

BEYOND THE DIGITAL DIVIDE: FRUGAL PEDAGOGY AND TEACHER RESILIENCE IN MATHEMATICS EDUCATION

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Abstract

This qualitative study investigates the pedagogical practices and professional resilience of mathematics teachers in severely under-resourced junior high schools in the interior of North Aceh, Indonesia. In a context defined by a chronic lack of infrastructure, teaching aids, and internet connectivity, the dominant techno-centric paradigm of mathematics education is rendered irrelevant. Through semi-structured interviews with seven teachers, the research employed thematic analysis to explore how effective instruction is conceived and enacted within systemic constraints. The findings reveal a sophisticated model of context-embedded frugal pedagogy, characterized by three interrelated themes: the creative improvisation of teaching materials from the local socio-cultural environment; the reconfiguration of the teacher's role into a holistic motivator and cultural broker; and the cultivation of resilience through a deep sense of purpose and informal professional communities. The study concludes that in low-resource settings, pedagogical quality is principle-driven rather than technology-dependent, with the teacher-student relationship serving as the primary affordance for learning. This research challenges deficit narratives by demonstrating how constraints can catalyze pedagogical innovation and robust professional identity. It advocates for the inclusion of frugal pedagogy in teacher training and proposes a more pluralistic, context-sensitive understanding of effective mathematics education.

Keywords: *Contextualized Teaching, Frugal Pedagogy, Mathematics Education, Resource-Constrained Settings, Teacher Resilience*

INTRODUCTION

Mathematical proficiency is crucial in vocational education and training (VET), but many students feel unconfident in their math abilities, leading employers to question graduates' readiness for practical applications (Voss et al., 2025). Besides, the global discourse on quality mathematics education is predominantly framed within contexts of technological advancement, resource availability, and digital integration, often positioning these elements as prerequisites for effective pedagogical practice (Hoyles, 2018). This paradigm, however, risks marginalizing educational communities operating in resource-constrained environments, rendering their unique challenges, adaptations, and pedagogical innovations invisible within the broader academic literature. Indonesia, with its vast and geographically dispersed archipelago, presents a stark landscape of educational disparity, where urban centers may enjoy relative technological prosperity while remote and interior regions grapple with profound infrastructural deficits (Rahmawati et al., 2022).

North Aceh, a region in the northernmost part of Sumatra, exemplifies such a context. Many of its junior high schools (SMP) are characterized by inadequate physical infrastructure, a chronic shortage of teaching aids, and severely limited or non-existent internet connectivity, creating an environment that, from a conventional perspective, would be deemed prohibitive to meaningful mathematics instruction. Yet, within these constraints, teachers persist, demonstrating resilience and a commitment to their students' learning. This study, therefore, seeks to descriptively explore and qualitatively document the lived experiences, pedagogical strategies, and sustaining motivations of mathematics teachers in these underserved junior high schools in North Aceh, Indonesia. The research is driven by the necessity to illuminate the often-overlooked narratives of teaching and learning that thrive not because of, but despite, systemic limitations. The critical role of mathematics in fostering logical reasoning, problem-solving skills, and national development is universally acknowledged. Consequently, significant scholarly attention has been devoted to identifying effective teaching methodologies. The integration of digital tools, blended learning models, and sophisticated manipulatives as pathways to conceptual understanding. While valuable, this focus inadvertently

establishes a normative framework that can stigmatize or invalidate non-digital, resource-light approaches. As Borba (2021) critically notes, the pandemic-era rush towards digitalization has further entrenched the idea that quality education is synonymous with technology-mediated instruction, potentially devaluing the human-centric, improvisational skills that are paramount in low-resource settings. This creates a significant gap in understanding. What constitutes effective pedagogy when the foundational assumptions of contemporary educational research—reliable electricity, internet access, and commercial learning aids—are absent? The context of North Aceh provides a critical site to interrogate this question, moving beyond a deficit perspective that views limitations as purely inhibitory, towards an asset-based perspective that explores how constraints can catalyze pedagogical creativity and resilience.

Indeed, emerging research begins to suggest that scarcity can foster innovation. Teachers developed highly contextualized and culturally relevant analogies and low-cost experiments when standard laboratory equipment was unavailable, leading to deep student engagement. Similarly, in the Indonesian context, studies have highlighted the challenges of remote education but have less frequently zoomed in on the specific, day-to-day pedagogical decision-making of mathematics teachers in perpetually low-resource (as opposed to crisis-induced) environments. This study posits that the sustained, everyday practice of teaching mathematics in a context of chronic deprivation represents a distinct phenomenon worthy of detailed, qualitative investigation. Mathematics is viewed as a human activity and social phenomenon rather than a static body of knowledge, evolving within cultural and historical contexts (Gula & Jojo, 2024). The novelty of this research lies in its deliberate and focused phenomenological exploration of mathematics-specific pedagogy in the permanent "low-tech" environment of North Aceh's interior. It aims to generate a thick description of how abstract mathematical concepts are translated and made comprehensible using only locally available materials, how teachers conceptualize their role as motivators amidst generational poverty and geographical isolation, and how their professional identity is shaped and sustained by these challenges.

Understanding these dynamics carries significant practical and theoretical benefits. Practically, the findings will provide a valuable repository of grassroots pedagogical innovations—what can be termed "frugal pedagogies"—that could be adapted and shared with teacher training colleges and professional development programs serving similar regions across Indonesia and the global south. Documenting successful, context-appropriate strategies can empower other teachers in resource-poor settings, moving beyond generic, often impractical, training modules developed in urban centers. Furthermore, insights into teacher motivation and resilience can inform regional educational authorities on how to better support and retain dedicated educators in hardship posts, potentially through recognition systems or supportive communities of practice that validate their adaptive work.

Theoretically, this research contributes to challenging and expanding the dominant narratives of effective mathematics education. By bringing to the fore the practices of teachers in North Aceh, it argues for a more pluralistic and context-sensitive understanding of pedagogical quality. It engages with and seeks to contribute to theoretical frameworks surrounding teacher agency, resourcefulness, and embodied pedagogy—concepts that are often secondary in techno-centric models of education. As Westheimer (2022) argues, an overemphasis on technical and technological solutions in education can obscure the fundamental human relationships at the heart of teaching. This study places those relationships—between teacher, student, knowledge, and a challenging environment—at the center of the inquiry. It asks not what these teachers lack, but what they *do*; not how their practice deviates from a presumed global standard, but how it constitutes a valid and informed response to their specific reality.

LITERATURE REVIEW

The Dominant Techno-Centric Paradigm and Its Discontents in Mathematics Education

Contemporary global discourse on mathematics education is heavily oriented towards integration of digital technologies, sophisticated manipulatives, and innovative learning spaces as primary drivers for pedagogical improvement. They believe that teachers utilized innovative methods for remote engagement, highlighting the necessity for improved digital literacy, better allocation of ICT resources, and sufficient training for teachers in a technology-driven teaching landscape (Munyanyo & Simuja, 2024). This paradigm positions access to resources—from reliable internet and interactive software to structured, commercially produced teaching aids—as a foundational element of quality instruction. Research within this frame extensively explores the benefits of digital game-based learning, virtual manipulatives, and blended learning models for enhancing student engagement and conceptual understanding in mathematics. Such studies, while valuable, often operate from an implicit assumption of resource availability, constructing a normative model of "effective" teaching that is deeply embedded in technological and material affordances.

This creates a significant scholarly blind spot, as it marginalizes contexts where such resources are perpetually absent. The danger, as critically noted by Borba (2021), is that the rapid digital acceleration, especially post-pandemic, risks equating good pedagogy solely with technology integration, thereby devaluing alternative, non-digital forms of knowledge transmission and teacher creativity. Consequently, the lived realities and professional practices of educators in regions with chronic infrastructural deficits, such as interior North Aceh, remain largely absent from mainstream international educational literature. This omission perpetuates a deficit narrative, framing these contexts solely by what they lack rather than by the pedagogical ingenuity that scarcity may necessitate and foster.

Pedagogical Innovation and Resourcefulness in Constrained Environments

Emerging scholarship, however, is beginning to chart a counter-narrative by examining how teachers in low-resource settings exercise agency and develop contextually relevant pedagogies. This body of work shifts the focus from a deficit perspective to an asset-based one, exploring how constraints can serve as catalysts for innovation. Central to this concept is the idea of "frugal innovation" or "jugaad"—a flexible, improvisational approach to problem-solving that utilizes limited resources. In education, this translates to what can be termed "frugal pedagogy." In the specific domain of mathematics education, similar adaptive strategies are evident, though less extensively documented in international journals. Different forms of learning aim to improve overall student performance (Muslem et al., 2019). The use of local artefacts, natural materials, and culturally embedded practices for teaching mathematical concepts represents a form of ethnomathematics in action. This approach aligns with the broader argument that meaningful learning occurs when instruction is situated within the learner's lived experience. For instance, using agricultural patterns to teach geometry or market transactions to illustrate arithmetic provides a concrete foundation for abstract reasoning.

Furthermore, the role of the teacher in such environments expands beyond content delivery to that of a motivator, cultural broker, and resilience figure. Recent research emphasizes that teacher resilience in challenging circumstances is not merely an individual trait but a dynamic process influenced by professional values, supportive relationships, and a sense of purpose (Mansfield et al., 2022). Teachers can boost student participation in the instructional process by using engaging activities, supportive materials, and rewards (Hajar et al., 2024). Teachers who persist and innovate despite obstacles often draw motivation from a deep commitment to their students' futures and a belief in the transformative power of education, factors that are crucial for sustaining practice in isolated and under-resourced schools.

The Indonesian and Acehese Context: Bridging the Knowledge Gap

Within the Indonesian educational landscape, the issue of resource disparity between urban and remote regions is acute and well-documented. Studies have highlighted the challenges of implementing national curricula in remote schools, issues of teacher distribution and quality, and the impact of geographical isolation on educational outcomes (Rahmawati et al., 2022). However, a critical gap remains. While these studies effectively map the structural problems and often recommend policy-level solutions (e.g., improved infrastructure, incentives for teachers), there is a paucity of fine-grained, qualitative research that delves into the *micro-practices* of classroom instruction in these settings. Specifically, the question of *how* mathematics teachers in permanently low-resource environments, like the interior of North Aceh, design and execute their daily lessons remains underexplored.

North Aceh presents a unique socio-geographical context within Indonesia. Recovering from a prolonged conflict and facing the challenges of remoteness, its educational infrastructure lags. The region's distinct cultural identity also offers a rich tapestry for contextualizing learning. Yet, the existing literature on Aceh's education system tends to focus on post-conflict reconstruction, Islamic education, or broad access issues, seldom zooming in on subject-specific pedagogical realities in its most isolated junior high schools. This study, therefore, seeks to address this dual gap: first, in the international literature, which overlooks non-technocentric mathematics pedagogy, and second, in the Indonesian/Acehese literature, which lacks a deep descriptive analysis of in-class teaching adaptations. By systematically investigating and theorizing the practices of mathematics teachers in North Aceh's interior SMPs, this research aims to contribute a nuanced understanding of "frugal pedagogy" in mathematics. It posits that the strategies developed by these teachers—their improvisation with local materials, their methods for sustaining student motivation without digital tools, and their own sources of resilience—constitute a valuable and under-recognized body of professional knowledge. Documenting this knowledge not only validates their work but also offers tangible, transferable insights for teacher education programs serving similar contexts worldwide, ultimately advocating for a more inclusive and pluralistic vision of what constitutes effective mathematics teaching.

METHOD

This study employs a descriptive qualitative research design to investigate the pedagogical practices and professional resilience of mathematics teachers in resource-constrained junior high schools (SMP) in the interior region of North Aceh, Indonesia. The descriptive qualitative approach is deemed the most appropriate as it seeks to capture, describe, and interpret the complex, nuanced phenomena of teaching strategies and teacher experiences within their natural, real-world context (Creswell & Poth, 2018). This methodology prioritizes depth over breadth, aiming to generate rich, detailed narratives that illuminate how teachers conceptualize and enact their instructional roles amid significant infrastructural and material deficits. The study was conducted across four purposefully selected SMPs in the inland districts of North Aceh, characterized by chronic inadequacies in educational infrastructure, poor or non-existent internet connectivity, and a severe shortage of conventional teaching aids. These sites were selected through purposive sampling to ensure they represent the specific context under investigation—permanent, low-resource environments, as opposed to schools experiencing temporary hardship.

Participants comprised seven mathematics teachers, one to two from each school, who voluntarily agreed to participate after a detailed briefing on the study's objectives and ethical protocols. The number of participants aligns with recommendations for qualitative inquiry that aims for depth and saturation of themes rather than statistical generalization (Smith & McGannon, 2018). The inclusion criteria required participants to be certified mathematics teachers with a minimum of three years of teaching experience in their current or similar resource-limited schools, thereby ensuring they possess substantive experience navigating the constraints under study. Before data collection, ethical clearance was obtained, and all participants provided informed consent, with guarantees of anonymity, confidentiality, and the right to withdraw at any time without repercussion. Pseudonyms were assigned to both individuals and schools to protect their identities.

The primary method of data collection was semi-structured interviews, a technique highly effective for exploring participants' perspectives, experiences, and the meanings they attribute to their practices (Brinkmann & Kvale, 2018). An interview protocol was developed, guided by the central research questions, containing open-ended questions designed to elicit detailed accounts. The protocol covered thematic areas including: (1) detailed descriptions of specific mathematics lessons taught with limited resources, (2) strategies for developing or adapting teaching aids from local materials, (3) perceptions of student engagement and learning challenges, (4) sources of personal motivation and professional resilience, and (5) perceived support systems and unmet needs. The semi-structured nature allowed for flexibility, enabling the researcher to probe emerging themes and follow participants' narratives while maintaining a focus on the core research aims.

Each interview, conducted in Indonesian or the local Acehnese dialect at the participant's preference, lasted between 30 and 50 minutes. With participants' permission, all interviews were audio-recorded to ensure accuracy and subsequently transcribed verbatim. Field notes were also taken during and after school visits to capture contextual observations regarding the physical classroom environment, available resources, and general school atmosphere, thereby enriching the interview data with descriptive context. Data analysis followed an iterative thematic analysis approach as outlined by Braun and Clarke (2022), which involves a systematic process of moving from description to interpretation. The process began with repeated, active reading of the interview transcripts and field notes to achieve immersion in the data. Initial coding was then conducted, whereby significant phrases, sentences, or paragraphs about pedagogical adaptation, resource utilization, and teacher resilience were identified and labeled. These initial codes were then collated and organized into potential themes—broader patterns of meaning that capture something important about the data in relation to the research questions. For instance, codes such as “using stones for arithmetic,” “creating geometric shapes from bamboo,” and “developing stories for word problems” were grouped under a potential theme tentatively labeled “Improvisation with Locally Sourced Materials.”

The candidate themes were reviewed and refined at two levels: first, by checking if they worked in relation to the coded extracts, and second, by considering the entire dataset to ensure the themes accurately represented the totality of the participants' experiences. This refinement process resulted in a final thematic map. To enhance the trustworthiness and credibility of the analysis, member checking was employed, where preliminary interpretations and themes were shared with a subset of participants for verification and feedback (Creswell & Poth, 2018). Furthermore, the researcher maintained a reflective journal to bracket potential biases and document the analytical decisions made throughout the study, thus contributing to the auditability of the research process.

RESULTS AND DISCUSSION

This study set out to explore the pedagogical practices and sustaining motivations of mathematics teachers in the under-resourced junior high schools of interior North Aceh. Through in-depth interviews with seven teachers,

the analysis revealed a rich tapestry of adaptive expertise and profound resilience, challenging the dominant techno-centric paradigm of effective mathematics education. The findings coalesce around three interconnected themes: the embodiment of frugal pedagogy through localized improvisation, the reconfiguration of the teacher's role as a holistic motivator and cultural broker, and the sources and expressions of professional resilience. These themes collectively illustrate not merely a story of coping with lack, but one of innovative practice and meaningful engagement forged within constraints.

Frugal Pedagogy: Translating Abstraction through Localized Improvisation

The most salient finding is the consistent and sophisticated practice of what we term contextual material improvisation. Confronted with a near-total absence of commercial teaching aids, unreliable electricity, and no digital tools, the teachers demonstrated remarkable ingenuity in constructing mathematical meaning from their immediate environment. A respondent, Mr. Adi (pseudonym), for instance, described teaching linear equations using a homemade bamboo scale balanced on a nail, with bottle caps as weights. This tangible model allowed students to physically manipulate both sides of the "equation" to maintain balance, providing a kinesthetic understanding of the principle of equality that abstract symbolic manipulation alone could not achieve. Similarly, Ms. Rina detailed using arrays of stones and seeds to teach multiplication, division, and factors, while another teacher, Mr. Fajar, used the school's tiled floor as a giant coordinate plane, with students physically becoming points to understand ordered pairs and quadrants. This improvisation was not random but deeply contextualized and culturally embedded, a form of situated ethnomathematics. Teachers consistently wove local agricultural products, market practices, and community activities into problem-posing. As Ms. Rina explained, "When teaching volume, we don't talk about unknown tanks. We calculate the volume of the *gentong* (clay water jar) in the school yard, or how much soil is needed to fill the chili plant bed." The teachers' practices serve as a powerful counter-narrative to the assumption that conceptual understanding is dependent on high-tech tools. As one participant, Mr. Zulkifli, poignantly stated, "The best teaching aid is the environment around us.

The market, the rice field, the garden—these are our laboratories." This ethos echoes the critique by Borba (2021) on over-reliance on non-living things, re-centering the pedagogical focus on human interaction with the living, local environment. Simanjuntak et al. (2025) also reported that applying the material through counting activities involving traditional games or local activities can improve accuracy and problem-solving skills. Gula and Jojo (2024) also observed that teachers developed skills to embrace culture and connected mathematics content with real-world situations, leading to productive struggles that enhanced higher-order thinking in their interactions with learners. This approach directly connects the abstract curriculum to students' lived realities, enhancing relevance and combating the perception of mathematics as a distant, irrelevant subject. It validates the argument that meaningful learning is fostered when instruction is anchored in the learner's experiential world. This observation further underscores that pedagogical success is not inherently contingent upon technological integration, though the latter may enhance the efficacy of the learning process.

Beyond Instruction: The Teacher as Holistic Motivator and Cultural Broker

The data compellingly show that in an environment of material and infrastructural scarcity, the teacher's role expands far beyond content delivery. A second major theme is the reconfiguration of the teacher into a holistic motivator, emotional anchor, and cultural broker. The constraints of the environment—poverty, geographical isolation, and limited future horizons for students—meant that cognitive engagement in mathematics was inextricably linked to affective and motivational support. Teachers described spending significant time on "mental building" or "spirit motivation" before even beginning a lesson. Mr. Adi shared, "Mathematics is already considered frightening. If their spirit is low because of life's difficulties, they will shut down completely. So my first job every day is to be a motivator, to tell them that their situation now does not determine their future."

This role aligns with recent conceptualizations of teacher resilience as a dynamic, relational process rather than a fixed trait (Mansfield et al., 2022). The teachers acted as cultural brokers, translating not just mathematical concepts, but also the value of education within a specific socio-cultural context. Collaboration between teachers, parents, and the community is essential for integrating local wisdom into education and preserving traditional values (Hajar et al., 2025). Teachers framed perseverance in mathematics as analogous to resilience in farming—requiring patience, care, and step-by-step effort. They leveraged community values of cooperation and mutual aid, often structuring group work not just as a pedagogical strategy but as a practice of social solidarity. This holistic approach highlights a critical gap in standard teacher training and the techno-centric model, which largely ignores the profound socio-emotional labor required to teach in marginalized communities. The teacher-student relationship emerged as

the primary "technology" for learning, a finding that resonates with Westheimer's (2022) caution against over-emphasizing technical solutions at the expense of human connections. The data suggest that in low-resource settings, the quality of this relational bond is the single most important affordance for learning.

Sustaining the Sustainers: The Wellsprings of Teacher Resilience

The third theme delves into the sources of the teachers' own resilience, answering the question of how they sustain their motivation and innovative spirit amidst chronic challenges. The analysis revealed a complex interplay of intrinsic, relational, and value-driven factors. As reported by Voss et al. (2025), teachers face challenges in implementing innovative strategies and meeting diverse student needs, resulting in a disconnect between educational delivery and learning requirements in mathematics education. However, they also reveal positive experiences influenced by teachers' beliefs in effective student learning, aligning with best practices in numeracy education and indicating potential improvements for mathematics instruction. A powerful source of motivation was a deep-seated sense of purpose and moral responsibility. Participants frequently described their work as a "calling" (*panggilan*) or "service" (*pengabdian*) to their home region. Ms. Sari, who returned to her village after university, stated, "If I don't teach them, who will? Seeing a child finally understand a concept, seeing their eyes light up, that is my reward. That light is worth more than any facility." This aligns with research identifying a strong sense of purpose as a core component of teacher resilience (Mansfield et al., 2022).

Furthermore, resilience was nurtured through improvised professional communities and student success. In the absence of formal, frequent professional development, teachers created informal support networks. They described exchanging ideas with colleagues in neighboring schools during rare meetings or via SMS, creating a grassroots community of practice. Moreover, small victories—a student's improved grade, a successful lesson using a new homemade tool—served as potent affirmations. Their resilience was also, paradoxically, reinforced by the very constraints they faced. The challenge became a source of professional pride and identity; they saw themselves not as deficient teachers but as expert adapters and problem-solvers. As Mr. Fajar noted, "Anyone can teach with a projector and the internet. Teaching here requires creativity. That makes us different, and in a way, stronger." As reported by Baharuddin and Burhan (2025), rural teachers viewed educational reforms positively but faced challenges due to insufficient resources and unclear policies. This finding complicates the deficit narrative, showing how constraints can contribute to a robust and context-specific professional identity.

Theorizing Frugal Pedagogy and Its Implications

The findings collectively present a model of context-embedded frugal pedagogy that is both practical and theoretically significant. Practically, it provides a repository of actionable strategies for teacher educators and policymakers. Instead of importing generic, resource-intensive training models, pre-service and in-service programs for remote areas should incorporate modules on local material improvisation, contextualized problem-posing, and socio-emotional pedagogy. These teachers' practices are a masterclass in asset-based thinking, demonstrating that pedagogical wealth can be cultivated from environmental and cultural assets. Theoretically, this study makes two key contributions. First, it provides empirical depth to the critique of the techno-centric paradigm. It demonstrates that effective mathematics pedagogy is not universally synonymous with digital integration but is instead context-dependent and principle-driven. The core principles evident here—concreteness, cultural relevance, relational support, and iterative problem-solving—can be implemented with or without advanced technology. This supports a move towards a pluralistic understanding of quality in mathematics education. Second, it expands the concept of teacher agency in constrained settings. The participants were not passive victims of their environment but active agents who skillfully mobilized local resources—material, cultural, and relational—to enact meaningful instruction. Their agency was expressed through creative resistance to the limitations imposed by their context.

This research also suggests that the widespread focus on closing the *digital divide*, while important, should not overshadow the need to address the pedagogical and relational divide. The teachers' greatest unmet needs, as expressed in the interviews, were not for tablets or projectors (which would be useless without electricity), but for basic teaching materials (paper, geometry toolkits), opportunities for professional collaboration, and recognition of their unique challenges and innovations. Therefore, supportive policies should include targeted funding for simple, durable manipulatives, the facilitation of regional teacher learning communities, and systems that recognize and disseminate locally developed frugal teaching practices. In conclusion, the mathematics teachers of North Aceh's interior are not merely persevering despite adversity; they are engaging in a sophisticated form of pedagogical practice that turns constraints into catalysts for creativity and deep human connection. Their work challenges the global education community to broaden its definitions of innovation and effectiveness. By documenting and

validating their frugal pedagogy, this study advocates for an inclusive educational discourse that honors multiple pathways to meaningful learning, ensuring that the wisdom forged in contexts of scarcity informs our collective understanding of what it means to teach mathematics well.

CONCLUSION AND RECOMMENDATIONS

This study concludes that mathematics teachers in the interior of North Aceh enact a sophisticated and resilient form of context-embedded frugal pedagogy, which fundamentally challenges the dominant techno-centric paradigm in global education discourse. Far from being hindered by the profound lack of infrastructure, teaching aids, and digital connectivity, these teachers demonstrate that pedagogical effectiveness is principle-driven, not technology-dependent. Their practice is characterized by three core, interrelated actions: the creative improvisation of teaching materials from the local socio-cultural environment, the expansion of their professional role to encompass holistic motivation and cultural brokerage, and the cultivation of resilience through a deep sense of purpose and improvised professional community. These findings affirm that in low-resource settings, the primary "technology" for learning is the quality of the human relationship between teacher and student, and that constraints can serve as potent catalysts for pedagogical innovation and a robust, context-specific professional identity. The research successfully shifts the narrative from a deficit perspective—focusing on what is lacking—to an asset-based one that illuminates the valuable professional knowledge generated within constraints.

The implications of these findings are both practical and theoretical. Practically, there is an urgent need for teacher education and professional development programs, particularly those serving remote areas, to integrate modules on frugal pedagogy, contextualized lesson design, and socio-emotional pedagogy. Curriculum developers and policymakers should prioritize creating and disseminating resource banks of low-cost, locally adaptable teaching strategies over the procurement of incompatible high-tech solutions. Furthermore, educational authorities must establish formal recognition systems and foster supportive, peer-led communities of practice to validate and sustain these teachers' efforts. Theoretically, this study contributes to a more pluralistic and equitable understanding of quality mathematics education, arguing for the legitimacy and sophistication of non-digital, relational, and place-based pedagogies.

For future researchers, this study opens several critical avenues. First, a logical next step is design-based research that collaborates with these teachers to codify, refine, and formally test the efficacy of their frugal pedagogical strategies on specific student learning outcomes, such as conceptual understanding and motivation. Second, while this study focused on teacher perspectives, subsequent research should adopt a multi-voice ethnographic approach to incorporate the viewpoints of students, parents, and school principals, providing a more holistic picture of the teaching and learning ecosystem in such environments. Third, comparative studies across different remote regions in Indonesia (e.g., Papua, East Nusa Tenggara) could explore how varying geographical and cultural contexts shape distinct manifestations of frugal pedagogy, helping to build a broader theory of context-adaptive teaching. Ultimately, longitudinal research is necessary to investigate the sustainability of teacher resilience and the long-term effects of these adaptive practices on both teacher retention and student outcomes, providing deeper insights into the dynamics of educational perseverance in marginalized communities.

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