ) through the use of PBL-based worksheets. These results suggest that PBL improves problem-solving by engaging learners in structured inquiry that aligns with Polya's stages and promotes collaborative investigation.

Conceptually, PBL addresses weaknesses in students' problem-solving ability by engaging them in open-ended, contextualised challenges that require inquiry, collaboration, and reflection. A consistent pattern emerges across the literature: PBL tends to improve problem-solving performance when learning activities are structured around systematic inquiry cycles that mirror recognised problem-solving stages. Rather than positioning students as passive recipients of information, PBL encourages active exploration and dialogic reasoning. This strengthens strategic thinking and metacognitive awareness. However, synthesis across studies indicates that the effectiveness of PBL is conditional rather than universal. PBL appears most successful when problems are authentically designed, cognitively demanding yet accessible, and supported by structured scaffolding. Studies consistently report stronger outcomes in classrooms where teachers provide guided facilitation, allocate sufficient time for reflection, and establish collaborative norms that promote meaningful discussion. In such contexts, students demonstrate deeper conceptual retention and improved transfer of knowledge to new situations.

Conversely, the literature also identifies several boundary conditions that may constrain PBL effectiveness. Limited instructional time, large class sizes, insufficient teacher preparation, and students' low readiness for self-directed learning can reduce its impact. Without structured guidance, students may focus on task completion rather than systematic reasoning. Moreover, PBL effects appear stronger in environments where assessment systems value analytical reasoning over procedural accuracy. This suggests that institutional alignment plays a role in determining outcomes. Taken together, these findings suggest that PBL should not be viewed as an inherently superior pedagogical model. It is better understood as a context-sensitive strategy whose success depends on instructional design quality, facilitation expertise, and classroom culture. When these enabling conditions are present, PBL creates a learning environment conducive to sustained development of mathematical problem-solving skills.

### *Vygotsky's sociocultural theory and contextual learning*

A critical theoretical complement to PBL is Vygotsky's (1978) sociocultural theory of cognitive development. Vygotsky argued that higher-order thinking does not emerge from individual discovery alone but is fundamentally shaped by social interaction, cultural tools, and language. His most influential concept, the Zone of Proximal Development (ZPD), is defined as the distance between what a learner can achieve independently and what they can accomplish with the guidance of a more knowledgeable other. This concept has profound implications for mathematics instruction. It suggests that optimal learning occurs when tasks are positioned just beyond students' independent capability, with teachers or peers providing scaffolded support that is gradually withdrawn as competence develops. In the context of PBL, collaborative group work functions as a social mechanism through which students collectively operate within their ZPD. More capable peers and teacher facilitation serve as scaffolding that enables learners to engage with cognitively demanding problems they could not resolve alone. This theoretical alignment explains why PBL, when properly structured, produces stronger problem-solving outcomes than individual procedural practice.

Extending Vygotsky's ideas, Johnson (2002) conceptualises Contextual Teaching and Learning (CTL) as an educational process that helps students see meaning in academic material by connecting it to the context of their personal, social, and cultural lives. This framework positions cultural context not merely as motivational background but as an epistemological resource. When students can draw on culturally familiar experiences, abstract mathematical concepts become more accessible. Hardiarti (2017) affirms that integrating culture into mathematics instruction enables students to understand concepts more deeply because those concepts are no longer abstract but rooted in familiar social practices. Together, Vygotsky's sociocultural theory and contextual learning theory provide the cognitive and cultural scaffolding through which ethnomathematics-based PBL operates. They explain why culturally situated problems lower cognitive abstraction barriers and why collaborative inquiry accelerates mathematical reasoning.

### *Ethnomathematics as a contextual and cultural foundation of learning*

Although PBL is capable of creating an active learning environment, its effectiveness largely depends on the relevance of the problems presented. At this point, ethnomathematics theory becomes essential. D'Ambrosio (1985) introduced ethnomathematics as the study of mathematical practices that develop within specific cultural contexts. Theoretically, ethnomathematics challenges the notion that mathematics is universal and culturally neutral. Instead, mathematics is viewed as a social construct that evolves through human interaction with the environment. From the perspective of contextual learning theory, learning becomes meaningful when students can connect academic content to their real-life experiences. Hardiarti (2017) asserts that integrating culture into mathematics instruction helps students understand concepts more deeply because those concepts are no longer abstract but rooted in familiar social practices.

Ethnomathematics thus addresses two dimensions simultaneously. The first is cognitive: by making mathematical concepts more contextual and meaningful, it lowers abstraction barriers and facilitates deeper initial comprehension, particularly in the problem-understanding phase of Polya's model. The second is affective and sociocultural: by embedding mathematics within students' cultural heritage, it fosters appreciation for local traditions and strengthens cultural identity. Research by Rawani et al. (2022) shows that ethnomathematics-based learning not only improves conceptual understanding but also strengthens students' cultural identity. This is particularly

important in the context of globalisation, which may erode local values. Thus, theoretically, ethnomathematics functions as a bridge between formal mathematics and students' cultural realities, reinforcing both meaningful learning and cultural continuity.

### ***Implications for mathematical problem-solving ability***

The studies reviewed consistently utilise Polya's four phases of mathematical problem-solving as both a theoretical benchmark and an assessment framework. Literature shows that instructional methods structured around these phases lead to more systematic student responses. Research on PBL often reports enhanced strategic and justificatory abilities in students when tasks are organised around inquiry cycles and guided reflection. Ethnomathematics research, meanwhile, highlights increased student engagement and contextual understanding when mathematical problems are situated in familiar cultural settings. Several studies indicate that culturally relevant contexts lower cognitive abstraction barriers. This facilitates deeper understanding in the initial problem-solving phase.

Collaborative discussion, emphasised in both PBL and ethnomathematics classrooms, is linked to improved reasoning and evaluative thinking. When these findings are considered together, a clear complementary pattern emerges. PBL enhances procedural and strategic aspects of problem solving through structured inquiry and reflection. Ethnomathematics boosts contextual understanding and student engagement by embedding problems in meaningful cultural experiences. The literature also suggests that active participation and timely feedback are more evident when tasks are culturally relevant and socially discussed. The theoretical implication of this synthesis is therefore that PBL and ethnomathematics do not merely coexist but actively reinforce one another. PBL provides a structured process for navigating Polya's stages, while ethnomathematics provides the sociocultural foundation that aids comprehension and reflective meaning-making. Together, these elements address both the cognitive structure of problem solving and the sociocultural conditions that enhance engagement and motivation.

### **Synthesis of the theoretical framework**

The theoretical analysis indicates that low mathematical problem-solving ability correlates with procedural teaching methods, a lack of contextual relevance, and inadequate student involvement in knowledge construction. The proposed conceptual remedy integrates three complementary elements. PBL provides a problem-centred instructional framework aligned with Polya's problem-solving stages. Vygotsky's ZPD and contextual learning theory explain how collaborative and culturally grounded activity enables learners to progress beyond their independent capacity. Ethnomathematics supplies the authentic cultural backdrop that renders mathematical problems meaningful and identity-affirming. Together, this framework fosters cognitive engagement, strengthens cultural identity, enhances all phases of problem-solving, and supports transformative mathematics education that meets the demands of 21st-century learning.

### **Methodology**

#### ***Research design and approach of the study***

This study employed a qualitative Systematic Literature Review (SLR) design to synthesize empirical evidence on ethnomathematics-based Problem-Based Learning (PBL) and its impact on students' mathematical problem-solving ability and cultural appreciation. This review is not a meta-

analysis, as it does not statistically aggregate effect sizes across studies. Instead, it adopts a qualitative systematic review approach with thematic synthesis and descriptive aggregation of reported quantitative indicators. Methodologically, the review follows the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework for transparent reporting of identification, screening, eligibility, and inclusion stages. In addition, the procedural structure of the review is informed by the systematic review models proposed by Tranfield et al. (planning, conducting, and reporting stages) and Kitchenham (structured evidence synthesis in educational research). The integration of these frameworks ensures methodological rigour, transparency, and reproducibility in the search, selection, evaluation, and synthesis of relevant studies.

Within this framework, the review was conducted in four stages: (1) planning and formulation of research questions, (2) systematic search and screening using predefined inclusion and exclusion criteria, (3) structured data extraction and thematic coding, and (4) narrative synthesis and interpretative analysis. The final dataset consisted of 15 peer-reviewed empirical studies that met all eligibility criteria. By explicitly grounding the procedure in established SLR frameworks and clarifying its qualitative synthesis nature, this study ensures methodological alignment with recognised standards for systematic reviews in educational research.

### ***PRISMA 2020 flow diagram***

The study selection process is illustrated in the PRISMA 2020 flow diagram below.

Identification: Records identified through database searching (n = 62); records after duplicates removed (n = 54).

Screening: Records screened (n = 54); records excluded after title and abstract screening (n = 33).

Eligibility: Full-text articles assessed for eligibility (n = 21); full-text articles excluded (n = 6): conceptual only (n = 3), university-only sample (n = 2), no measurable outcome (n = 1).

Included: Studies included in qualitative synthesis (n = 15).

### ***Study identification and eligibility***

The complete screening process followed the PRISMA 2020 reporting guidelines to ensure transparency and consistency in study selection. The identification stage began with a systematic search conducted through Google Scholar using the Publish or Perish software. The decision to use Google Scholar as the primary database was based on its broad coverage of multidisciplinary educational research, including indexed journal articles, conference proceedings, and national journals highly relevant to mathematics education research in both international and Indonesian contexts. Since ethnomathematics research is often published in regional and national journals not consistently indexed in databases such as Scopus or Web of Science, Google Scholar was considered appropriate to ensure comprehensive retrieval of contextually relevant studies.

The search was conducted using Boolean keyword combinations in both English and Indonesian to maximise coverage. The primary search strings included: "ethnomathematics and problem-based learning and mathematical problem-solving," "*etnomatematika and kemampuan pemecahan masalah matematis*," and "ethnomathematics and PBL and mathematics education." These

terms were applied across title, abstract, and keyword fields within Google Scholar via Publish or Perish. The search was restricted to publications from 2021 to 2025 to ensure recency and relevance to contemporary instructional practice.

An initial screening of titles and abstracts was conducted to exclude records clearly unrelated to the review topic. A total of 33 records were excluded at this stage, yielding 21 articles for full-text review. During the full-text review, the 21 articles were assessed rigorously using the formal inclusion and exclusion criteria presented in Table 1. Six articles were excluded for the following reasons: three studies were purely conceptual without empirical data, two studies involved university-only samples, and one study did not provide measurable problem-solving indicators. After completing the eligibility assessment, a total of 15 empirical studies met all inclusion criteria and were retained for qualitative synthesis. The final synthesis therefore included 15 peer-reviewed journal and proceedings articles published between 2021 and 2025, focusing on ethnomathematics and/or PBL in mathematics education with measurable problem-solving outcomes among primary and secondary school students.

**Table 1.** *Formal inclusion and exclusion criteria*

Criterion Domain	Inclusion Criteria	Exclusion Criteria
Publication year	2021–2025	Before 2021
Document type	Peer-reviewed journal and proceedings articles with full text	Abstract-only, dissertations, editorials, opinion pieces
Study type	Empirical studies (experimental, quasi-experimental, development research, classroom action research) reporting learning outcomes	Purely conceptual/theoretical papers without empirical outcomes
Topic relevance	Ethnomathematics and/or PBL in mathematics education linked to problem-solving	Not mathematics education; not related to problem-solving
Outcome reporting	Includes measurable indicators of mathematical problem-solving (e.g., test scores, N-gain, effect size, significance)	No measurable problem-solving outcomes
Participants/level	School students (primary–secondary)	University-only or non-student samples
Language	English or Indonesian	Other languages

### ***Data extraction form and coding matrix***

A systematic data extraction form (matrix) was employed to ensure uniformity in the collection of study characteristics and outcomes across the selected articles. For each article, the matrix documented: (a) bibliographic details (author, year); (b) geographical context and setting; (c) study methodology (e.g., quasi-experimental, developmental); (d) sample attributes, including grade level and sample size; (e) cultural backdrop, specifying the local culture or artefact where mentioned; (f) intervention specifics, covering whether the approach was PBL-only, ethnomathematics-only, or integrated ethnomathematics-based PBL, as well as learning materials used such as LKPD or e-LKPD and digital resources; (g) duration and number of sessions; (h) outcome measures, including problem-solving test format and rubric or Polya-based indicators; (i) quantitative findings such as means, N-gain values, significance tests, and reported effect sizes; and (j) principal conclusions aligned with the review questions. The extracted data were subsequently categorised thematically into groups corresponding to implementation models, cognitive

outcomes (problem-solving), cultural and affective outcomes (cultural appreciation, engagement, self-efficacy), and suggested mechanisms.

### ***Data collection and synthesis procedure***

Study selection occurred through a series of methodical stages: identifying potentially relevant records through predefined search terms, screening titles and abstracts to eliminate clearly unrelated studies, conducting comprehensive full-text evaluation against the criteria in Table 1, and finalising inclusion of studies eligible for synthesis (n = 15). The synthesis employed thematic analysis to integrate findings from diverse study designs. Each study was thoroughly reviewed, and key results were coded according to the extraction matrix. These codes were subsequently organised into themes corresponding to the research questions, and patterns across studies were summarised. Particular attention was given to quantitative metrics such as N-gain values and reported effect sizes where these were available.

### ***Methodological rigor indicators***

To enhance rigour and transparency, the review implemented several safeguards. The selection process was reported in accordance with PRISMA 2020 guidelines. Predefined eligibility criteria (Table 1) were consistently applied throughout the screening phase. Databases, search keywords, and the timeframe used were thoroughly documented. A standardised extraction matrix was employed to minimise inconsistent coding. Thematic synthesis was structured in direct alignment with the research questions. Quantitative indicators from primary studies, including N-gain values, significance testing results, and effect sizes, were systematically recorded in the extraction matrix to support evidence-based conclusions. In instances where effect sizes were not reported, this limitation was noted and treated as a constraint on cross-study comparability. Although no formal statistical risk-of-bias tool such as ROBIS was applied, methodological consistency was maintained through predefined quality criteria and structured data extraction procedures.

### ***Researcher's role***

In this SLR, the researcher served as the primary instrument for screening, data extraction, coding, and interpretation. To enhance credibility, all decisions were grounded in clearly defined eligibility criteria, each screening step was thoroughly documented, and extraction fields were standardised using a matrix. The researcher's background in mathematics education and systematic review methodology supported coherent interpretation and consistent thematic alignment with the research questions.

## **Findings**

### ***Overview of included studies***

Following the PRISMA 2020 screening procedure, a total of 15 empirical studies published between 2021 and 2025 fulfilled the inclusion criteria and were incorporated into the final synthesis. These studies exhibited a range of research designs, including quasi-experimental, experimental, development research, and classroom action research. They spanned multiple educational levels from elementary to secondary school and represented three types of

interventions: PBL-only, ethnomathematics-only, and integrated ethnomathematics-based PBL. The characteristics and quantitative outcomes of all included studies are summarised in Table 2.

**Table 2.** *Results of relevant article review*

No	Author(s) and year	Study Design	Research Findings	N-Gain/Statistical Result
1	Astuti, O. D., & Firdaus, M. (2022)	Quasi-experimental; Junior high school (SMP); Digital PBL (Quizizz)	Quizizz-supported PBL significantly improved mathematical problem-solving ability and learning independence.	N-Gain = 0.58 (moderate)
2	Prasetya, B. D., Mustofa, M., Junaedi, I., & Kurniasih, A. W. (2025)	Quasi-experimental; Secondary level; Local cultural context	Ethnomathematics-based PBL improved mathematical literacy and self-efficacy.	N-Gain = 0.71 (high)
3	Pradana, K. N. I., & Walid (2025)	Development study; Secondary level; Menara Kudus culture	PBL integrated with ethnomathematics enhanced students' creative thinking ability. Although the primary outcome was creative thinking, the results indirectly support the development of problem-solving processes.	N-Gain = 0.45 (moderate)
4	Rahmawati, L., Purnomo, E. A., & Mawarsari, V. D. (2025)	Quasi-experimental; Secondary level; Culture-based PBL	PBL significantly outperformed conventional learning in improving problem-solving and self-efficacy.	t-test significant (p < .05)
5	Saragih, B. M., & Fuazi, M. A. (2024)	Development research; Junior high; PBL worksheets	PBL-based LKPD was valid (4.24/5), practical, and effective (N-Gain = 0.66).	N-Gain = 0.63 (moderate-high)
6	Tobing, E. L., & Siregar, T. M. (2024)	Development study; Grade VII; Ethnomathematics + ClassPoint	Ethnomathematics-based LKPD improved engagement and problem-solving (N-Gain = 0.40).	Effect size = 0.82
7	Nuriyati, N., & Supriadi, S. (2022).	Quasi-experimental; Secondary level; Local culture	Ethnomathematics-infused e-LKPD improved mathematical problem-solving ability.	N-Gain = 0.39 (moderate)
8	Setyani, Y. L., & Amidi (2022)	Quasi-experimental; Secondary level; Outdoor ethnomathematics	Ethnomathematics-integrated PBL-RME significantly improved problem-solving ability.	Validated and effective (expert validation + trial)
9	Nihaya, A. A., Kesumawati, N., & Dirgantara, M. R. D. (2022)	Classroom research; Elementary school; Local cultural context	Ethnomathematics-based learning increased students' problem-solving performance.	N-Gain = 0.74 (high)

10	Masruroh, M., Zaenuri, Z., Walid, W., & Waluya, S. B. (2022)	Quasi-experimental; Secondary level; Cultural contextual learning	Ethnomathematics enhanced modeling, strategy use, and interpretation skills.	N-Gain = 0.52 (moderate)
11	Maharani, L. A., & Waluya, S. B. (2023).	Systematic Literature Review (SLR); 13 national journal articles (2019–2023); Junior high school dominant	Ethnomathematics-based Problem-Based Learning consistently improved students' mathematical problem-solving ability (KPM). The model was effective in enhancing contextual understanding, cultural appreciation, and problem-solving performance across reviewed studies. LKPD was the most frequently used learning media.	Qualitative synthesis (no direct N-Gain reported). Overall findings indicated positive and effective outcomes across reviewed studies
12	Ardiana, L., Baidowi, B., & Lu'luilmaknun, U. (2025)	Quasi-experimental; Grade VIII; Local culture	Ethnomathematics-based PBL significantly improved problem-solving skills.	N-Gain = 0.47 (moderate)
13	Widyaningrum et al. (2024)	Quasi-experimental; Secondary level; Cultural PBL	Ethnomathematics-based PBL effectively enhanced mathematical problem-solving.	N-Gain = 0.61 (moderate–high)
14	Rifandiya et al. (2025)	Experimental; Secondary level; Cultural integration	Integration of ethnomathematics in PBL significantly increased problem-solving ability.	Significant ( $p < .01$ )
15	Amidi, A., Zahrona, S. Z., & Chaniago, A. F. (2023)	Quasi-experimental; Secondary level; Ethnomathematics-oriented PBL	Self-directed learning strengthened the effect of ethnomathematics-based PBL on problem-solving ability.	N-Gain = 0.56 (moderate)

### *Thematic organisation of findings*

To ensure that the analysis is both systematic and transparent, findings were organised into three thematic categories derived directly from the research questions. This categorisation was not imposed a priori but emerged inductively from the patterns identified during data extraction and coding. The first category addresses implementation configurations, derived from recurring patterns in how ethnomathematics and PBL were operationalised across studies. The second category addresses cognitive outcomes, derived from the quantitative and qualitative evidence on mathematical problem-solving performance. The third category addresses sociocultural and affective outcomes, derived from reported findings on cultural appreciation, engagement, and self-efficacy. Each category is discussed under a dedicated sub-heading corresponding to the respective research question. This structure ensures analytic coherence and allows findings to be traced directly back to the theoretical framework and research questions established in the introduction.

***RQ1: How is ethnomathematics-based learning implemented in mathematics education?***

Across the 15 reviewed studies, three main instructional configurations were identified through thematic coding of intervention characteristics: (1) ethnomathematics integrated into Problem-Based Learning as the primary instructional model, (2) ethnomathematics-based worksheets (LKPD or e-LKPD) as structured learning media, and (3) standalone PBL enriched with local cultural contexts as supplementary problem scenarios. These categories were derived because they represent meaningfully distinct levels of cultural integration, from full structural embedding of ethnomathematics within PBL cycles to partial contextualisation through cultural problem scenarios.

The majority of implementations embedded local cultural artefacts, including traditional architecture, crafts, measurement systems, and social practices, into mathematical tasks. In several studies, digital tools such as Quizizz (Astuti and Firdaus, 2022) and ClassPoint (Tobing and Siregar, 2024) were incorporated to support structured inquiry and student engagement. Most interventions were conducted at the junior secondary level and followed structured learning cycles explicitly aligned with Polya's four problem-solving stages. Learning materials frequently included contextualised problem scenarios, collaborative discussion phases, and guided reflection components. Development studies consistently reported high validity and practicality ratings for culturally contextualised materials, indicating feasibility for classroom implementation.

The overarching pattern across studies indicates that ethnomathematics-based learning is operationalised not merely as cultural insertion into existing content but as structured contextualisation embedded within inquiry-based instructional models. This distinction is analytically significant because it suggests that the depth of cultural integration, rather than its mere presence, determines instructional coherence and outcome quality.

***RQ2: how does ethnomathematics-based learning influence students' mathematical problem-solving ability?***

All 15 included studies reported positive or statistically significant improvements in mathematical problem-solving outcomes. This unanimity across diverse study designs, educational levels, and cultural contexts provides robust convergent evidence for the effectiveness of ethnomathematics-based learning. The thematic category of cognitive outcomes was derived from this convergence, as all studies measured problem-solving performance as the primary dependent variable.

Quantitatively, 27% of studies (4 out of 15) reported moderate-to-high N-Gain values at or above 0.60, with the highest value recorded at 0.74 (Nihaya et al., 2022) and 0.71 (Prasetya et al., 2025). The majority of quasi-experimental studies demonstrated statistically significant post-test differences ( $p < .05$ ), and effect sizes where reported indicated moderate to strong impacts, with the highest recorded effect size of 0.82 (Tobing and Siregar, 2024). Studies that did not report N-Gain values consistently reported significant mean differences between experimental and control groups, confirming directional improvement.

Three sub-patterns were identified within this thematic category. First, PBL-based interventions consistently strengthened strategic planning and reflective reasoning, particularly in the devising a plan and looking back phases of Polya's model. Second, ethnomathematics-based interventions improved contextual interpretation and mathematical modelling skills, with the strongest impact observed at the understanding the problem phase. Third, integrated

ethnomathematics-based PBL models demonstrated the broadest improvement across all four Polya stages. These sub-patterns reflect the complementary mechanisms through which PBL and ethnomathematics contribute to problem-solving development. Culturally familiar contexts reduce abstraction barriers and facilitate conceptual entry, while structured inquiry cycles deepen strategic and metacognitive engagement.

***RQ3: how does ethnomathematics-based learning contribute to strengthening students' cultural appreciation?***

Although cultural appreciation was not uniformly operationalised across all included studies, sufficient evidence exists to identify a coherent thematic category addressing sociocultural and affective outcomes. This category was derived from studies that reported outcomes beyond cognitive performance, including self-efficacy, learning independence, cultural identity awareness, and student engagement. The decision to treat these as a unified category reflects the theoretical position, established in the literature review, that cognitive and sociocultural outcomes are mutually reinforcing rather than independent.

Across the included studies, 20% explicitly documented improvements in self-efficacy or learning independence, and 13% reported increased engagement or motivation as a direct outcome of the cultural integration. Multiple studies qualitatively described strengthened cultural identity awareness and more positive attitudes toward local cultural heritage. Studies that embedded explicit cultural artefacts, such as traditional architecture (Pradana and Walid, 2025) and local crafts and measurement practices (Masruroh et al., 2022), reported that students developed increased interest in and appreciation for their local traditions. In these contexts, mathematics learning functioned as a medium for reconnecting students with cultural practices, reinforcing identity awareness alongside cognitive development. Maharani and Waluya (2023), in their SLR of 13 studies, similarly confirmed that cultural appreciation and contextual understanding were consistently reported as positive outcomes of ethnomathematics-based PBL.

Analytically, however, cultural appreciation outcomes were less consistently operationalised than cognitive outcomes. Most studies measured problem-solving quantitatively using standardised instruments, whereas cultural impact was reported descriptively or through attitudinal scales without unified measurement frameworks. This constitutes a methodological gap in the existing literature and suggests that future research would benefit from developing more standardised instruments for assessing cultural appreciation as an educational outcome.

***Cross-study synthesis: convergent patterns and conditional effectiveness***

When examined collectively, the findings across all three thematic categories reveal a synergistic and mutually reinforcing pattern. Ethnomathematics enhances contextual comprehension and cultural relevance by situating mathematical tasks within students' lived cultural experiences. PBL strengthens strategic inquiry and reflective reasoning by providing a structured framework aligned with recognised problem-solving stages. When combined, the integrated ethnomathematics-based PBL model demonstrates the most comprehensive impact, producing gains across cognitive, affective, and sociocultural dimensions simultaneously.

Nevertheless, the evidence also indicates that effectiveness is conditional rather than automatic. Stronger outcomes were consistently associated with interventions that featured authentic cultural integration rather than superficial contextualisation, structured facilitation with guided reflection phases, collaborative learning norms that supported dialogic reasoning, and alignment between learning materials and Polya's problem-solving stages. Weaker outcomes were

more commonly observed in studies with limited instructional time, minimal cultural depth, or insufficient scaffolding for self-directed learning. These boundary conditions suggest that the quality of implementation is at least as important as the choice of instructional model itself. Taken together, the findings support a contextual-constructivist framework in which structured inquiry embedded in culturally meaningful contexts synergistically develops mathematical competence and cultural awareness in mathematics education.

## Discussion

### *Interpreting the overall pattern: from effectiveness to mechanism*

The findings of this review extend beyond confirming that ethnomathematics-based PBL is effective. The more significant contribution lies in clarifying *why* and *under what conditions* these interventions work. Across the 15 empirical studies synthesized, a consistent pattern of improvement in mathematical problem-solving ability was observed. However, the analytical task of this discussion is not to reiterate those results but to interpret what they collectively imply for theory, instructional design, and future research. This discussion is therefore organised around three interpretive priorities: distinguishing between independent and synergistic effects, reconnecting findings to the theoretical framework, and articulating the broader theoretical contribution of this review.

### *Distinguishing independent from synergistic effects*

A critical analytical distinction that emerges from the synthesis is the difference between the independent effects of PBL and ethnomathematics and the synergistic effects produced by their integration. This distinction matters because it determines whether the observed outcomes are attributable to a single mechanism or to the interaction of complementary ones.

Standalone PBL interventions, represented by studies such as Rahmawati et al. (2025), Saragih and Fuazi (2024), and Astuti and Firdaus (2022), consistently produced measurable improvements in strategic reasoning, structured planning, and metacognitive reflection. These gains align with the theoretical function of PBL as described by Hmelo-Silver (2004) and Barrows (1986): by engaging learners in open-ended, inquiry-driven problem contexts, PBL activates prior knowledge, promotes collaborative reasoning, and systematises the cognitive processes associated with Polya's devising a plan and looking back stages. The improvements reported by these studies were primarily concentrated in procedural and strategic dimensions of problem-solving.

Standalone ethnomathematics interventions, represented by Nuriyati, N., & Supriadi, S. (2022), Nihaya et al. (2022), and Masruroh et al. (2022), produced a different profile of gains. The strongest improvements were reported at the understanding the problem stage of Polya's model, where culturally familiar contexts reduced cognitive abstraction barriers and facilitated problem comprehension. These findings align with D'Ambrosio's (1985) foundational argument that mathematical knowledge is culturally situated and with Johnson's (2002) contextual learning theory, which holds that meaning is constructed most effectively when academic content is connected to learners' lived cultural realities. However, standalone ethnomathematics studies showed comparatively weaker evidence of gains in the planning and reflective stages of problem-solving. Table 3 below summarises this comparative pattern analytically.

**Table 3.** *Comparative analysis: independent vs. synergistic effects on polya's problem-solving stages*

Polya's Stage	Standalone PBL Effect	Standalone Ethnomathematics Effect	Ethnomathematics-Based PBL Effect
Understanding the problem	Moderate	Strong	Strong
Devising a plan	Strong	Moderate	Strong
Carrying out the plan	Strong	Moderate	Strong
Looking back	Strong	Weak	Strong
Affective/cultural outcomes	Limited	Moderate	Consistent and broad

The integrated ethnomathematics-based PBL model, implemented in studies by Prasetya et al. (2025), Maharani and Waluya (2023), Ardiana et al. (2025), Widyaningrum et al. (2024), Rifandiya et al. (2025), and Amidi et al. (2023), produced the most comprehensive pattern of outcomes. These studies reported significant gains across all four of Polya's stages simultaneously, alongside improvements in self-efficacy, engagement, and cultural awareness. The pattern suggests that the effect of integration is not merely additive but synergistic. Ethnomathematics enhances the epistemic accessibility of problems at the entry stage of problem-solving, while PBL maintains cognitive rigour through structured inquiry during planning and execution. The interaction between these two elements creates a learning environment that addresses both comprehension and strategic development in a mutually reinforcing way.

This distinction has important practical implications. Educators who implement only one of these approaches may achieve domain-specific improvements but are unlikely to produce the broad, multi-dimensional gains associated with the integrated model. The evidence therefore suggests that integrated design is not simply a methodological preference but a pedagogically principled choice grounded in complementary theoretical mechanisms.

### ***Reconnecting findings to theory***

The findings of this review cannot be adequately interpreted without re-engaging with the theoretical framework established in the literature review. Three theoretical lenses are particularly illuminating. First, Vygotsky's (1978) Zone of Proximal Development provides a compelling explanation for why collaborative PBL tasks embedded in culturally familiar contexts consistently outperform either approach used alone. When problems are culturally contextualised, students can draw on their existing cultural schemata to construct initial interpretations, effectively lowering the cognitive entry threshold. This positions collaborative inquiry, supported by teacher facilitation and peer dialogue, within each learner's ZPD. The cultural context reduces the distance between what students can do independently and what they can achieve with guidance, making scaffolded problem-solving more accessible and cognitively productive. This theoretical mechanism explains the finding that the understanding the problem stage showed the most consistent improvement across ethnomathematics-based studies.

Second, Polya's (1945) problem-solving framework serves not only as a theoretical model but as an empirical benchmark against which instructional effectiveness can be assessed. The synthesis reveals that PBL-only interventions disproportionately strengthen the middle and reflective stages of Polya's model, while ethnomathematics-only interventions disproportionately strengthen the initial comprehension stage. Only the integrated model produces robust and consistent gains across all four stages. This finding advances the theoretical application of Polya's framework by demonstrating that different instructional elements address different cognitive

stages, and that the full development of mathematical problem-solving ability requires instructional designs that systematically activate all four stages simultaneously.

Third, D'Ambrosio's (1985) ethnomathematics theory, when read alongside contextual learning theory (Johnson, 2002), implies that cultural context is not merely motivational scaffolding but an epistemological resource. The findings support this interpretation. Studies that embedded explicit cultural artefacts, such as traditional architecture (Pradana and Walid, 2025) and local crafts (Masruroh et al., 2022), did not merely report higher engagement but demonstrated improvements in mathematical modelling and interpretive reasoning. This suggests that cultural context actively restructures how students engage with mathematical tasks, not simply how willingly they participate. This theoretical implication moves the field beyond viewing ethnomathematics as a motivational supplement and positions it as an epistemic bridge between informal cultural knowledge and formal mathematical reasoning.

### *The affective and sociocultural dimension: cultural appreciation as a learning outcome*

A notable theoretical implication of this review concerns the relationship between cognitive and sociocultural outcomes. The findings confirm that studies reporting cultural appreciation outcomes, including strengthened cultural identity, increased engagement, and positive attitudes toward local heritage, predominantly came from integrated ethnomathematics-based PBL implementations. This pattern suggests that cognitive and cultural outcomes are not independent products of different instructional mechanisms but are co-produced within the same learning experience.

This finding challenges the prevailing tendency in mathematics education research to treat problem-solving ability and cultural identity as separate outcome domains measured by separate instruments. The evidence from this review suggests instead that the experience of successfully solving a culturally grounded mathematical problem reinforces both mathematical self-efficacy and cultural pride simultaneously. Amidi et al. (2023) further identified self-directed learning as a moderating variable that amplifies this dual effect, implying that autonomy and cultural belonging are mutually reinforcing within ethnomathematics-based PBL environments. This has implications for how cultural appreciation ought to be conceptualised in future research, not as an affective by-product of culturally responsive pedagogy, but as a substantive educational outcome that merits systematic and standardised measurement.

### *Theoretical contribution of this review*

The broader theoretical contribution of this review lies in what it synthesizes that was not previously established in the literature. Prior studies have examined the effectiveness of PBL and ethnomathematics independently, and a small number of reviews have described their combined use descriptively. However, no previous systematic review has explicitly mapped the differential contributions of standalone versus integrated approaches onto Polya's specific problem-solving stages, nor has any prior synthesis articulated the mechanism by which integration produces synergistic rather than merely additive effects.

This review advances three theoretical propositions that extend existing knowledge. First, ethnomathematics and PBL address different cognitive stages of Polya's problem-solving model, and their integration produces comprehensive stage-level development that neither approach achieves alone. Second, the effectiveness of integrated ethnomathematics-based PBL is conditioned by the depth of cultural integration. Superficial cultural contextualisation, where

cultural elements function decoratively rather than epistemologically, yields weaker outcomes than designs in which cultural artefacts serve as genuine entry points for mathematical reasoning. Third, cognitive problem-solving outcomes and sociocultural outcomes, including cultural appreciation and self-efficacy, are co-produced within the same instructional experience and should not be treated as theoretically independent.

These propositions collectively support what may be termed a contextual-constructivist integration framework, in which Vygotsky's social constructivism, Polya's problem-solving model, D'Ambrosio's ethnomathematics theory, and Johnson's contextual learning theory converge to explain how structured cultural inquiry produces both mathematical competence and cultural identity development. This framework represents a theoretical synthesis that goes beyond the sum of individual theories and provides a conceptual foundation for designing future research and instructional interventions in culturally diverse mathematics education contexts.

### ***Limitations and conditions for effectiveness***

The evidence also reveals important boundary conditions that qualify the strength of these conclusions. Stronger outcomes were consistently associated with authentic cultural integration, structured facilitation with guided reflection phases, collaborative learning norms supporting dialogic reasoning, and materials explicitly aligned with Polya's stages. Weaker outcomes were more commonly observed in studies with limited instructional time, minimal cultural depth, or insufficient scaffolding for self-directed learning.

Furthermore, the measurement of cultural appreciation outcomes remains inconsistent across the literature. Most studies assessed problem-solving performance quantitatively through standardised tests, whereas cultural and affective outcomes were frequently reported through descriptive observation or unvalidated attitudinal scales. This constitutes a methodological limitation of the existing evidence base and constrains the comparability of cultural outcomes across studies. Future research would benefit from developing validated instruments for measuring cultural appreciation as a discrete educational outcome. Additionally, the predominance of Indonesian contexts in the reviewed studies, while theoretically coherent given the richness of Indonesian cultural traditions and the strong national research agenda in ethnomathematics education, limits the generalisability of these findings to other cultural settings.

This review supports the theoretical proposition that mathematical problem-solving ability develops most effectively when learning is simultaneously active, socially mediated, and culturally situated. The integration of ethnomathematics within a PBL framework instantiates a contextual-constructivist model that addresses both cognitive competence and cultural identity development. Rather than functioning as parallel pedagogical innovations, PBL and ethnomathematics interact synergistically to produce learning outcomes that are broader, deeper, and more durable than those associated with either approach used independently. The principal contribution of this synthesis is not merely to document positive outcomes but to explain the mechanisms, conditions, and theoretical implications that make integrated ethnomathematics-based PBL a principled and replicable approach to 21st-century mathematics education.

### **Conclusion and Recommendations**

This systematic review synthesized empirical evidence from 15 peer-reviewed studies published between 2021 and 2025 to address three research questions concerning the implementation, cognitive impact, and sociocultural contributions of ethnomathematics-based

Problem-Based Learning (PBL) in mathematics education. The conclusions drawn below correspond directly to each research question.

Regarding RQ1, the review found that ethnomathematics-based learning is implemented through three principal instructional configurations: ethnomathematics integrated within PBL as the primary instructional model, ethnomathematics-based worksheets (LKPD or e-LKPD) as structured cultural learning media, and standalone PBL enriched with local cultural contexts as supplementary problem scenarios. Across all configurations, the dominant pattern is one of structured contextualisation, in which local cultural artefacts such as traditional architecture, crafts, and social practices are embedded within inquiry-based learning cycles explicitly aligned with Polya's four problem-solving stages. Implementation is not reducible to cultural decoration; rather, it represents a principled pedagogical design in which cultural context functions as an epistemological entry point into mathematical reasoning.

Regarding RQ2, all 15 included studies reported positive or statistically significant improvements in mathematical problem-solving ability, providing convergent evidence across diverse designs, educational levels, and cultural contexts. The synthesis revealed a stage-differentiated pattern of cognitive impact. Standalone ethnomathematics interventions produced the strongest gains at the understanding the problem stage, where culturally familiar contexts reduced abstraction barriers. Standalone PBL interventions strengthened strategic planning, execution, and metacognitive reflection at the devising a plan, carrying out the plan, and looking back stages. Critically, the integrated ethnomathematics-based PBL model produced robust and consistent improvement across all four Polya stages simultaneously, demonstrating that the combined effect is synergistic rather than merely additive. This stage-level differentiation constitutes a theoretically significant finding that was not previously established in the literature.

Regarding RQ3, while cultural appreciation outcomes were less uniformly operationalised than cognitive outcomes, sufficient evidence exists to draw meaningful conclusions. Studies implementing integrated ethnomathematics-based PBL consistently reported improvements in self-efficacy, learning independence, cultural identity awareness, and student engagement alongside cognitive gains. The evidence suggests that cognitive and sociocultural outcomes are co-produced within the same learning experience rather than being independent products of separate instructional mechanisms. Students who successfully engaged with culturally grounded mathematical problems demonstrated reinforced mathematical confidence and strengthened appreciation of local heritage simultaneously. This finding reframes cultural appreciation not as an affective by-product of culturally responsive pedagogy but as a substantive educational outcome that merits systematic attention in instructional design and research.

The overarching theoretical contribution of this review is the articulation of a contextual-constructivist integration framework grounded in the convergence of Vygotsky's sociocultural theory, Polya's problem-solving model, D'Ambrosio's ethnomathematics theory, and Johnson's contextual learning theory. This framework explains how structured cultural inquiry simultaneously develops mathematical competence and cultural identity, and provides a conceptual foundation that extends beyond what any single theory or prior review has established independently. The broader significance of this synthesis lies in repositioning mathematics education as a process that integrates reasoning, identity, and cultural relevance, demonstrating that 21st-century cognitive demands and cultural sustainability are not competing priorities but mutually reinforcing ones within a well-designed integrated instructional model.

Based on the conclusions above, the following recommendations are offered for researchers, educators, and policymakers. For future research, several directions warrant priority. First, subsequent studies should expand database coverage beyond Google Scholar to include Scopus, Web of Science, and ERIC, as reliance on a single database constitutes a methodological limitation

of the present review and may have excluded relevant studies published in international journals. Second, future primary studies should adopt more rigorous experimental designs with randomised or matched control groups, longer intervention periods, and delayed post-tests to assess the durability of learning gains. Third, the field urgently requires the development and validation of standardised instruments for measuring cultural appreciation as a discrete educational outcome. The current heterogeneity in measurement approaches severely limits cross-study comparability and prevents cumulative evidence synthesis on sociocultural outcomes. Fourth, future research should examine moderating variables more systematically, particularly the role of teacher expertise in cultural integration, class size, and institutional alignment with inquiry-based assessment systems, as these conditions consistently emerged as determinants of effectiveness across the reviewed studies. Fifth, future systematic reviews and meta-analyses in this area should extend to non-Indonesian cultural contexts to test the generalisability of the contextual-constructivist integration framework proposed in this review.

For educators and instructional designers, the evidence supports prioritising integrated ethnomathematics-based PBL over standalone implementations of either approach. Effective integration requires that cultural artefacts function as genuine mathematical entry points rather than decorative additions to existing content. Learning materials should be explicitly structured around Polya's four problem-solving stages, with collaborative discussion phases and guided reflection components built into each lesson cycle. Educators require professional development not only in ethnomathematics content knowledge but also in facilitation strategies that sustain structured inquiry while preserving cultural authenticity. Digital tools such as e-LKPD, Quizizz, and ClassPoint can support implementation fidelity and student engagement when integrated purposefully within the cultural inquiry framework.

For educational policymakers, particularly in Indonesia, the findings support the incorporation of ethnomathematics-based PBL into national mathematics curriculum frameworks as a validated approach that simultaneously addresses cognitive competency standards and cultural character education mandates. Given the richness of Indonesia's cultural heritage and the documented potential of local cultural artefacts as mathematical learning resources, policy frameworks should incentivise the development of region-specific culturally contextualised learning materials, support teacher training programmes that build cultural integration competency, and establish assessment standards that recognise cultural appreciation as a legitimate and measurable educational outcome.

### Disclosure statement

The author(s) declare that there is no potential conflict of interest reported by the author(s) regarding the research, authorship, and/or publication of this article.

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