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Indigenous Knowledge as Educational Asset: Culturally Responsive Mathematics Education and Equity Pursuit in Indonesia's Multilingual Contexts

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Abstrak

Di negara multibahasa seperti Indonesia, pembelajaran matematika selama ini beroperasi dalam paradigma terstandar yang kurang mengakomodasi keragaman budaya dan linguistik, sehingga menimbulkan kesenjangan penelitian mengenai model berskala besar yang mengimplementasikan pedagogi responsif budaya dalam sistem yang sangat heterogen. Untuk menjawab kesenjangan tersebut, studi ini memperkenalkan model GEMBIRA sebagai kerangka analitis baru untuk mengkaji bagaimana pengetahuan matematika berbasis budaya serta penggunaan bahasa ibu dapat diintegrasikan secara sistematis. Penelitian ini mensintesis dokumen kebijakan, studi empiris yang diindeks dalam Scopus (2020–2025), dan laporan internasional untuk menganalisis koherensi kebijakan, praktik pedagogis, dan hambatan struktural. Temuan menunjukkan bahwa pendidikan matematika responsif budaya berfungsi sebagai mekanisme dekolonisasi yang memperkuat pemahaman konseptual, afirmasi identitas, dan pemerataan. Studi ini menegaskan bahwa integrasi sistem matematika lokal dalam reformasi nasional menyediakan jalur yang kuat secara matematis menuju keadilan pendidikan serta menawarkan wawasan yang dapat ditransfer untuk transformasi berorientasi kesetaraan di berbagai konteks global.

Kata Kunci: Pedagogi Responsif Budaya; Kesetaraan Pendidikan; Pengetahuan Matematika Adat; Dekolonisasi Pendidikan Matematika; Pendidikan Multibahasa Berbasis Bahasa Ibu.

Abstract

In multilingual nations such as Indonesia, mathematics instruction has long operated under standardized paradigms that suppress cultural–linguistic diversity, creating a research gap in large-scale models that operationalize culturally responsive pedagogy within highly heterogeneous systems. Addressing this gap, this study introduces the novel GEMBIRA model—treated here as a GEMBIRA model—as an analytical lens for examining how culturally rooted mathematical knowledge and mother-tongue instruction can be systematically integrated. The research synthesizes policy documents, empirical studies indexed in Scopus (2020–2025), and international reports to analyze policy coherence, pedagogical enactment, and structural constraints. Findings show that culturally responsive mathematics education functions as a decolonizing mechanism that strengthens conceptual understanding, identity affirmation, and equity. The study demonstrates that embedding indigenous mathematical systems within national reforms provides a mathematically robust pathway toward educational justice and offers transferable insights for equity-oriented transformation in diverse global contexts.

Keywords: Culturally Responsive Pedagogy; Educational Equity; Indigenous Mathematical Knowledge; Decolonizing Mathematics Education; Mother Tongue-Based Multilingual Education.

I. INTRODUCTION

Indonesia's extraordinary linguistic and cultural diversity—over 700 living languages across 17,000 islands—represents both an invaluable asset and a persistent challenge to equitable educational outcomes. Yet formal mathematics education has historically marginalized indigenous knowledge systems and local mathematical practices, positioning them as deficits rather than resources. This educational marginalization contributes to persistent inequities: only 18% of 15-year-old Indonesian students achieved above minimum competency on PISA 2022 mathematics, with 81.7% unable to demonstrate proficiency beyond lower-order thinking skills (OECD, 2023). More concerning, substantial regional disparities reveal that students from linguistically and culturally minoritized communities—particularly those in remote and frontier regions (Daerah 3T)—experience compounded disadvantages extending beyond resource constraints to fundamental challenges in pedagogical approaches, curriculum responsiveness, and cultural inclusivity (Marfuah et al., 2022; Kurniawati et al., 2018).

Indonesia's policy response demonstrates sophisticated understanding of these principles. The 2025 National Numeracy Movement (*Gerakan Numerasi Nasional*, GNN) explicitly acknowledges cultural and linguistic diversity as strategic educational resources, launching targeted initiatives emphasizing foundational numeracy through culturally grounded instructional models within the broader *Merdeka Belajar* reform architecture (Widdiharto et al., 2025). The movement operationalizes deep learning pedagogy—*Pendekatan Pembelajaran Mendalam*—emphasizing meaningful, mindful, and joyful learning characterized by authentic problem-solving, collaborative engagement, and technology-enabled interactivity (Feriyanto & Anjariyah, 2024; Musslifah et al., 2025). A distinctive feature is explicit integration of culturally responsive pedagogy, positioning students' cultural backgrounds, indigenous knowledge systems, and local mathematical practices as valuable learning resources rather than deficits (Nurhayati & Judijanto, 2025).

Indonesia's culturally responsive mathematics education is exemplified by the GEMBIRA learning model—an acronym representing integrated dimensions: *Gali dan Eksplorasi* (explore contexts close to students), *Muat konten* (embed numeracy content), *Buat aktivitas* (design meaningful activities), *Ikuti alur pikir* (follow students' thinking), and *Rayakan* (celebrate learning) (Widdiharto et al., 2025). Concrete implementations include Balinese "*Wa Pat Nem Tus Dasa*" (base-six counting system), which research documents enhances numeracy through culturally meaningful reasoning (Payadnya et al., 2025), and Javanese traditional mathematical language bridging home language experiences with formal concepts (Hendriana et al., 2025). Supporting research demonstrates culturally responsive teaching enhances engagement, deepens understanding, promotes positive mathematical identity, and supports equitable outcomes. Mother tongue-based multilingual education supports both numeracy development and

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gender-equitable outcomes in Indonesian contexts (Laksana et al., 2025).

Despite promising policy frameworks and documented intervention effectiveness, substantial implementation challenges persist. Teachers struggle with translating curriculum goals emphasizing higher-order thinking into appropriate classroom tasks, with assessments often remaining focused on lower-order skills (Zana et al., 2024). Questions persist regarding scalability, sustainability, and effectiveness across Indonesia's diverse contexts. Accountability mechanisms focused on learning outcomes remain underdeveloped, with documented evidence that Indonesia's most expensive education policies show "no discernible effects on improving learning outcomes" (Kurniawati et al., 2018). The COVID-19 pandemic created substantial learning loss disproportionately affecting disadvantaged students (Marfuah et al., 2022), amplifying pre-existing inequities.

This study addresses these critical gaps through systematic analysis examining: (1) How Indonesia's National Numeracy Movement conceptualizes culturally responsive pedagogy within policy frameworks; (2) What implementation strategies have demonstrated effectiveness; and (3) How GEMBIRA and Ethno-Realistic Mathematics Education (Ethno-RME) operationalize culturally responsive pedagogy toward transformative, equitable improvement. Through synthesis of government policy documents, Scopus-indexed empirical publications (2020-2025), and international implementation reports, this analysis triangulates policy aspirations with documented outcomes, illuminating both convergences and tensions. These findings contribute to advancing multicultural education theory and practice by examining how large-scale systems can genuinely integrate indigenous knowledge systems, validate cultural diversity, and advance educational equity through transformative pedagogy positioned within systemic, policy-level frameworks.

This study grounds itself in three interconnected theoretical traditions that illuminate how culturally responsive mathematics education can advance educational equity: sociocultural theory, ethnomathematics, and culturally responsive pedagogy.

A. Ethnomathematics as Decolonizing Practice

D'Ambrosio's (1985) ethnomathematics framework investigates mathematical ideas embedded within cultural groups, arguing that every culture develops sophisticated mathematical ways of understanding reality deserving recognition in formal education. This perspective challenges Western mathematical hegemony by positioning indigenous mathematical systems—counting methods, measurement practices, spatial reasoning, pattern recognition embedded in traditional crafts, architecture, and daily practices—as legitimate mathematical knowledge rather than informal precursors to "real" mathematics. Bishop (1988) extended this framework by identifying six universal mathematical activities—counting, locating, measuring, designing, playing, explaining—while acknowledging cultural

variations in manifestation. Ethnomathematics operates as decolonizing practice by validating marginalized knowledge systems, challenging dominant epistemologies, and creating space for multiple mathematical ways of knowing.

B. Culturally Responsive Pedagogy

Culturally responsive pedagogy, articulated by Ladson-Billings (1995) and Gay (2018), emphasizes that effective teaching in diverse contexts requires validating students' cultural identities, building on cultural knowledge as instructional foundation, and developing critical consciousness about societal inequities. This framework extends beyond superficial cultural content integration toward fundamental transformation in how teachers conceptualize knowledge, design instruction, assess learning, and position students as knowledge holders.

Paris and Alim's (2017) culturally sustaining pedagogy further emphasize that education should not merely respond to cultural diversity but actively sustain and revitalize marginalized cultural practices and languages. Applied to mathematics education, culturally responsive pedagogy requires recognizing students' home mathematical practices—marketplace calculations, traditional measurement systems, indigenous counting methods—as sophisticated knowledge deserving curricular centrality rather than mere motivational hooks.

C. Synthesis: Toward Transformative Equity

These frameworks converge in positioning cultural diversity as fundamental educational resource rather than pedagogical challenge. Indonesia's GEMBIRA model and Ethno-RME approach operationalize these principles by: (1) grounding instruction in culturally meaningful contexts (sociocultural theory); (2) validating indigenous mathematical systems as legitimate knowledge (ethnomathematics); and (3) affirming students' cultural identities while building critical consciousness (culturally responsive pedagogy). This integration positions mathematics education not merely as skill acquisition but as transformative practice advancing educational equity through cultural validation, epistemological justice, and empowerment of historically marginalized communities.

II. METHOD

This study employed comprehensive policy analysis integrating document analysis with systematic literature review to examine how Indonesia's National Numeracy Movement operationalizes culturally responsive pedagogy. This mixed-method approach triangulated findings across multiple data sources, illuminating alignment between policy aspirations and implementation realities—essential for equity-focused multicultural education research.

A. Data Sources

Three complementary data categories were systematically compiled. First, policy documents from Indonesia's Ministry of Education included: National Numeracy Movement framework (Pusat Standar dan Kebijakan Pendidikan, 2025), deep learning pedagogy strategy (Tim Penyusun, 2025), *Kurikulum Merdeka* guidelines, National Assessment reports, and Ministerial

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Regulation Number 13 of 2025. These documents reveal how policymakers conceptualize foundational numeracy, position cultural diversity as educational asset, and structure implementation support. Second, peer-reviewed academic literature indexed in Scopus database was systematically searched covering publications from January 2020 to October 2025. The Boolean search string combined keywords across three concept clusters: (1) foundational numeracy concepts ("numeracy" OR "foundational skills" OR "numeracy development"), (2) geographic and linguistic context ("Indonesia" OR "Southeast Asia" OR "multilingual context" OR "linguistically diverse"), and (3) pedagogical approach ("culturally responsive" OR "ethnomathematics" OR "indigenous knowledge" OR "culturally sustaining" OR "culturally grounded"). The search string was constructed as: ("numeracy" OR "foundational skills" OR "numeracy development") AND ("Indonesia" OR "Southeast Asia" OR "multilingual") AND ("culturally responsive" OR "ethnomathematics" OR "indigenous knowledge" OR "culturally sustaining"). Initial search yielded 487 articles. Third, international reports from OECD (2024), including PISA 2022 assessments and policy analysis, provided comparative context.

B. Literature Selection and Screening Process

A systematic selection process following PRISMA guidelines ensured transparency and replicability (Page et al., 2021). Title and abstract screening of the 487 initial results eliminated 401 articles not meeting inclusion criteria (non-empirical studies, non-relevant geographic contexts, publication date prior to 2020), yielding 86 articles for full-text review. During full-text assessment, 45 additional articles were excluded: insufficient methodological rigor (n=17), focus on higher education (n=15), lack of equity analysis (n=8), and insufficient implementation outcome detail (n=5). Final synthesis analyzed 41 peer-reviewed empirical studies.

Purposive supplementary searching identified 6 additional articles from reference lists and author tracking, bringing final literature set to 47 peer-reviewed sources. Selection decisions were documented in standardized forms ensuring consistent criterion application.

C. Selection Criteria

Literature inclusion criteria specified: (1) empirical studies on numeracy interventions or culturally responsive mathematics pedagogy in Indonesian settings; (2) research on culturally responsive or ethnomathematical approaches in multicultural contexts; (3) policy implementation studies addressing foundational skills; (4) peer-reviewed publications or reputable institutional reports; and (5) English or Indonesian language publications. Exclusion criteria eliminated purely theoretical papers, higher education research, studies predating 2020 unless foundational, and brief pilot projects lacking sustainability analysis.

D. Analytical Framework

This study employed Cardno's (2018) systematic policy analysis framework, a rigorous multi-dimensional approach designed to interrogate policy documents

and uncover policy intentions, mechanisms, and consequences. Documents were examined across five integrated analytical dimensions. First, document production and location identified policy origins, institutional authorization, and contextual positioning within Indonesia's education reform architecture. Second, authorship and audience determined creators, intended recipients, stakeholder engagement mechanisms, and how power dynamics shaped policy formulation. Third, policy context analyzed political, economic, social, and educational forces shaping numeracy policy formulation, including global competitiveness pressures, Sustainable Development Goals, and Indonesia's development vision. Fourth, policy text scrutinized stated objectives, theoretical foundations (deep learning, cultural responsiveness), implementation strategies, resource allocations, equity provisions, and how indigenous knowledge was positioned. Fifth, policy consequences and accountability evaluated intended learning outcomes, measurement mechanisms, accountability structures, and potential gaps between aspirations and achievable results.

Thematic analysis of academic literature synthesized evidence by implementation strategy (adaptive cooperative learning, cultural integration, digital media, differentiated remediation, mother tongue-based instruction) while maintaining critical equity lens. Analysis specifically examined how interventions addressed equitable outcomes for linguistically and culturally minoritized students and whether cultural diversity was positioned as pedagogical asset.

E. Integration of Triangulated Data Sources

Analysis integrated three complementary data categories through systematic triangulation ensuring comprehensive understanding of policy-to-practice alignment. Policy documents analysis revealed official policy intentions, theoretical frameworks, and stated mechanisms. Empirical literature provided evidence of implementation outcomes, challenges, and effectiveness across diverse contexts. International reports offered comparative benchmarks and global policy trends.

Triangulation occurred through iterative comparison: findings from policy analysis were systematically cross-referenced against empirical evidence to identify alignment and gaps; instances where policy aspirations diverged from implementation realities were identified and examined; international comparative context illuminated whether Indonesia’s approach was distinctive or aligned with global patterns. When sources converged (e.g., both policy documents and empirical studies emphasized cultural responsiveness), this strengthened conclusions about genuine policy commitment. When sources diverged (e.g., policy emphasized indigenous knowledge, but empirical studies documented superficial integration), analysis explicitly addressed these tensions, recognizing them as critical implementation barriers. This triangulation process enhanced analytical validity by grounding conclusions

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in multiple evidence types rather than relying on single data category.

III. RESULT AND DISCUSSION

Analysis of Indonesia's National Numeracy Movement within the *Merdeka Belajar* reform architecture reveals a sophisticated policy framework explicitly positioning cultural and linguistic diversity, 700+ languages across 17,000 islands, as pedagogical asset rather than obstacle to mathematical learning (Tim Penyusun, 2025; Pusat Standar dan Kebijakan Pendidikan, 2025; OECD, 2024). This represents a fundamental epistemological shift from deficit orientations that have historically marginalized indigenous knowledge systems toward equity-oriented approaches validating students' cultural identities and community mathematical practices as foundational to formal education (Widdiharto et al., 2025; Nurhayati & Judijanto, 2025). Findings are organized thematically to illuminate how culturally responsive pedagogy operates as transformative practice: policy framework conceptualization positioning diversity as strategic resource, GEMBIRA and Ethno-Realistic Mathematics Education as decolonizing pedagogical models, empirical evidence of equity outcomes across linguistically diverse contexts, persistent implementation barriers reflecting deeper systemic tensions, and synthesis toward sustainable multicultural mathematics education.

A. Policy Framework: Positioning Cultural Diversity as Educational Equity Strategy

Indonesia's National Numeracy Movement (*Gerakan Numerasi Nasional*, GNN), launched August 2025, explicitly integrates culturally responsive pedagogy within national policy architecture—a distinctive feature differentiating Indonesia's approach from standardization-focused reforms common in developing country contexts (Tim Penyusun, 2025; Pusat Standar dan Kebijakan Pendidikan, 2025; OECD, 2024). Policy document analysis using Cardno's (2018) framework reveals three dimensions demonstrating sophisticated understanding of equity in multicultural education.

Cultural diversity as strategic asset, not deficit – Government documents position Indonesia's extraordinary linguistic and cultural diversity—over 700 documented languages, hundreds of ethnic groups with distinct mathematical traditions embedded in daily practices—as strategic educational resource rather than pedagogical challenge to overcome (Tim Penyusun, 2025; Pusat Standar dan Kebijakan Pendidikan, 2025). These framing challenges dominant deficit narratives positioning cultural difference as obstacle, instead aligning with multicultural education scholarship emphasizing that effective teaching in diverse contexts requires validating students' cultural identities and building on cultural knowledge as instructional foundation (Gay, 2018; Ladson-Billings, 1995). Policy explicitly encourages educators to integrate local knowledge systems—indigenous counting methods, traditional measurement practices, cultural mathematical language, marketplace calculations, architectural patterns—into curriculum implementation, moving beyond superficial "cultural content"

toward genuine epistemological pluralism recognizing multiple valid mathematical ways of knowing (D'Ambrosio, 1985; Bishop, 1988).

Deep learning pedagogy as cultural responsiveness framework – The policy operationalizes deep learning pedagogy through four integrated dimensions explicitly connecting to culturally responsive principles (Tim Penyusun, 2025; Akbar et al., 2025). Authentic pedagogical practices prioritize meaningful problem-solving rooted in students lived experiences and cultural contexts rather than decontextualized procedures, addressing documented limitations where mathematics instruction remains disconnected from students' realities, particularly for linguistically and culturally minoritized communities (Preus, 2012; Hammadi et al., 2023). Learning partnerships transform traditional hierarchical teacher-student relationships toward collaborative knowledge construction honoring students as knowledge holders with valuable mathematical practices from homes and communities, a fundamental tenet of culturally sustaining pedagogy (Tim Penyusun, 2025; Kintoko et al., 2024; Rahman et al., 2025). Flexible learning environments accommodate diverse cultural learning styles, pace variations, and linguistic needs rather than imposing uniform approaches inappropriate for Indonesia's diversity (Tim Penyusun, 2025). Strategic digital technology utilization creates opportunities for culturally grounded interactive learning, with research documenting ethnomathematics-based digital media enhancing engagement when designed with cultural authenticity (Cheng et al., 2025; Massa et al., 2023; Nurhusain et al., 2025).

Equity-oriented implementation structures – Policy architecture demonstrates understanding that sustainable educational equity requires multi-level coordinated action rather than classroom-level interventions alone (OECD, 2024; Balala et al., 2021). Professional learning communities facilitate sustained teacher collaboration addressing culturally responsive pedagogy implementation challenges through cycles of planning, observation, and reflection, creating spaces for educators to develop capacity for honoring diverse cultural mathematical practices (Admiraal et al., 2021). Principal leadership development recognizes school leaders' critical roles in creating institutional conditions supporting culturally inclusive instruction, challenging deficit mindsets, and allocating resources equitably across diverse student populations (He et al., 2024). Community-based learning initiatives extend numeracy beyond formal schooling through family engagement and cultural integration, positioning families and communities as valued partners with mathematical knowledge worthy of curriculum integration (Zhou, 2025; Soesanto & Dirgantoro, 2025). These structures reflect equity-focused implementation science recognizing that marginalized communities require targeted support and resource allocation—moving beyond equality (treating everyone the same) toward equity (providing what each community needs to thrive) (Hosseinpoor et al., 2018; Khodabin & Arsalani, 2025).

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B. GEMBIRA and Ethno-RME: Culturally Responsive Pedagogy as Decolonizing Practice

The GEMBIRA learning model and Ethno-RME represent Indonesia's theoretical-practical contributions to global multicultural mathematics education discourse, operationalizing culturally responsive pedagogy within large-scale policy implementation (Widdiharto et al., 2025; Shahidayanti et al., 2024; Prahmana, 2022). Content analysis reveals Indonesia dominates global ethnomathematics research, with one Indonesian journal ranking among top four contributors—positioning GEMBIRA and Ethno-RME within rich scholarly tradition while extending it through explicit national policy integration (Darmawan et al., 2024).

GEMBIRA as transformative framework for cultural inclusion – GEMBIRA's seven interconnected dimensions embody culturally responsive pedagogy principles validated through international multicultural education research (Widdiharto et al., 2025). Guided dimension emphasizes structured scaffolding honoring students' diverse starting points and cultural ways of knowing, aligned with Vygotsky's sociocultural theory positioning learning as culturally mediated rather than universal process (Potgieter & van der Walt, 2022). Engaging prioritizes intrinsic motivation through authentic problems connecting to students' cultural interests and community concerns rather than extrinsic rewards—consistent with self-determination theory and culturally sustaining pedagogy's emphasis on meaningful learning (Nyuhuan, 2024; Meland & Brion-Meisels, 2024). Meaningful connects mathematical concepts to lived experiences, cultural practices, community contexts, and future aspirations, creating personal relevance supporting deeper engagement documented in culturally responsive pedagogy research—when students see their cultures and identities reflected in curriculum, they develop stronger mathematical identities and more positive dispositions (Gay, 2018; Ladson-Billings, 1995; Soesanto & Dirgantoro, 2025).

Beneficial ensures learning contributes to holistic development—cognitive, social, emotional, cultural, civic—beyond narrow academic outcomes, recognizing that education in multicultural contexts must simultaneously build academic competence and cultural competence, supporting students to navigate multiple cultural worlds (Meland & Brion-Meisels, 2024). Innovative encourages creative problem-solving and multiple solution strategies rather than algorithmic reproduction—validating diverse cultural problem-solving approaches as legitimate rather than positioning Western mathematical methods as singular correct approach (Ruiz-del-Pino et al., 2022; Zhan et al., 2024). Responsive demands continuous formative assessment informing instructional adjustments addressing diverse cultural-linguistic needs and learning trajectories—core principle in equity-oriented differentiated instruction recognizing one-size-fits-all approaches perpetuate inequities (Eysink & Schildkamp, 2021; Sortwell et al., 2024). Adaptive recognizes Indonesia's

extraordinary contextual variability—geographic, linguistic, cultural, socioeconomic—requiring flexible implementation respecting local knowledge and avoiding prescriptive uniformity inappropriate for diverse contexts.

Ethno-RME: Validating indigenous mathematical knowledge systems – Ethno-RME extends Indonesia's Realistic Mathematics Education tradition by explicitly incorporating ethnomathematical elements, positioning indigenous knowledge as foundational rather than supplementary (Prahmana, 2022; Shahidayanti et al., 2024). Research documents rich Indonesian linguistic-cultural diversity—718 different local languages, 1,340 ethnicities—offering tremendous potential for culturally inclusive teaching when genuinely engaged rather than marginalized (Safitri et al., 2024). Concrete implementations demonstrate validation of indigenous mathematical systems: Balinese "*Wa Pat Nem Tus Dasa*" (base-six counting system embedded in Hindu rituals and agricultural cycles) enhances early numeracy through culturally meaningful modular reasoning and pattern recognition—when mathematical learning connects to students' religious practices and community life, it becomes personally significant rather than abstract and alienating (Payadnya et al., 2025). Javanese traditional mathematical language integration bridges home language quantitative experiences with formal Indonesian-medium instruction, supporting both mathematical understanding and linguistic inclusivity—addressing reality that many Indonesian students experience cognitive-linguistic overload when instruction occurs exclusively in unfamiliar language (Hendriana et al., 2025).

Beyond language, documented successful integrations include traditional games (*congklak*/*dakon* for strategic thinking), indigenous measurement systems reflecting local agricultural and architectural practices, architectural patterns from traditional houses (*rumah adat*) involving sophisticated geometric principles, textile designs (batik motifs) requiring understanding of geometric transformations and symmetry, and marketplace mathematics demonstrating authentic contexts for developing reasoning and computational fluency (Sunzuma & Umbara, 2025; Shahidayanti et al., 2024). Shahidayanti et al. (2024) developed Ethno-RME-based three-dimensional learning modules integrating cultural and realistic contexts, achieving high validity, practicality, and potential effectiveness for critical thinking development, with students demonstrating 75.60-88.39% achievement across six critical thinking indicators—notably, findings emphasize that cultural element integration shaped positive attitudes toward mathematics by making material engaging and personally relatable.

Decolonizing potential and persistent limitations – GEMBIRA and Ethno-RME operate as decolonizing practices by challenging Western mathematical hegemony—the implicit assumption that Western mathematical traditions represent universal, culture-free knowledge while non-Western mathematical practices are dismissed as "informal," "unscientific," or mere "cultural artifacts" unworthy of

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formal education (D'Ambrosio, 1985; Bishop, 1988). By positioning indigenous knowledge systems as legitimate mathematical knowledge deserving curricular centrality, these approaches validate marginalized epistemologies and affirm students' cultural identities—addressing profound educational inequity where dominant culture knowledge is privileged while minoritized culture knowledge is erased (Gay, 2018; Ladson-Billings, 1995).

However, research reveals persistent limitations constraining transformative potential. Ethnomathematics application often lacks depth, failing to fully address cultural identity complexities, with practices sometimes restricted to superficially framing local cultural practices within existing formal mathematical knowledge rather than genuine epistemological integration—a form of "additive multiculturalism" that leaves power dynamics unchanged (Payadnya et al., 2025; Hendriana et al., 2025). This narrow focus creates situations where students not part of specific highlighted communities have their cultural dimensions overlooked, perpetuating marginalization of some groups while centering others (Safitri et al., 2024). These findings suggest that truly transformative culturally responsive pedagogy requires sustained critical reflection on whose knowledge is centered, whose remains marginalized, and how to create genuinely inclusive spaces honoring all students' cultural mathematical practices.

C. Illustrative Example or Vignette: GEMBIRA and Ethno-RME in Practice

To illustrate how GEMBIRA and Ethno-RME frameworks operationalize culturally responsive pedagogy in authentic classroom practice, consider the following illustrative example grounded in documented ethnomathematics exploration of Javanese batik motifs in number patterns learning (Khasanah et al., 2025).

Ms. Dwi teaches Grade 5 mathematics in Yogyakarta, Java, where most students' families maintain connection to batik traditions—either through artisanal work, economic participation, or cultural heritage appreciation. Recognizing batik as authentic mathematical repository rather than supplementary cultural content, Ms. Dwi designed a lesson integrating *Kawung* and *Grompol* batik pattern structures with formal mathematical concepts of number patterns, sequence, and symmetry. She selected these patterns deliberately: *Kawung* represents rectangular number patterns ($2 \times 3 = 6$, $3 \times 4 = 12$) traditionally symbolizing balance and harmony in Javanese worldview, while *Grompol* embodies square numbers (1^2, 2^2, 3^2, 4^2) representing complete family units and unity. The lesson operationalizes GEMBIRA and Ethno-RME principles through structured yet culturally responsive pedagogy addressing Indonesia's linguistic diversity—the class includes students from Javanese, Sundanese, and Banjarese family backgrounds.

Ms. Dwi begins by displaying authentic batik cloth samples and digital images from documented ethnomathematical research on *Kawung* motifs. "*These patterns your*

grandparents created—look carefully. Do you see mathematics?" Students immediately recognize repetitive structures. Khai, whose grandmother is batik artisan, excitedly points out the oval shapes: "*These come in groups—one, then two beside it, then more... it keeps growing but stays balanced!*" Ms. Dwi affirms this intuitive observation, introducing formal language: "*Khai noticed what mathematicians call rectangular numbers—when we arrange objects in rows and columns.*" She scaffolds understanding through structured activities (Guided dimension): students physically arrange wooden blocks into rectangular configurations (2×3, 3×4, 4×5), discovering the pattern formula $n(n+1)$. Using *Grompol* motif images, they arrange blocks into perfect squares (1×1, 2×2, 3×3), deriving n^2 formula. Critically, Ms. Dwi connects cultural meaning: "*Grompol means gathering. Watch—one dot is family beginning, four dots are parents and children, nine dots represent spiritual journey to perfection.*" This bridges indigenous knowledge with formal mathematics, validating students' cultural understanding as legitimate mathematical thinking.

This lesson operationalizes GEMBIRA through integrated dimensions. Guided scaffolding progresses from concrete (physical blocks, authentic batik), to representational (diagrams of patterns), to abstract (algebraic formulas). Engaging learning emerges authentically—students work with culturally meaningful objects connecting to their family histories and community practices, not artificial word problems. Motivation is intrinsic: Khai leads group discussions about family knowledge; Siti (Sundanese speaker) demonstrates spatial reasoning particularly strongly using visual manipulatives, revealing mathematical capability previously obscured in language-heavy instruction. Meaningful learning anchors number patterns in lived experience. When students see rectangular and square numbers embedded in batik their families recognize as valuable, mathematics becomes personally significant rather than abstract. Beneficial outcomes extend beyond cognitive learning: cultural identity affirmation (indigenous knowledge recognized as mathematical), linguistic inclusivity (geometric patterns accessible across language backgrounds), and emerging mathematical identities ("*my family's work is mathematics*"). Innovative problem-solving emerges when Ms. Dwi asks: "*If Kawung follows 2×3, 3×4, 4×5 pattern, what comes next? Could your family create new patterns?*" Students propose variations, discovering that multiple solution pathways exist. Responsive assessment through observation reveals that manipulatives-based learning with opportunity for home language explanation surfaces mathematical understanding Siti and non-Javanese speakers previously struggled to demonstrate in traditional instruction. Adaptive implementation recognizes diverse student backgrounds—the lesson's batik context is culturally anchored in Yogyakarta setting, while mathematical principles transfer to any cultural patterns students' communities create.

Following the lesson, students demonstrate both cognitive and affective

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growth aligning with ethnomathematics research findings. Quantitatively, post-lesson assessment shows students can identify and generalize number patterns with significantly higher accuracy when patterns are grounded in batik contexts versus abstract numerical sequences, consistent with evidence that culturally meaningful contexts enhance mathematical understanding and engagement. Qualitatively, student reflections reveal profound equity shifts. Khai states: "*I didn't know making batik was doing mathematics. My grandmother is a mathematician!*" This transformation from home knowledge as "non-academic" to legitimate mathematical knowledge represents foundational equity outcome. Siti, previously discouraged by mathematics instruction conducted entirely in Indonesian unfamiliar from home, demonstrates confident spatial reasoning and asks: "*Can we make batik patterns using the number rules we found?*" indicating emergent mathematical identity and sense of belonging. Students from non-artisan backgrounds request to investigate mathematical patterns in their own families' practices, weaving, cooking, building, signaling that lesson communicated inclusive message: all communities possess mathematical knowledge worthy of curricular recognition. These outcomes exemplify how GEMBIRA-based implementation operationalizing Ethno-RME principles addresses documented equity challenges. By positioning indigenous mathematical knowledge as foundational rather than supplementary, by creating learning environments where students' cultural practices and home languages are recognized as mathematical resources, and by using formative assessment responsive to diverse learning strengths, the lesson moves beyond standardized approaches that perpetuate marginalization toward genuinely inclusive mathematics education where historically underserved students experience validation, belonging, and empowerment.

This vignette demonstrates that culturally responsive mathematics education requires not merely theoretical sophistication but deliberate pedagogical choices, scaffolding, meaningful contexts, responsive assessment, adaptive implementation, that position students' cultural knowledge as foundational to mathematical learning. The outcomes documented through ethnomathematics research, presented in the following section, confirm that such implementation produces measurable equity gains across diverse student populations.

D. Equity Outcomes: Evidence from Linguistically Diverse Contexts

Empirical research documents measurable equity outcomes when culturally responsive approaches are implemented with fidelity, particularly for linguistically and culturally minoritized students historically underserved by standardized mathematics instruction.

Mother tongue-based multilingual education: Linguistic justice and equity – Laksana et al. (2025) investigated mother tongue-based multilingual education (MTB-MLE) programs beginning mathematics instruction in students' first languages

before transitioning to Indonesian, documenting through longitudinal quasi-experimental research support for both numeracy development and gender-equitable outcomes with notable improvements in male and female students' national assessment performance. These findings address Indonesia's extraordinary linguistic reality, over 700 documented languages, where many students' home languages differ substantially from Indonesian instructional medium, creating cognitive-linguistic load hindering mathematical understanding while implicitly communicating that their languages and cultures are inferior (Laksana et al., 2025; Zein, 2020). MTB-MLE reduces cognitive load while validating linguistic-cultural identities, simultaneously supporting effectiveness and equity goals, when students learn mathematics in languages they think and dream in, they access mathematical concepts more deeply while experiencing affirmation that their linguistic heritage is valued (Laksana et al., 2025; OECD, 2024).

Research on early numeracy determinants confirms engaging children in home-based numeracy activities in their mother tongue enhances school readiness and subsequent achievement trajectories, with particular benefits for children from linguistically minoritized communities (Makur et al., 2019; Graven & Jorgensen, 2024). These findings substantiate that linguistic diversity represents pedagogical asset rather than deficit when educational systems honor rather than suppress home languages, a fundamental principle of culturally sustaining pedagogy emphasizing that education should not merely respond to cultural diversity but actively sustain and revitalize marginalized cultural practices and languages (Laksana et al., 2025).

Cultural integration promoting mathematical identity and engagement – Ethnomathematics research demonstrates that explicit integration of indigenous mathematical systems enhances not only achievement but also students' mathematical identities and dispositions, critical equity outcomes beyond test scores (Payadnya et al., 2025; Hendriana et al., 2025; Shahidayanti et al., 2024). When Balinese students engage with "*Wa Pat Nem Tus Dasa*" counting system embedded in their religious and cultural practices, they experience mathematics as connected to their identities rather than imposed from external dominant culture, fostering sense of belonging and competence rather than alienation (Payadnya et al., 2025). When Javanese students encounter traditional mathematical language bridging home quantitative experiences with formal concepts, they recognize their families and communities as knowledge holders with valuable mathematical practices worthy of academic recognition (Hendriana et al., 2025).

Systematic literature reviews confirm ethnomathematics research in Indonesia has grown substantially, particularly during 2019-2020, with documented implementations spanning traditional games, indigenous measurement systems, architectural patterns, textile designs, agricultural mathematics, and marketplace practices as authentic contexts for developing reasoning (Darmawan et al., 2024; Sunzuma & Umbara, 2025). Critically, research documents that cultural element

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integration shapes positive attitudes toward mathematics by making material engaging and relatable—addressing persistent challenge where mathematics is experienced as abstract, irrelevant, and disconnected from students' lives, particularly for culturally minoritized students whose experiences are rarely reflected in standardized curriculum (Shahidayanti et al., 2024).

E. Implementation Practical Challenges and Systemic Impact Transformation to Educational Equity

Despite promising frameworks and documented intervention effectiveness, substantial systemic barriers impede policy-practice translation, revealing deeper tensions between standardization imperatives and genuine cultural responsiveness.

Teacher capacity and epistemological shifts – Teacher capacity deficits constitute primary implementation barrier, though this reflects deeper ideological challenges beyond technical skill gaps. While curricula emphasize higher-order thinking, assessments remain focused on lower-order skills, with teachers struggling to translate equity-oriented goals into culturally responsive tasks (Zana et al., 2024; Marfuah et al., 2022). When teachers view indigenous mathematical practices as "informal" rather than sophisticated knowledge systems, they undermine pedagogical transformation—superficially incorporating cultural content while maintaining hierarchies privileging Western traditions (Zana et al., 2024). Conceptual confusion between "mathematics" as formal discipline and "numeracy" as practical problem-solving undermines implementation fidelity (Forgasz & Hall, 2019). Professional development effectiveness varies considerably; while interventions enhanced knowledge, they faced technological barriers and limited practical application opportunities (Marfuah et al., 2022). Sustainable capacity building requires fundamental shifts in epistemological beliefs about whose knowledge counts and how cultural diversity relates to educational excellence.

Superficial integration and epistemological violence – Research reveal ethnomathematics application often lacks depth, failing to challenge Western mathematical hegemony (Payadnya et al., 2025; Hendriana et al., 2025). Practices sometimes frame local cultural knowledge within existing formal mathematical frameworks—using culture as motivational hook rather than genuine epistemological resource, perpetuating "epistemological violence" where indigenous knowledge is appropriated within dominant frameworks rather than honored on its own terms (Safitri et al., 2024). This narrow approach overlooks communities whose cultural dimensions remain unrepresented, reproducing marginalization culturally responsive pedagogy aims to address.

Toward transformative change – These gaps reflect broader tensions between standardization pressures and cultural pluralism. Indonesia demonstrates theoretically sophisticated policy frameworks positioning cultural diversity as strategic asset, with GEMBIRA and Ethno-RME providing concrete, scalable

operationalization (Pusat Standar dan Kebijakan Pendidikan, 2025; Widdiharto et al., 2025; Shahidayanti et al., 2024). Empirical evidence documents equity outcomes—mother tongue instruction supporting gender equity, cultural integration enhancing mathematical identities, adaptive approaches addressing diverse needs (Laksana et al., 2025; Payadnya et al., 2025; Hendriana et al., 2025; Shahidayanti et al., 2024). Yet sustainable equity requires confronting uncomfortable questions: Can large-scale systems genuinely honor 700+ linguistic-cultural communities, or does standardization inherently marginalize diversity? Who determines legitimate mathematical knowledge? Indonesia's integration of culturally responsive pedagogy within national policy positions it to lead global discourse on mathematics education in diverse developing contexts (OECD, 2024; Khodabin & Arsalani, 2025).

Persistent tensions and pathways forward – Substantial implementation challenges reveal deeper systemic tensions requiring fundamental epistemological shifts challenging deficit mindsets and Western mathematical hegemony. Culturally responsive pedagogy implementation demands confronting power dynamics: whose knowledge is privileged and how educational systems perpetuate or challenge marginalization. Accountability mechanisms must evolve toward equity-focused evaluation examining whether all cultural communities experience validation and inclusion.

Indonesia's extraordinary cultural-linguistic diversity represents pedagogical asset provided systems genuinely engage rather than marginalize it (Safitri et al., 2024). Sustainable equity requires moving beyond efficiency-focused reforms toward transformative approaches positioning cultural diversity as foundational to mathematics education. The National Numeracy Movement's success will ultimately be measured by whether historically marginalized communities experience genuine validation, inclusion, and empowerment—whether indigenous mathematical knowledge moves from periphery to center, challenging dominant epistemologies.

IV. CONCLUSION

Indonesia's National Numeracy Movement demonstrates theoretically sophisticated policy frameworks positioning cultural and linguistic diversity as pedagogical asset. The GEMBIRA learning model and Ethno-Realistic Mathematics Education operationalize culturally responsive pedagogy, with empirical evidence documenting effectiveness: adaptive cooperative learning, cultural integration utilizing indigenous mathematical systems, mother tongue-based instruction, and differentiated remediation enhance both numeracy outcomes and educational equity. However, substantial gaps between policy aspirations and classroom realities reveal that transforming frameworks into practice requires deliberate teacher preparation targeting specific competencies.

Critical teacher development must focus on two pedagogical stages: *Gali dan Eksplorasi* (explore contexts close to

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students) phases focusing on ethnomathematics exploration and *Bahas* (translanguaging). For *Gali dan Explorasi* phases, teachers require competencies to identify mathematical structures embedded in cultural artifacts through systematic observation; collaborate with community members and cultural practitioners as co-learners; analyze how cultural symbols encode mathematical principles; and design culturally grounded mathematical tasks where cultural contexts serve as foundational rather than supplementary. Furthermore, for the phases of *Buat aktivitas* (design meaningful activities) and *Ikuti alur pikir* (follow students' thinking), teachers must: recognize and legitimize multilingual students' home language mathematical reasoning; facilitate strategic code-switching enabling students to transition from home language to formal Indonesian mathematics; explicitly teach translation between informal cultural-embedded mathematical language and academic terminology; and conduct formative assessment responsive to linguistic diversity. Developing these competencies demands sustained professional development, not isolated workshops, including ethnographic field experiences, collaborative lesson design cycles, discourse analysis of multilingual mathematical thinking, and critical examination of epistemological assumptions about whose knowledge "counts."

Transforming sophisticated frameworks into classroom realities benefiting 53+ million students—particularly linguistically minoritized and economically disadvantaged communities—depends on unwavering commitment to teacher preparation, school leadership support, and equity-focused assessment. Whether Indonesia's numeracy reform becomes a model for transformative multicultural education ultimately rests on whether these specific teacher competencies are deliberately developed and systematically supported across all schools.

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