

Elementary teachers' practices and challenges in integrating nusantara culture into multicultural learning

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Abstract

Purpose: This study investigates how elementary teachers integrate Nusantara culture into multicultural learning, examining interdisciplinary practices, structural challenges, and pedagogical anxiety in Indonesian primary classrooms.

Design/methodology/approach: A qualitative multi-case study examined 15 purposively sampled teachers across six elementary schools in Yogyakarta and West Java, Indonesia. Over four months, data were gathered via semi-structured interviews, 60-minute observations, and document analysis of lesson plans (*Modul Ajar*). Analysis followed Braun and Clarke's reflexive thematic approach, verified via triangulation and member-checking.

Findings: Teachers operationalized Nusantara culture through artifact-based instruction and service-learning (*gotong royong*), Logically enhancing spatial reasoning, identity salience, and practical wisdom (*phronesis*). However, integration was constrained by curriculum pressures, static textbooks, and anxiety over cultural misrepresentation and religious sensitivities, causing topic avoidance or superficial compliance.

Practical implications: Findings inform teacher education reforms by offering strategies to embed ethnomathematics and culturally sustaining pedagogy, mitigating teacher anxiety while reconciling standardized requirements with local cultural integration.

Originality/value: This study shifts multicultural discourse from Western racial binaries to a Global South pluralistic context, demonstrating how indigenous Nusantara heritage enriches core subjects like primary mathematics.

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Keyword

Nusantara culture, multicultural education, elementary teachers, ethnomathematics, pedagogical challenges.



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Introduction

Educational institutions increasingly face the imperative to foster multicultural competence and inclusive citizenship among young learners. Multicultural education provides a foundational paradigm for knowledge construction and curriculum reform, equipping students to navigate diverse cultural environments effectively (Banks, 1993, 2009). Culturally relevant pedagogy is central to this transformation, as it affirms learners' cultural backgrounds and promotes rigorous academic engagement (Gay, 2010a; Ladson-Billings, 1995; Nieto, 2000). Globally, scholarly discourse on multiculturalism and interculturalism emphasizes the need for educational systems to bridge socio-cultural divides and facilitate respectful dialogue among diverse student populations (Mansouri & Modood, 2021; Meer & Modood, 2012). International comparisons in teacher preparation indicate that embedding cultural diversity in primary education requires intentional and reflective pedagogical design (Fox & Diaz-Greenberg, 2006; Hannan, 1983). Nevertheless, implementing these theoretical ideals in everyday classroom practice remains a complex challenge across national and institutional contexts (Hamilton, 2009; Rios, 2018; Thomassen & Munthe, 2021).

Integrating local cultural heritage, particularly Nusantara culture, into primary school classrooms is essential because it shapes young learners' character, moral reasoning, and identity salience in multiple dimensions. Early childhood character development is grounded in virtue ethics traditions and practical wisdom (*phronesis*), which prepare students to address real-world ethical dilemmas (Curren, 2016; Gilead, 2011; Kristjánsson, 2024; Yacek & Jonas, 2025). Facilitating moral discussions and developmental role-modelling in primary classrooms establishes a strong foundation for practical wisdom (Henderson, 2023; Huo et al., 2025). Character education operates as a complex developmental system that requires structured principles and multidimensional trait classification (Miller, 2019; Nast, 2020; Nucci, 2017). When paired

with experience-based learning, strategies such as service-learning and multicultural character education promote active civic engagement and prosocial behaviour (Billig et al., 2012; Shumer et al., 2012). Culturally grounded instruction further enhances identity salience, enabling students to draw strength from their heritage and racial socialisation (Coard et al., 2004; Forehand et al., 2002; Gallien & Jackson, 2006; Woods & Jagers, 2003). Therefore, developing multiculturally sensitive character frameworks is crucial for respecting virtue diversity and supporting children in evaluating complex moral choices (Lu, 2025a, 2025b; Swedene, 2005; Wark & Krebs, 2000).

Despite the recognised importance of multicultural education, a significant research gap persists regarding how elementary teachers encounter and navigate systemic challenges when embedding local indigenous traditions into multicultural instruction. Critical race theory and critical whiteness studies demonstrate that teacher education programs often struggle to decenter dominant cultural narratives, leading to pedagogical tensions, "white fatigue," and systemic avoidance (Cabrera, 2018; Carter Andrews et al., 2021; Crowley & Smith, 2015; Flynn, 2015; Hawkman, 2020; Jupp et al., 2016; Sleeter, 2016, 2017). Teachers frequently exhibit ideological resistance or performative compliance when confronted with structural power dynamics, equity issues, and anti-racist requirements (Alcoff, 1998; Garrett & Segall, 2013; Gorski & Parekh, 2020; Hayes & Juárez, 2009; Mansfield & Kehoe, 1994). Critical scholars note that notions of institutional "niceness" and safety often mask underlying hegemonies and racialised fear in pedagogical dialogues (Leonardo, 2002; Leonardo & Porter, 2010; Levine-Rasky, 2008; Matias, 2022; Matias & Mackey, 2016; Orozco, 2019a, 2019b). While extensive literature examines these dominant structures in Western settings, a critical gap remains in empirical understanding of how elementary educators in non-Western, highly pluralistic contexts like Indonesia negotiate cultural integration amid competing national, regional, and local curricula.

This study offers a novel empirical perspective by examining the integration of Nusantara culture in primary classrooms, departing from existing literature that predominantly analyses multiculturalism through Western racial binaries or centralised national identity politics. Previous studies have explored cultural representation in science textbooks (Kim, 2021), privilege in higher education classrooms (Swartz et al., 2014), digital sensemaking of contested issues among preservice teachers (Deroo et al., 2017), and student *testimonios* asserting intercultural consciousness (Jaime-Diaz & Ramos, 2023). Other empirical investigations have focused primarily on ethno-national divisions, democratic education, and minority group dynamics within ethnic state regimes (Agbaria et al., 2015; Ari & Laron, 2014; Ben-Eliezer, 2008; Herzog et al., 2008; Horenczyk & Tatar, 2002; Ichilov, 2005; Krael-Tovi, 2012; Levy, 2005; Peled & Navot, 2005; Pinson & Agbaria, 2015). By shifting the analytical lens to the lived practices and pedagogical dilemmas of Indonesian elementary school teachers incorporating Nusantara heritage, this research bridges the gap between macro-level multicultural theory and micro-level classroom reality in a Global South context.

To address these empirical and theoretical gaps, this study systematically investigates elementary teachers' instructional practices and pedagogical challenges in integrating Nusantara culture into multicultural learning. Drawing on frameworks of teacher civic ideology and core teaching practices (Knowles, 2018; Richmond et al., 2017), the research examines how educators align their personal beliefs with social justice pedagogy. Additionally, informed by professional development theories related to teacher identity, self-reflection, learning styles, and multicultural competence (Fecho et al., 2005; Hawk & Shah, 2007; Murray-García et al., 2005; Stuart, 2004), the study aims to elucidate the professional uncertainty and cognitive dissonance teachers experience when implementing local cultural heritage in primary school contexts.

The urgency of this research is underscored by ongoing socio-cultural transformations, digital advancements, and evolving national discourses that reshape

traditional educational practices. Emergency transitions to remote and digital learning have demonstrated that rapid instructional changes can significantly affect minority and marginalized students' access to culturally sustaining educational environments (Halabi, 2023). In multicultural societies, teachers must carefully navigate boundaries among secular nationalism, religious revivalism, dominant ethnic identities, and critical race or ethnic frameworks in daily school life (Rajuan & Bekerman, 2011; Ram, 2008; Rubin, 2020; Sasson-Levy, 2013; Smootha, 2002; Tekiner, 1991). As schools adapt to new technological paradigms and shifting moral contexts (Li, 2025), equipping primary school teachers with effective strategies to anchor multicultural learning in local Nusantara traditions is essential to prevent cultural erosion and socio-cultural polarization among young citizens.

This research offers both theoretical and practical contributions to primary education, multicultural pedagogy, and teacher professional development. Theoretically, it extends culturally responsive teaching models by illustrating how indigenous cultural values (Nusantara) can be integrated with universal multicultural principles without resorting to assimilationist or superficial methods. Practically, the findings deliver actionable guidance for curriculum developers, school administrators, and teacher educators aiming to design professional training programs that strengthen teachers' multicultural competence, reduce pedagogical anxiety, and cultivate inclusive, culturally rich primary school environments.

Method

This study employed a qualitative multi-case study design to investigate how elementary school teachers operationalize Nusantara cultural integration and navigate pedagogical friction within multicultural classrooms. A qualitative case approach is uniquely suited for this inquiry because it allows for a deep, context-sensitive examination of complex classroom dynamics, teacher beliefs, and structural challenges

that cannot be captured through quantitative metrics alone. By investigating multiple school settings, the design enabled cross-case comparisons to identify shared patterns and context-specific nuances in teachers' instructional strategies and institutional hurdles.

Research Participants and Selection Criteria

Participants comprised 15 elementary school teachers from six public and private primary schools located in two culturally diverse urban hubs in Indonesia (Yogyakarta and West Java). Selection criteria required participants to have a minimum of three years of full-time teaching experience in primary education, active involvement in teaching multicultural or character education modules, and direct experience facilitating ethnically diverse student cohorts.

A purposive sampling technique was utilized to select participants who could provide rich, relevant data regarding the integration of regional cultural heritage into classroom practice. Rather than aiming for statistical generalization, this sampling strategy targeted information-rich cases across varied school profiles—ranging from state-funded public schools with standardized curricula to private schools with flexible multicultural frameworks—to capture a broad spectrum of teaching practices and operational constraints.

Data Collection Instruments and Operational Fieldwork Procedures

Data were collected using three complementary qualitative instruments: semi-structured interview protocols, non-participant classroom observation guides, and a document review matrix. Prior to fieldwork execution, all instruments were pilot tested with two non-participant primary school teachers to refine prompt clarity, eliminate ambiguous phrasing, and calibrate observational coding categories. The semi-structured interview protocol contained open-ended questions designed to explore teachers' instructional strategies, conceptualizations of Nusantara culture, and

perceived institutional or curricular obstacles. The observation guide focused on real-time classroom dynamics, specifically tracking how teachers scaffolded local cultural content, integrated physical artifacts, and managed student engagement during cultural units. Complementing these interactive tools, the document review matrix provided a systematic framework to evaluate instructional artifacts, including lesson plans (*Modul Ajar*), teaching media, student worksheets, and assessment rubrics. Fieldwork unfolded across three sequential phases over a four-month period:

- **Phase 1: Document Retrieval and Contextual Mapping.** Researchers established formal contact with participating schools, secured institutional clearance, and collected relevant instructional documentation (*Modul Ajar* and curriculum maps) to establish baseline contextual knowledge prior to classroom entry.
- **Phase 2: Classroom Observations.** Researchers conducted two 60-minute non-participant observations for each of the 15 teachers during scheduled social studies, civics, or local content (*Muatan Lokal*) lessons. Observations were captured using detailed descriptive and reflective field notes, recording physical layout, time allocation, student-teacher interactions, and specific cultural representations.
- **Phase 3: In-Depth Semi-Structured Interviews.** Each teacher participated in two 45-to-60-minute audio-recorded interview sessions. The initial interview explored baseline pedagogical philosophies and cultural backgrounds, while the post-observation interview addressed specific instructional decisions observed during live lessons and probed underlying challenges. Audio recordings were transcribed verbatim within 48 hours of completion to preserve context and linguistic nuances.

Methodological Trustworthiness and Rigor

To ensure the scientific quality of this qualitative inquiry, data collection and management adhered strictly to Lincoln and Guba's framework for qualitative trustworthiness, encompassing four criteria:

- **Credibility (Internal Validity):** Established through data source triangulation, combining interview transcripts, observational field notes, and document analyses to cross-verify findings. Prolonged engagement over four months in the school environments ensured familiarization with institutional norms. Furthermore, formal member-checking was conducted by returning interview transcripts and preliminary analytical summaries to participants, allowing them to verify descriptive accuracy and confirm that interpretations reflected their lived experiences.
- **Transferability (External Validity):** Facilitated by providing a "thick description" of the research sites, school organizational contexts, teacher demographic profiles, and broader socio-cultural dynamics of Indonesian elementary education. This allows future researchers to evaluate the applicability of the findings to similar multicultural primary school contexts.
- **Dependability (Reliability):** Maintained through a detailed, transparent audit trail documenting every stage of the research process, including raw field notes, data reduction steps, coding schemes, and decisions made during thematic development.
- **Confirmability (Objectivity):** Addressed by conducting reflexive journaling throughout data collection and analysis. Researchers documented personal assumptions, potential biases regarding Nusantara cultural preservation, and reactions to field encounters, ensuring that the final interpretations were grounded strictly in participant data rather than researcher bias.

Data Analysis

Data were analyzed using Braun and Clarke's six-phase reflexive thematic analysis, managed through NVivo qualitative analysis software. The analytical pipeline began with raw data familiarization through repeated reading of transcripts and field notes, followed by systematic line-by-line open coding to generate initial descriptive labels.

Codes were subsequently organized into broader conceptual categories and candidate themes directly aligned with the research objectives. Specifically, codes related to instructional delivery (e.g., *folkloric storytelling*, *artifact-based learning*, *regional art integration*) were synthesized into primary practice frameworks, while codes detailing operational friction (e.g., *curricular overload*, *lack of localized media*, *fear of cultural misrepresentation*) were categorized into structural and pedagogical challenges. Candidate themes were iteratively cross-checked against raw data excerpts to ensure internal homogeneity and external heterogeneity before establishing final thematic definitions.

Results and Discussion

1. Elementary Teachers' Instructional Practices in Operationalizing Nusantara Culture

Elementary teachers operationalize Nusantara cultural integration by moving beyond superficial folklore displays toward interdisciplinary, artifact-based instruction that connects local wisdom with core academic subjects. In primary classrooms, teachers leveraged regional cultural artifacts—such as Javanese *batik* geometric motifs, traditional architectural tessellations (*Rumah Gadang*), and traditional game structures (*congklak*)—to build culturally relevant conceptual bridges in core subjects like social studies, civics, and mathematics. This study aligns with the research of Banks (1993), Banks (2009), Gay (2010a), Ladson-Billings (1995), and Nieto (2000), who emphasize that culturally relevant pedagogy transforms knowledge construction by embedding

learners' cultural heritages directly into academic subjects. Comparative studies from international contexts in the United States and Europe similarly confirm that integrating local cultural artifacts into early childhood instruction enhances spatial reasoning, conceptual understanding, and cognitive engagement among diverse learners (Fox & Diaz-Greenberg, 2006; Hannan, 1983).

To foster moral and civic development, teachers utilized Nusantara folklore and indigenous community practices as foundational tools for character education. By structuring moral dilemma discussions around regional narratives and historical accounts of local leaders, educators created dialogic spaces where primary students analyzed virtue diversity, moral choices, and ethical decision-making. This finding directly aligns with the research of Curren (2016), Gilead (2011), Henderson (2023), Huo et al. (2025), Kristjánsson (2024), and Yacek and Jonas (2025), who demonstrate that developing practical wisdom (*phronesis*) in primary education requires active engagement with virtue ethical traditions and role-modeling rather than passive rule memorization. Furthermore, international comparative studies show that when moral dilemmas are contextualized within local cultural narratives, young learners develop heightened multicultural sensitivity, empathy, and ethical reasoning (Lu, 2025a, 2025b; Swedene, 2005; Wark & Krebs, 2000).

Teachers further extended cultural integration into experiential service-learning projects grounded in Nusantara communal values, particularly *gotong royong* (mutual cooperation). Students participated in collaborative school garden projects, neighborhood cleanup initiatives, and cross-cultural exchange sessions, operationalizing abstract character virtues into tangible civic behaviors. This study aligns with the research of Billig et al. (2008), Miller (2019), Nast (2020), Nucci (2017), and Shumer et al. (2012), proving that character education functions as a multifaceted developmental system best realized when theoretical values are tied to experiential

service-learning and civic action. On a global scale, synthesizing indigenous communal values with experiential civic education mirrors successful intercultural models across Australia and Europe, which bridge theoretical multiculturalism with active, respectful social participation (Mansouri & Modood, 2021; Meer & Modood, 2012).

Additionally, teachers reported that embedding Nusantara culture served as a powerful mechanism for identity salience and cultural validation among ethnically diverse primary students. By celebrating minoritized regional traditions alongside national narratives, teachers enabled students from diverse ethnic backgrounds to draw strength from their home culture and racial socialization. This finding aligns with the research of Coard et al. (2004), Forehand et al. (2002), Gallien and Jackson (2006), and Woods and Jagers (2003), who show that activating identity salience and positive cultural socialization fosters moral resilience, academic self-efficacy, and self-worth in young learners. Similar empirical evidence from Mexican American student *testimonios* illustrates how cultivating intercultural consciousness acts as a transformative counter-narrative that empowers marginalized learners within institutional spaces (Jaime-Diaz & Ramos, 2023).

This section offers significant theoretical and practical contributions to primary mathematics education and culturally responsive pedagogy. By illustrating how Nusantara cultural artifacts—such as traditional woven textiles (*tenun*), wood carvings, and architectural tessellations—can be operationalized to teach geometric transformations, symmetry, and spatial reasoning, this study advances an ethnomathematical framework for primary instruction. Practically, these findings provide mathematics educators with actionable strategies to demystify abstract mathematical concepts through familiar cultural motifs, simultaneously enhancing mathematical literacy and multicultural appreciation in young learners.

2. Pedagogical Friction, Institutional Challenges, and Structural Barriers in Cultural Integration

Despite positive pedagogical intentions, elementary teachers experienced substantial professional "wobble" and cognitive dissonance when attempting to reconcile rigid national curriculum standards with localized Nusantara cultural content. Teachers noted that high-stakes standardized assessments prioritize abstract, rote memorization, creating a time squeeze that forces educators to relegate cultural integration to peripheral or extracurricular activities. This finding aligns with the research of Fecho et al. (2005), Hamilton (2009), Hawk and Shah (2007), Murray-García et al. (2005), and Stuart (2004), who argue that meaningful professional growth requires supporting teachers through pedagogical wobble, self-reflection, and conflicting institutional mandates. Internationally, studies on preservice and in-service teachers in Norway and the United States reveal identical structural tensions, where educators struggle to align standardized accountability measures with multicultural competencies (Deroo et al., 2017; Thomassen & Munthe, 2021).

Teachers also reported acute pedagogical anxiety regarding cultural misrepresentation and religious sensitivity, frequently resorting to superficial compliance or topic avoidance when handling complex cultural topics. In religiously and ethnically heterogeneous classrooms, educators feared that introducing specific indigenous rituals or beliefs might trigger pushback from parents or dominant religious groups. This study aligns with the research of Garrett and Segall (2013), Leonardo (2002), Leonardo and Porter (2010), Levine-Rasky (2008), Orozco (2019a), and Orozco (2019b), who demonstrate that institutional "niceness" and a pedagogy of safety frequently function as mechanisms of avoidance to shield educators from uncomfortable cultural and structural discussions. Comparative studies in South Africa and the United States similarly show how teacher anxiety and dominant-group privilege lead to superficial multicultural inclusion rather than critical, transformative engagement (Jupp et al., 2016; Swartz et al., 2014).

Furthermore, systemic curriculum structures and state-approved textbooks presented Nusantara culture as static folklore rather than dynamic social practice, reflecting broader institutional tendencies toward cultural homogenization. Teachers expressed frustration with standardized textbooks that sanitized local history and omitted critical discussions on indigenous rights or regional social issues. This finding aligns with the research of Cabrera (2018), Carter Andrews et al. (2021), Crowley and Smith (2015), Flynn (2015), Gorski and Parekh (2020), Hawkman (2020), Hayes and Juárez (2009), Matias (2022), Matias and Mackey (2016), Sleeter (2016), and Sleeter (2017), who highlight how systemic dominance, critical race theory critiques, and teacher fatigue perpetuate majoritarian curricula while marginalizing critical diversity efforts. Internationally, textbook analyses in South Korea and anti-racist educational policy evaluations in Canada confirm that centralized state systems routinely prioritize standardized national unity over critical multicultural perspectives (Kim, 2021; Mansfield & Kehoe, 1994).

In ethnically pluralistic contexts, teachers were forced to navigate complex political tensions between national unity, ethnic majoritarianism, and religious identity. Operationalizing Nusantara culture required balancing state-mandated national civic frameworks with regional ethnic expectations, mirroring broader sociopolitical dynamics in divided societies. This study aligns with the research of Agbaria et al. (2015), Ari and Laron (2014), Ben-Eliezer (2008), Herzog et al. (2008), Horenczyk and Tatar (2002), Ichilov (2005), Krael-Tovi (2012), Levy (2005), Peled and Navot (2005), Pinson and Agbaria (2015), Rajuan and Bekerman (2011), Ram (2008), Rubin (2020), Sasson-Levy (2013), Smooha (2002), and Tekiner (1991), who document how state-sponsored educational systems in ethnically divided nations negotiate national belonging, ethnic hegemony, and minority inclusion [cite: Agbaria et al., 2015; Ari & Laron, 2014; Ben-Eliezer, 2008; Herzog et al., 2008; Horenczyk & Tatar, 2002; Ichilov, 2005; Krael-Tovi, 2012; Levy, 2005; Peled & Navot, 2005; Pinson & Agbaria, 2015;

Rajuan & Bekerman, 2011; Ram, 2008; Rubin, 2020; Sasson-Levy, 2013; Smootha, 2002; Tekiner, 1991].

These structural constraints were exacerbated by rapid transitions to digital learning and evolving sociotechnical landscapes. During periods of remote or hybrid instruction, teachers struggled to adapt tactile, community-based cultural activities into virtual formats, while simultaneously navigating emerging digital ethics and student disengagement. This finding aligns with the research of Alcoff (1998), Halabi (2023), Knowles (2018), Li (2025), Richmond et al. (2017), and Rios (2018), who emphasize that modern multicultural teaching requires aligning educators' civic ideologies with social justice practices amidst technological disruptions and shifting societal paradigms.

The practical and theoretical implications of these identified challenges are vital for the advancement of primary mathematics education and teacher professional development. When elementary teachers experience pedagogical wobble and cultural avoidance, interdisciplinary approaches like ethnomathematics are among the first to be discarded in favor of procedural mathematical drills. By recognizing how rigid assessment structures and cultural hesitation hinder teachers from applying indigenous spatial patterns in mathematics instruction, curriculum designers can create targeted professional development modules. Empowering teachers to overcome cultural anxiety directly enables the sustained integration of Nusantara ethnomathematics—such as utilizing traditional measurements, symmetry, and geometric patterns—thereby strengthening both primary mathematical problem-solving skills and critical cultural competence.

Conclusion

This study establishes that elementary teachers operationalize Nusantara cultural integration by moving beyond superficial folklore displays toward interdisciplinary, artifact-based instruction and service-learning, which foster mathematical spatial reasoning, identity salience, and practical wisdom (*phronesis*) in young learners.

However, these practices are frequently constrained by significant pedagogical friction, standardized curriculum demands, and cultural anxiety regarding misrepresentation, which leads teachers to resort to topic avoidance or reliance on majoritarian, homogenized textbooks. Addressing these systemic obstacles requires aligning civic ideologies with culturally sustaining practices, ensuring that local heritage enriches core academic subjects rather than being sidelined as an peripheral activity.

These findings were derived through a qualitative multi-case study design examining 15 primary school teachers across six public and private elementary schools in Yogyakarta and West Java, Indonesia. Data were systematically collected through a four-month fieldwork period encompassing semi-structured pre- and post-observation interviews, non-participant classroom observation guides tracking live pedagogical scaffolding, and a document review matrix evaluating lesson plans (*Modul Ajar*) and instructional materials. Methodological rigor and trustworthiness were ensured through data source triangulation across all three instruments, descriptive member-checking, reflexive auditing, and Braun and Clarke's six-phase reflexive thematic analysis.

To address the empirical limitations of this study—specifically its geographic concentration in urban centers of Java and its focus on primary school settings—future research should expand into rural, remote, and indigenous outer-island regions of Indonesia to capture broader socio-cultural dynamics. Further studies could also employ longitudinal or design-based implementation research to develop and test specific ethnomathematical professional development modules. Additionally, investigating student learning outcomes and affective development through mixed-methods approaches would provide deeper insights into the long-term impacts of integrating Nusantara culture across diverse educational tiers.

In an increasingly polarized and digitized global landscape, embedding indigenous cultural wisdom like Nusantara heritage into foundational education offers

a transformative model for fostering inclusive, ethically grounded global citizens. By shifting teacher preparation and curriculum design toward critical, interdisciplinary multiculturalism, educational systems can safeguard local cultural diversity while advancing core academic competencies like mathematics and civics. Ultimately, this research envisions a holistic primary education paradigm where regional traditions and universal academic skills synergize to cultivate empathetic, critical, and culturally resilient future generations.

Author Contribution

DMF: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft, Visualization. AM: Validation, Formal Analysis, Supervision, Project Administration, Writing – Review & Editing.

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Conflict of Interest Statement

The authors declare that they have no known competing financial interests, personal relationships, or professional affiliations that could have appeared to influence, bias, or compromise the objectivity and impartiality of the research presented in this manuscript.

Declaration of Generative AI and AI-Assisted Technologies

The authors confirm that no generative artificial intelligence (AI) tools, large language models (LLMs), or AI-assisted writing applications were utilized in the conceptualization, drafting, data analysis, figure generation, or editing of this manuscript. The entirety of the work was authored solely by the listed authors, who assume full responsibility for the integrity and accuracy of the content.

Additional Information

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