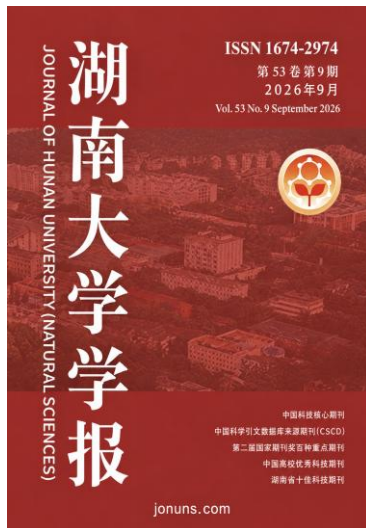




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Localizing Early Numeracy Policy in Decentralized ECE Systems: Evidence from Indonesia

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Abstract: Early numeracy is central to school readiness and educational equity, yet national policies may be implemented unevenly across geographically and institutionally diverse early childhood education (ECE) settings. This study examined the implementation of Indonesia's 2024 early literacy-numeracy policy in urban, rural, and remote settings in West Nusa Tenggara and explored the feasibility of the LENTAS (Locally Contextualized Early Numeracy with Technology Support) model. A convergent concurrent mixed-methods design combined policy and document analysis, a teacher-parent survey, interviews with 15 key informants, focus groups with 50 parents or caregivers, and an embedded single-group pre-post pilot involving 60 children and six teachers across three ECE sites. Of 900 survey questionnaires distributed, 662 complete responses were included in the final analysis; the remaining 238 were incomplete or not returned. Findings showed an implementation gradient favoring the urban site, where teacher preparation, materials, infrastructure, and family-engagement mechanisms were stronger. Rural and remote implementation was constrained by limited professional support, unreliable infrastructure, restricted access to learning materials, and weaker cultural and linguistic alignment. LENTAS integrated culturally familiar play-based activities, offline-first technology, structured parent engagement, and continuous teacher mentoring. Descriptively, the proportion of children meeting the count-to-ten criterion increased from approximately 75% to 85% in Mataram, from 60% to 78% in East Lombok, and from 50% to 80% in remote Sumbawa. These preliminary changes should not be interpreted as causal effects because the pilot was small and lacked a comparison group. Equitable implementation therefore requires differentiated, sustained support for teachers, locally relevant resources, offline-capable technology, family-community partnerships, and stronger local coordination.



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Keywords: early numeracy; early childhood education; education policy; policy implementation; localization; culturally responsive pedagogy; educational technology.

分权化学前教育体系中的早期数概念政策本土化：来自印度尼西亚的证据

摘要： 早期数概念能力是儿童入学准备和教育公平的重要基础，但国家政策在地理条件和机构环境不同的学前教育（ECE）情境中可能存在实施不均衡的现象。本研究考察了印度尼西亚2024年早期读写与数概念政策在西努沙登加拉省城市、农村和偏远地区的实施情况，并探讨了LENTAS（本土情境化早期数概念与技术支持）模式的可行性。研究采用聚合式同期混合研究设计，结合政策与文件分析、教师和家长问卷调查、对15名关键知情人的访谈、由50名家长或照护者参加的焦点小组，以及在3个学前教育点开展的嵌入式单组前后测试点研究，试点共涉及60名儿童和6名教师。共发放900份问卷，其中662份完整问卷纳入最终分析，其余238份问卷因填写不完整或未回收而未纳入分析。研究结果显示，政策实施呈现出明显的城市优势梯度，城市地区在教师准备、教学材料、基础设施和家庭参与机制方面表现更为充分。农村和偏远地区的政策实施受到专业支持不足、基础设施不稳定、学习材料获取受限以及文化和语言适切性较弱等因素的制约。LENTAS模式整合了儿童熟悉的文化情境化游戏活动、离线优先技术、结构化家长参与和持续性教师指导。描述性结果表明，达到“数到十”标准的儿童比例在玛塔兰由约75%提高至85%，在东龙目由60%提高至78%，在偏远的松巴哇地区由50%提高至80%。由于试点规模较小且未设置比较组，这些初步变化不应被解释为因果效应。因此，实现公平的政策实施需要针对不同地区提供差异化且持续的教师支持、本土相关资源、可离线使用的技术、家庭—社区合作伙伴关系以及更有力的地方协调。

关键词： 早期数概念；学前教育；教育政策；政策实施；本土化；文化响应式教学；教育技术。

1. Introduction

ECE provides a critical foundation for later learning. Early numeracy is especially vital because children's first encounters with quantity, pattern, comparison, and spatial reasoning serve as the building blocks for later mathematics. Even in the same context, there is evidence that foundational learning inequalities can already appear before or at school entry and potentially last a lifetime without adequate support. Recent evidence in England suggests large socioeconomic differences in early number performance among children [1], and wider evidence indicates that high-quality early learning provision offers longer-term educational and social development benefits [2]. In addition, meta-analytic evidence suggests that early numeracy interventions conducted in a structured way have significant learning effects, even for children from socioeconomically disadvantaged families [3, 4]. Thus, early numeracy is not just an area of pedagogy but an equity problem in education.

However, access to ECE in Indonesia has expanded, albeit with continuing differences in program quality, teacher preparation, learning materials, and parent involvement. Previous analyses of Indonesian ECE policy noted persistent difficulties connected to

governance fragmentation and uneven local implementation [5]. Recent work on ECE quality in Indonesia similarly identifies the need for multi-level responses at practitioner, learning material, and household levels [6]. In this context, the national policy focus for 2024 emphasizes more developmentally appropriate (play-based) learning for foundational literacy and numeracy, rather than formal drilling at too young an age with little integration of local significance. While such a policy orientation may potentially align well with culturally responsive approaches, its practical implications are contingent on how national guidance is employed by local practitioners.

Implementation takes on special significance in provinces with geographic dispersion and uneven institutional capacity. The question thus posed can be usefully explored through the lens of West Nusa Tenggara (NTB), where ECE provision ranges across urban, rural, and remote island contexts, but with local conditions differing in teacher availability, infrastructure, parental resources, and cultural-linguistic environment. Policy implementation research has shown that centrally-designed reforms need coordination across administrative levels, sufficient local capacity, and mechanisms for adaptation and feedback [7, 8]. Consensus issues are exacerbated by

disparities in electricity, connectivity, device access, and teacher digital capacity in technology-supported learning [9]. Therefore, the same national policy can lead to varied practices based on the institutional and social context that determines how policy is implemented.

Local cultural resources may help bridge this implementation gap. Research on culturally situated mathematics education shows that traditional games, patterned textiles, local narratives, and market practices can provide meaningful contexts for mathematical reasoning. Indonesian studies indicate that local wisdom can strengthen learner engagement and numeracy learning [10, 11]. Parent involvement is also important for early numeracy development, particularly when families are supported to incorporate mathematics into everyday routines [12]. Technology may extend these opportunities when digital resources are integrated into teacher-child interaction and supported by professional learning [13, 14].

Even with this evidence, there are four gaps. First, there has been relatively little research on how a national ECE literacy-numeracy policy is negotiated across urban, rural, and remote settings within one Indonesian province. Second, local adaptation following cultural competence has been studied more in relation to pedagogical implementation than political implementation. Third, few studies investigate cultural localization, family engagement, teacher capacity, and educational technology as mutually dependent implementation conditions. Fourth, there is limited mixed-methods evidence to show how the interplay of fidelity and adaptation occurs across levels of the implementation system. Because the effectiveness of policy in decentralized systems cannot be inferred from design alone and needs to be explored as it is influenced by how practitioners and families enact policy in everyday settings, it is important to address these gaps.

The study used a concurrent mixed-methods design to explore the implementation of the early literacy-numeracy policy planned for Indonesia in 2024 in NTB. It centers on three interconnected components: implementation variation within urban, rural, and remote ECE settings; barriers to and enablers of delivery identified by practitioners and families; and the preliminary implementation of an innovative, locally contextualized technology-supported learning model known as LENTAS. It aims to answer four research questions:

- RQ1. How does the national early literacy-numeracy policy manifest in urban, rural, and remote ECE settings across NTB?
- RQ2. Specifically, what are the main bottlenecks at the classroom, school, and household levels for effective implementation?
- RQ3. What locally adapted strategies, including but not limited to cultural practices and educational

technology, seem to hold promise for strengthening early numeracy?

- RQ4. What recommendations, grounded in strong scientific evidence, could help improve the effectiveness, equity, and sustainability of policies and practices in under-resourced contexts such as NTB?

1.1 Conceptual Framework

The study employs a multi-level implementation framework where national policy direction is mediated through provincial and district coordination structures, ultimately influencing classroom and household enactment. Like many frameworks of this nature, it distinguishes between three levels of interaction: (1) Macro-policy level: encompassing national standards, guidance for curriculum and teaching content, resources, and monitoring; (2) Meso-institutional level: involving provincial and district actors who disseminate policy and provide guidance as part of a supportive agenda, including coordination of resources for implementation; and (3) Micro-level: comprising actors in classrooms or other educational settings where teachers shape daily learning practices through which children and families enact and adapt policy. These levels are horizontally coordinated and nested within each other, with feedback from practitioners and families influencing local policy refinement.

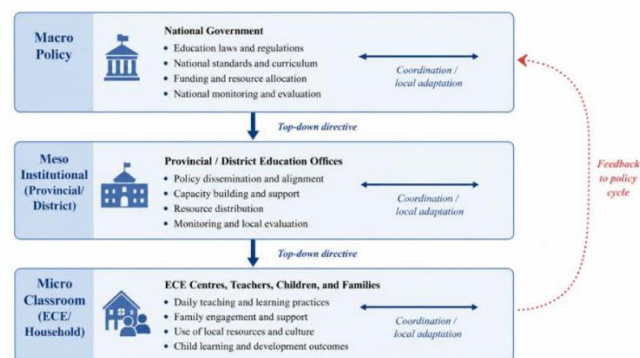


Figure 1. Conceptual implementation framework for early literacy-numeracy policy across macro-policy, meso-institutional, and micro-classroom/household levels.

Note. Source: Authors' conceptualization.

2. Literature Review

2.1 Early literacy and numeracy as a foundation for equity

Evidence consistently links early literacy and numeracy with longer-term educational outcomes and shows that unequal access to high-quality early learning can reproduce socioeconomic disadvantage. Large-scale implementation research indicates that effective early literacy instruction requires sustained attention to teacher practice and implementation conditions [2]. Research on early childhood development further

positions high-quality provision as a foundation for social and educational equity, especially in low- and middle-income settings [15, 16]. Meta-analytic and intervention evidence also shows that structured early numeracy support can improve children's mathematical learning, including among children from socioeconomically disadvantaged backgrounds [3, 4]. Scaling access to ECE is therefore necessary but insufficient unless policy also addresses the quality and equity of children's learning experiences.

2.2 Policy implementation in decentralized and disadvantaged contexts

The relationships between policy design, institutional capacity, local adaptation of policy ideas, and practitioner agency are shaped by the practice of education policy implementation. Implementation scholarship identifies categories such as top-down, bottom-up, and hybrid implementation, but highlights that all approaches require multi-level coordination with local actors with the capacity to enact policy in practice [7, 8]. Such dynamics can be especially important in decentralised systems, where resource and administrative capacity across local authorities and schools can vary significantly. The development and quality assurance of Indonesian ECE policy has been uneven across settings historically [5]. Emerging evidence also suggests that quality improvement involves continuous professional learning and organisational support rather than isolated projects [17, 6]. This supports an approach to policy implementation as a multilevel process rather than assuming that national guidance results in consistent classroom practice.

2.3 Local wisdom, ethnomathematics, and culturally responsive pedagogy

Culturally responsive pedagogy links formal learning goals with children's familiar social, linguistic, and cultural contexts. Ethnomathematics research similarly shows that everyday practices, games, patterns, and material culture can provide entry points for mathematical reasoning. Studies of traditional games and local cultural knowledge illustrate how familiar practices can support engagement and numeracy learning [10, 11]. In NTB, Sasak woven patterns, congklak, gasing, and market-based role play offer relevant contexts for counting, comparison, pattern recognition, and spatial reasoning. However, evidence remains stronger for classroom-level interventions than for the policy and institutional mechanisms that sustain localization. The present study therefore examines cultural adaptation together with implementation conditions.

2.4 Technology integration in early childhood settings

The integration of technology in early childhood education continues to be debated because many positive outcomes associated with its utilization are weighed against exposure to screens, lack of equitable access, and the potential loss of play and adult interaction. Research on digital interventions shows that technology can play a positive role in learning where it is developmentally appropriate and part of effective pedagogy [13]. While research on teacher digitalization has found that one-off training is insufficient for sustained use, it instead depends on coaching, learning, and self-evaluation [14]. In rural and remote settings, the digital divide has been described to include connectivity, electricity, language, device availability, and teacher digital literacy [9]. Such considerations lend support to an offline-first stance when technology is deployed in low-resource environments. So the relevant question is not whether we should use technology instead of traditional pedagogy, but how well-designed technology can be integrated with teacher-directed and play-based learning in local contexts where infrastructure limitations exist.

2.5 Parental engagement and community partnership

Another key piece of the early stages of math-based learning is Family Engagement. When families have practical opportunities and encouragement to use everyday activities as learning experiences, research shows parents can be an important support for children [12]. In a related vein, evidence from other settings suggests that early childhood involvement is more effective in closing developmental disparities when there is additional home stimulation [18, 19]. Of course, parental engagement in low-resource settings cannot be merely a question of motivation; time, employment, education, and access to materials define the landscape of what families have the chance to do. Thus, a policy implementation framework that facilitates smooth, flexible, culturally relevant home activity may arguably be better than one based on a universal assumption of capacity across family types.

2.6 Research Gap

Four interconnected gaps emerged from the literature. First, little is known globally about subnational implementation of national ECE literacy–numeracy reforms in decentralized middle-income countries like Indonesia, especially concerning countries' disadvantaged provinces. Second, the literature on local wisdom and numeracy is largely shaped by pedagogical interventions without addressing the structural policy and institutional drivers of their sustainability. Third, the need to facilitate the synthesis of cultural adaptation and sustainable technology by integrating teacher capacity and family engagement is seldom examined. Fourth, the comparative mixed-

methods evidence across all three settings of urban, rural, and remote ECE is still limited within a single jurisdiction. The current study addresses these gaps by introducing a multilevel approach to examining policy implementation and contextualizing findings within an initial, local-specific learning model.

3. Research Objective

Consistent with the research questions and the convergent concurrent mixed-methods design, the study pursued four interrelated objectives:

- a. Explore implementation of Indonesia's 2024 national early literacy–numeracy policy across diverse early childhood education (ECE) sites in West Nusa Tenggara, with a focus on differences between urban, rural, and remote settings.
- b. Characterize the key multi-level barriers and facilitating factors affecting policy implementation—e.g., teacher capacity, infrastructure and learning resources, parental involvement, cultural-linguistic fit, and local coordination.
- c. Develop and pilot a proof-of-concept, locally contextualised early numeracy integrated approach—the LENTAS (Locally Contextualised Early Numeracy with Technology Support) model—using cultural resources, offline-first technology, structured parental engagement, and teacher mentoring, to support feasibility and preliminary descriptive findings.
- d. Develop evidence-informed, equity-oriented recommendations for policymakers, ECE leaders, teacher educators, and other implementation actors seeking to strengthen early literacy-numeracy policy in geographically and socioeconomically disadvantaged settings.

4. Methods

4.1 Research Design

This study used a convergent concurrent mixed-methods design with an embedded single-group pre-post pilot. Quantitative and qualitative strands were collected during the same study period, analyzed separately, and integrated during interpretation through a joint display. Documentary and survey evidence characterized variation in policy implementation; interviews and focus groups examined barriers and enabling conditions; and the embedded LENTAS pilot explored feasibility and preliminary descriptive changes. Because the pilot included approximately 20 children per site and no randomized or nonrandomized comparison group, it was treated as an implementation component rather than a causal evaluation.

Ethical approval was obtained from the Research Ethics Committee of Universitas Mataram before participant recruitment and data collection. Adult participants provided written informed consent, and parents or legal guardians provided written consent for children's participation. All records were anonymized or de-identified before analysis.

4.2 Research Site and Context

The study was conducted in West Nusa Tenggara (NTB), Indonesia, a province comprising Lombok and Sumbawa and encompassing urban, rural, coastal, highland, and island communities. Three contrasting ECE settings were purposively selected to represent an urban-rural-remote implementation gradient: an urban center in Mataram, a rural village center in Janapria, East Lombok, and a remote island setting in Sumbawa.

The three sites were selected to contrast implementation contexts, rather than being statistically representative of all ECE centers in NTB. The objective of the comparison was to explore how local implementation of a national early literacy–numeracy policy differed because of variation in institutional capacity, infrastructure, teacher preparation, family circumstances, and geographical accessibility.

4.3 Participants and Sampling

Participants represented the stakeholder groups involved in ECE provision and policy implementation. The broader survey initially targeted 900 teachers, parents, and caregivers; 662 complete questionnaires met the analytic requirements and were retained, while 238 questionnaires were incomplete or not returned. The embedded pilot included 60 children (approximately 20 per site) and six lead teachers (two per site). Fifty parents or caregivers participated in focus groups and parenting activities, and 15 key informants were interviewed, including ECE teachers, school leaders, district education personnel, university faculty members involved in ECE, and community leaders. Participation across components was not summed into a single total because some adults contributed to more than one component.

Qualitative and pilot participants were selected purposively, while convenience sampling was used for the broader survey. The three pilot sites were deliberately selected to maximize contextual contrast rather than statistical representativeness.

Adults were eligible if they were teachers, school leaders, parents or caregivers of children enrolled in ECE, education officials, teacher educators, or community actors involved in the selected settings or the relevant policy process. Children were eligible if they were enrolled at one of the three pilot sites and had parental or guardian consent. Survey questionnaires without sufficient information for domain-level analysis were excluded from the final analytic dataset.

Table 1. Participant flow and final analyzed sample by study component.

Component	Analyzed sample	Sampling and flow
Survey	662 adults	Convenience sample of teachers, parents, and caregivers; 900 questionnaires distributed, 238 incomplete or not returned.
Interviews	15 informants	Purposive sample of ECE teachers, leaders, district personnel, teacher educators, and community leaders.
Focus groups	50 parents/caregivers	Purposive sample at the three pilot sites; some adults also joined parenting activities.
LENTAS pilot	60 children; 6 teachers	Approximately 20 children and two lead teachers per urban, rural, and remote site.
Documents	Policy and education records	National policy documents and relevant provincial education statistics.

Note. Adult participation is not summed across components because some individuals contributed to more than one component.

4.4 Instruments and Data Collection

Data collection comprised five elements. First, a semi-structured document-analysis protocol was used to examine national policy documents and provincial education statistics relevant to ECE access, staffing, infrastructure, and early literacy-numeracy implementation. Second, bilingual Indonesian-Sasak survey forms were administered to teachers and parents to document teacher preparation, access to learning materials and infrastructure, family numeracy practices, cultural-linguistic fit, and perceived implementation barriers. Third, semi-structured interviews were conducted with 15 key informants. Fourth, focus group protocols examined experiences of policy implementation, parenting practices, local barriers, and enabling conditions. Fifth, participating children completed pre- and post-pilot numeracy assessments.

The child assessment covered numeral recognition from 1 to 10, one-to-one counting, simple quantity comparisons (more, less, or equal), size comparisons, and pattern identification. The principal descriptive indicator reported in this article was whether a child met the study's count-to-ten criterion. The teacher and parent surveys used stakeholder-specific items organized around the implementation domains described above; teacher confidence was recorded on a five-point scale, while resource and implementation indicators were summarized categorically or as proportions. The survey was designed for descriptive implementation mapping rather than as a unidimensional psychometric scale. Accordingly, responses were analyzed at the item and domain levels, no overall composite score was calculated, and internal-consistency coefficients were not estimated. The instruments were pretested with teachers and parents to

assess clarity and cultural-linguistic suitability, after which wording was refined for the local context.

4.5 LENTAS Pilot Learning Model

The embedded LENTAS (Locally Contextualized Early Numeracy with Technology Support) model supplemented rather than replaced the existing curriculum. Its four integrated components were: (a) culturally responsive, play-based numeracy activities such as congklak counting, woven-pattern tasks, and market role play; (b) low-bandwidth, offline-first tablet applications with local-language content; (c) structured parent engagement through short workshops and home-activity guides; and (d) continuous teacher support through classroom-based mentoring by the research team.

In 2025, LENTAS was implemented through weekly learning cycles at the three pilot sites for approximately two to three months. The pilot examined feasibility, implementation conditions, and preliminary descriptive changes in children's numeracy indicators, teacher confidence, and parent engagement; it was not designed to estimate causal effects.

4.6 Data Analysis

4.6.1 Quantitative and Descriptive Analysis

Using descriptive statistics, teacher-, parent-, and child-level characteristics were summarized. For the pilot, pre- and post-numeric indicators were compared descriptively, e.g., changes in proportions of children who met the count-to-ten criterion. A further descriptive examination of cross-site differences in baseline conditions and the changes observed was also undertaken.

Because each site included about 20 children and there was no randomized comparison, inferential generalizations could not be made to claim causal effectiveness – although paired pre-post comparisons were examined within the pilot. Thus, the results are reported as early descriptive findings, complemented by qualitative triangulation. All formal inferential statistics should only be reported if actually calculated from the original data.

4.6.2 Qualitative Analysis

Recorded interviews and focus groups were transcribed verbatim and de-identified. Qualitative data were analyzed using the six phases of reflexive thematic analysis described by Braun and Clarke [20], with attention to subsequent methodological guidance for applied research [21]. Analysis involved familiarization, initial coding, theme development, review against the dataset, definition and naming of themes, and analytic reporting.

Inductive and deductive coding were used. Inductive coding enabled themes to emerge from participants' testimony, while deductive coding drew on the conceptual categories of policy barriers and enabling

conditions identified in the literature review. Two researchers coded a large subsample of the qualitative material independently and compared their interpretations to improve analytic consistency.

4.6.3 Mixed-Methods Integration

Integration occurred during interpretation through a convergent joint display. Qualitative themes were compared with quantitative and descriptive site-level patterns to determine where data sources converged, complemented one another, or diverged. This process enabled analysis of both the extent of cross-site implementation variation and participants' explanations of that variation.

4.7 Trustworthiness and Ethical Procedures

Trustworthiness was supported through prolonged engagement in the study settings, member checking during focus groups, triangulation across documentary, survey, interview, focus-group, and pilot data, and an audit trail of coding and interpretive decisions. Contextual description supported transferability, while independent coding of a substantial qualitative subsample and team discussion strengthened dependability and analytic credibility.

The pilot was designed as an early-phase implementation study to examine the feasibility and preliminary promise of an add-on instructional model within existing ECE provision. It did not replace the regular curriculum and did not provide definitive evidence of causal effectiveness.

5. Findings

5.1 Policy Implementation Across the Urban–Rural–Remote Gradient

The analysis of the documents revealed that the 2024 Ministry of Primary and Secondary Education (Kemendikdasmen) focuses on an early numeracy framework based on embedding basic mathematical ideas into daily life, play-based pedagogy, age-appropriate learning materials, as well as links between literacy, numeracy, and digital literacy. Instead of formal arithmetic drills, the framework gives a national policy direction to focus on purposeful integrated learning [22].

In 2024, policies were communicated from the national level down to provincial and district authorities in NTB, with the NTB Education Office developing guidance for implementation later in Q1. However, survey and qualitative data revealed considerable variation in implementation across each of the three study settings.

We found relatively high implementation fidelity at the Mataram urban sites: teachers had relevant training, learning materials were available, and mechanisms for parental engagement existed. However, rural sites in East Lombok reported only partial implementation. While teachers were committed to the policy direction, implementation was hampered by

limited resources and monitoring. The furthest remote Sumbawa sites showed the greatest limitations in implementation. Not all teachers have received training in literacy and numeracy (though most have); there are not many learning resources available, and systematic structures for parental involvement are lacking.

These differences also manifest in how participants described the policy. An urban teacher described the new framework as aligned with current practice, while a remote-school teacher labeled it a "new and promising" approach that was only just becoming known in their local area. These accounts demonstrate a clear gradient of implementation: while the national policy had been directionally consistent across sites, the ability to translate that direction into routine practice varied markedly.

The contrast across these three settings was later where the LENTAS pilot was implemented. The four components of our intervention—integrating local wisdom in ECE, using low-bandwidth educational technology, structured parental engagement, and ongoing teacher mentoring—were designed to be complementary (not substitutional) to existing modalities of ECE delivery.

5.2 Barriers to Policy Implementation

The survey, interviews, and focus groups consistently identified four interrelated categories of barriers: teacher capacity; infrastructure and learning materials; parental engagement; and cultural-linguistic fit.

5.2.1 Teacher Capacity

In rural and remote settings, teacher capacity was especially limited. Participants reported limited access to both pre-service and in-service preparation for play-based numeracy. A recurring theme was that teachers continued using paper-based and teacher-directed activities even after being trained in more interactive methods. In remote settings, where teachers felt less confident in delivering numeracy activities, such activities were also less reported. A common theme was the difference between teachers' understanding and practices, epitomised by this response: "We know what we should do but not how."

5.2.2 Infrastructure and Learning Materials

Limited infrastructure and learning materials constituted another major constraint. The survey revealed that there were shortages of manipulatives and basic numeracy resources such as counting games, number cards, measuring tools, etc. This shortage was more pronounced in remote sites. Only a subset of the study locations had consistent access to electricity and internet connectivity, with the most extreme constraints at the remote site in Sumbawa.

5.2.3 Parent Involvement and Home Numeracy Environment

However, while all parents reported a strong

commitment to children's education across the three settings, differing constraints on participation in home numeracy were identified. Urban parents tended to report having more formal education, greater work flexibility, and greater opportunities for incorporating numeracy in daily activities like shopping or board games. Parents attributed lower levels of educational attainment, long work hours, and lack of knowledge about how to assist with numeracy learning at home as limitations more commonly cited in rural areas and especially among remote parents.

5.2.4 Cultural and Linguistic Fit

Participants also found a disjuncture between the standardization of learning materials and children's real lives in their local context. Teachers and parents in Lombok and Sumbawa reported that certain materials developed for urban Java contexts contained illustrations, vocabulary, and examples not obviously relevant to local children. Additionally, in some cases, teachers concluded that either translation or adaptation to the local context was necessary for the materials to be comprehensible and useful.

Collectively, these findings highlight that barriers to implementation cannot be understood as unidimensional resource gaps but rather point to the interplay of teacher preparedness, availability of teaching materials and infrastructure beyond schools; family capacity for engagement with curricular content; and relevance in context.

5.3 Enabling Conditions and Locally Adapted Strategies

5.3.1 Integration of Local Wisdom

Teachers enlisted Sasak and Samawa cultural resources for numeracy activities by incorporating congklak, gasing, identification of woven-textile patterns, and market-based role play. Teachers found that children interacted and conceptually took up the content more effectively when using these locally familiar items compared to those that were perceived as culturally distant.

5.3.2 Low-Bandwidth Educational Technology

In settings where more traditional manipulatives are limited, the LENTAS tablet application provided visual and interactive representations of numerals and patterns. The application was reported by the teachers to have increased interactivity and children's engagement. More significantly, the offline mode permitted the approach to be implemented in the least connected site of all, exemplifying how an offline-first design is essential for resource-constrained ECE settings. Thus, the technology served as an adjunct educational tool rather than a replacement for teacher-child engagement.

5.3.3 Structured Parental Engagement

The structured parent-engagement component of LENTAS linked classroom activities with short workshops and home-activity guides. Embedding

engagement throughout the pilot rather than treating it as a stand-alone event made the activities more visible and practical for families. Parents reported involving children more frequently in everyday numeracy activities, including counting while shopping or preparing food.

5.3.4 Multi-Stakeholder Coordination

An association was identified between fewer reported implementation bottlenecks resulting from collaboration among local education offices, ECE coordinators, community leaders, and community-based ECE actors. Community actors such as Bunda ECE, and trained community mothers were pointed out by participants as significant supports for communication and local engagement.

The qualitative evidence across the four strategies suggests that successful adaptation relied on combinations of pedagogical, technological, family, and institutional support, rather than relying on one of these intervention components.

5.4 LENTAS pilot study — Results

Preliminary descriptive evidence of positive changes across all three sites was generated from the pilot phase of LENTAS. As the pilot was small and the reported comparisons were descriptive, these results should be considered exploratory rather than causal efficacy findings.

5.4.1 Children's Basic Numeracy Skills

Teachers and researchers observed greater engagement during numeracy activities after LENTAS was introduced. At the remote Sumbawa site, approximately 50% of children met the count-to-ten criterion at baseline, compared with approximately 80% after the pilot.

5.4.2 Teacher Confidence

Teachers described feeling more confident in organizing play-based numeracy activities and using the tablet application as a supplementary teaching resource. Descriptive site-level data indicated that self-reported teacher-confidence scores were on a five-point measure of 4.1 in Mataram, 3.4 in East Lombok, and 2.8 in Sumbawa, respectively.

5.4.3 Parent Participation

Parents said they were more interested and confident in helping their children learn numeracy at home. This included introducing counting and comparison into everyday experiences (shopping and preparing food). Focus group and survey data supported these findings.

The site-level comparison revealed increases in rates from around 75% to 85% at Mataram, 60% to 78% in East Lombok, and from 50% to 80% in Sumbawa. The greater absolute change at the remote site should be interpreted carefully as this occurred when baseline levels were lower and left more room for improvement. As such, the pattern is descriptive and we cannot say that

LENTAS was more effective in the remote site since a controlled comparative design was not used.

5.5 Cross-Site Variability and Mixed-Methods Convergence

A consistent gradient emerged across baseline resources, implementation conditions, and reported outcomes. Mataram had comparatively stronger teacher qualifications, availability of manipulatives, infrastructure reliability, parental responsiveness, and teacher confidence. East Lombok occupied an intermediate position, while Sumbawa experienced the greatest resource constraints and the lowest resource availability.

Table 2. Implementation conditions and preliminary outcomes across the three pilot sites.

Indicator	Mataram (Urban)	East Lombok (Rural)	Sumbawa (Remote)
Teacher ECE qualification (≥ S1 ECE)	High	Moderate	Low
Availability of manipulatives	High	Moderate	Low
Electricity/internet reliability	Reliable	Variable	Unreliable
Pre-pilot count-to-10	≈75%	≈60%	≈50%
Post-pilot count-to-10	≈85%	≈78%	≈80%
Parental engagement program	Strong	Moderate	Newly launched
Tablet application mode	Online	Hybrid	Offline
Teacher confidence (5-point scale)	4.1	3.4	2.8

Note. Values are descriptive approximate estimates from the study dataset. Pre-post comparisons should not be interpreted as causal estimates of intervention effects. Source: Authors' analysis of primary data.

The quantitative and qualitative findings largely converged across data sources. In keeping with the descriptive site-level comparisons, qualitative themes were cultural fit, parental involvement, teacher confidence, and infrastructure. The remote site, for example, had low baseline numeracy performance and fewer other resources, including reported teacher confidence levels, connectedness, and parental support, leading to a child development outcome where fewer children in the cohort were re-engaged.

Simultaneously, an important distinction in the experience of implementation barriers was uncovered from the qualitative data. Urban respondents tended to describe such barriers as needing minor adjustments, while remote respondents more often indicated that these same challenges are structural and urgent. That distinction matters — analytically, at least — because a national policy framework can produce widely divergent implementation experiences based on local institutional and socio-economic context.

Taken together, the findings show that implementation varied across the three contexts along a continuum shaped by teacher capacity, access to materials and infrastructure, family circumstances, cultural-linguistic fit, and local coordination. The LENTAS pilot suggests that locally relevant teaching resources, offline-capable technology, structured family engagement, and sustained teacher mentoring can be combined within a differentiated implementation strategy.

6. Discussion

This study investigated how Indonesia's 2024 early literacy-numeracy policy was translated into practice across urban, rural, and remote ECE settings in NTB. Four interconnected findings were most important. First, implementation capacity varied systematically across the urban-rural-remote gradient. Second, teacher capacity was a central implementation constraint. Third, local cultural resources, appropriate technology, structured parent participation, and multi-stakeholder coordination functioned as complementary enabling conditions. Fourth, the embedded LENTAS pilot produced preliminary descriptive improvements in numeracy indicators across all three sites. Because the study had no comparison condition, these changes are interpreted as exploratory evidence of feasibility and possible benefit, not as evidence of causal effectiveness.

6.1 The Implementation Gradient: From National Policy to Local Practice

Most notably, there was a disparity between an apparently uniform national policy agenda and its inconsistent local implementation. This pattern matches previous research on education policy implementation in decentralized systems, which shows that even a well-designed policy does not guarantee similar classroom practices. In particular, actionable guidance, organizational capacity, professional support, and administrative coordination across levels—together with mechanisms that allow local experience to inform future directions—are seen as essential to the successful implementation of reforms [8].

The evidence presented in the NTB literature adds nuance to this argument, revealing differences in implementation even within one provincial policy environment. Compared to rural and remote sites,

Mataram sites reported relatively better access to trained teachers, learning materials, parental engagement mechanisms, and reliable infrastructure. As a result, the apparent gap between policy and practice is less about varying intentions in terms of public policy than variation in local capacities to implement a shared framework. This view reflects previous observations on unequal education policy enforcement in Indonesia [5].

These findings suggest that the last step in delivering policy should not be regarded as a mere administrative footnote. Support for the "last mile" of ECE policy involves investing in local coordination, monitoring, adaptation to context, and distribution of resources for teachers. National policy coherence is necessary, but unlikely to translate into equitable classroom outcomes without equitable implementation capacity.

6.2 Teacher Capacity as a Key Implementation Constraint

Both qualitative and quantitative evidence showed that teacher capacity was the most common limiting factor. Such findings are in line with the literature on sustained, embedded professional development versus short-term episodic training [17]. Results from the trial showed that exposure to the new framework did not always lead to confidence in its use or its integration into regular classroom practices, particularly within a rural and remote context.

The difference in mean teacher-confidence scores - 4.1 in Mataram, 3.4 in East Lombok, and 2.8 in Sumbawa on a five-point scale - indicates persistent site-level capacity differences. Although these descriptive values should not be interpreted as statistically significant, they align with qualitative accounts of uncertainty among teachers in resource-constrained settings about how to translate policy principles into numeracy practice.

Therefore, policy implementation needs to move from training as an event to professional learning as a process. We suspect that long-term sustainability will best be achieved by combining mentoring, demonstration lessons, peer learning, classroom-based coaching, and repeated opportunities to adapt activities to local conditions, in contrast to one-off orientation sessions. Such investment is especially vital in areas where teachers do not have access to professional networks and expert support.

6.3 Local Wisdom as Pedagogy and Equity Mechanism

The local relevance of engaging materials leads this research study to suggest that cultural localization can function both as pedagogical materials and a socially equitable distribution mechanism. Educators included Sasak and Samawa games, textile patterns, and market-based role play to relate numeracy ideas with

experiences that children know. The significance of this finding corroborates the larger claim that children's cultural and linguistic resources provide important contexts for building new knowledge.

This is also an equity finding. Standardized materials can be formally standardized yet structurally inequitable when examples, vocabulary, and representations are culturally distant from children's everyday lives. This implies repurposing or adapting without the outright abandonment of the national framework. Adaptation, on the other hand, provides a way to interpret national learning goals in the context of what is meaningful at local levels.

The pre-post numeracy trends require further investigation and do not support causal conclusions. In Sumbawa, the proportion of children meeting the count-to-ten criterion increased by approximately 30 percentage points, from 50% to 80%. However, the absence of a comparison group and the small number of children at each site prevent attribution of this change to LENTAS. Future research should test whether culturally contextualized activities produce replicable effects in larger and more diverse samples.

6.4 Technology as an Enabler Infrastructure in the Context of Low-Resource Settings

Results indicate a complementary rather than a substitutive role for educational technology. The most useful LENTAS tablet application was one that addressed specific learning constraints while still allowing teachers to lead play-based activities. An offline-first configuration was most appropriate for remote settings where a constant connection was not available.

This conclusion fits with the more moderate stance found in the literature on technology-supported early childhood education, namely that technology alone is not expected to make up for poor instructional conditions. The extent to which it contributes will depend on its compatibility with infrastructure, teacher readiness, the right content, and its articulation with interaction-rich pedagogy [23]. In this study, the technology component was integrated into teacher mentoring, contextual content, and engagement with parents instead of being treated as a separate digital intervention.

The practical question, then, is not just about increasing device availability. Offline functionality, local language resources, technical or on-the-ground support, teacher preparation, and realistic maintenance arrangements should accompany technology investments. In the absence of these conditions, digital interventions risk exacerbating rather than alleviating existing inequalities.

6.5 Parental Engagement as an Equity-Oriented Support

Another condition for translating classroom numeracy learning into norms at home was parental engagement. While parents from all three settings shared a strong intrinsic value for education, they were limited by practical concerns around time, access to up-to-date information, and guidance appropriate to their education and employment level. The results support the use of strategies in which parental engagement is treated as a planned element of ECE delivery, rather than an assumed family resource.

The parent-engagement component of LENTAS demonstrated how numeracy concepts could be incorporated into everyday activities, such as counting while shopping or preparing food. Qualitative evidence suggested that sustained rather than episodic engagement supported participation, consistent with research on structured family involvement in early learning [24].

Yet this evidence is not sufficient to consider parenting as an independent, standalone intervention. We frame its contribution as one component of an integrated implementation strategy, given that the study did not isolate parental engagement from other LENTAS components. Future research needs to test different formats and levels of parental investment to see if modifying schedules, home visits, or inexpensive activity materials could attract higher participation rates from families whose livelihoods are very limited.

6.6 Coordination and Governance as the Backbone of Implementation

This suggests a governance dimension that runs the risk of being missed if implementation is examined solely at the classroom level, a point also highlighted by this cross-site evidence. In remote settings, coordination across education offices, ECE coordinators, school leaders, teachers, and community actors was weaker. Participants identified that such delivery coordination gaps resulted in reduced monitoring, fragmented support, and delays in responding to local implementation challenges.

Such a pattern reflects a common theory in implementation research on how actors from different levels of a policy system need to coordinate with each other [25]. Therefore, it follows that improvement in classroom practice may be ineffective unless the institutional support system for teachers is strengthened. A local coordination backbone should clarify roles and responsibilities, define mechanisms for regular cross-level communication, integrate monitoring information, and create a feedback mechanism that communicates local implementation challenges to district- and province-level decision makers.

Therefore, governance (capacity) should be treated as part of pedagogical infrastructure in decentralized ECE systems. In addition to learning materials and devices, the broader resources needed for

equitable numeracy implementation also encompass the institutional arrangements that deliver these resources and professional support to the settings in greatest need of them.

6.7 Integrated Policy Implications: Four Interconnected Levers

Four policy levers were identified that are best pursued together as an interlinked bundle rather than separately: teacher capacity development over time, provincial curriculum localization, offline-first technology integration, and flexible and targeted parental engagement.

These implications translate into four practical priorities. First, teacher development should move from one-off orientation toward sustained, practice-embedded learning through mentoring, demonstration, peer support, and follow-up. Second, locally developed resources should incorporate regional languages, cultural practices, and familiar examples while remaining aligned with national learning goals. Third, technology initiatives should reflect infrastructure realities through offline-first functionality and local-language content and should complement, not displace, teacher-child interaction. Fourth, parent engagement should accommodate livelihood constraints through flexible scheduling, simple home activities, and outreach to families with limited access to ECE institutions.

These four levers are not independent; they are interdependent and reinforce each other. Localized materials and their pedagogical use are also governed by teacher capacity, because localized resources can help to increase the relevance of classroom-home practices; technology can extend physical resources by providing options in areas that may be lacking these materials; and parental engagement can reinforce learning beyond templated classroom activities. The results of the study are also more consistent with a combined approach to implementation rather than treating each lever as an independent solution.

6.8 Implications for Practice, Policy, and Future Research

For practitioners, these findings suggest leveraging familiar cultural activities, everyday numeracy routines, and the strategic use of technology as part of play-based learning. The results suggest that for policymakers, implementation support should be tailored based on local capacity rather than a standardized delivery mechanism for urban, rural, and remote areas. The results further affirm the importance of sustained coaching and contextually relevant professional learning for teacher educators and professional-development providers.

Future research should use larger samples, longer implementation periods, and multi-site or multi-

province designs. Controlled or comparison-group designs are needed when causal effectiveness is the objective. Longitudinal studies should also examine whether changes in teacher practice, parent engagement, and children's numeracy are sustained after external support ends and whether the patterns identified in NTB are replicated in other culturally diverse, resource-constrained Indonesian settings.

7. Conclusion

This mixed-methods study investigated the implementation of the 2024 early literacy–numeracy policy across urban, rural, and remote ECE settings in West Nusa Tenggara (NTB), Indonesia. The key result is a well-defined implementation gradient, revealing that while the national framework established a common policy direction, differences in capacity to implement it were influenced by teacher preparation, infrastructure and learning resources, family circumstances, cultural and linguistic fit, and local coordination.

The findings also indicate that implementation support must be context-sensitive. The LENTAS pilot combined culturally relevant play, offline-first technology, structured parent engagement, and continuous teacher mentoring. It yielded preliminary descriptive improvements, including an increase from approximately 50% at baseline to 80% after the pilot in the proportion of children meeting the count-to-ten criterion at the remote Sumbawa site. Because the pilot was small, short, and conducted without a comparison group, the results indicate feasibility and possible benefit rather than causal efficacy.

Thus, the major contribution of the study is not a single intervention that will solve this implementation problem, but an evidence-based narrative on how national ECE policy interacts with local conditions for uneven implementation. However, equitable policy implementation also needs to resolve the 'last mile' of delivery: sustainable teacher development; curriculum resources contextualized and made relevant through technology support for maximum leverage; family engagement; and institutional coordination.

The study has several limitations. The pilot involved approximately 20 children per site, lasted around two to three months, and took place in one Indonesian province. The pilot was unblinded and not randomized (without a control arm); therefore, no causal inference can be made. Convenience sampling also limited generalizability to the broader survey. The implications of these limitations provide a further rationale for larger, longitudinal, and multi-province studies to assess the generalizability and sustainability of this implementation model.

Nevertheless, the findings contribute to international discussion of decentralized ECE policy by showing how geography, cultural diversity, teacher capacity, family participation, and digital infrastructure

shape the implementation of foundational numeracy policy. The evidence supports a differentiated approach that combines coherent national standards with locally adapted resources, professional support, and delivery mechanisms.

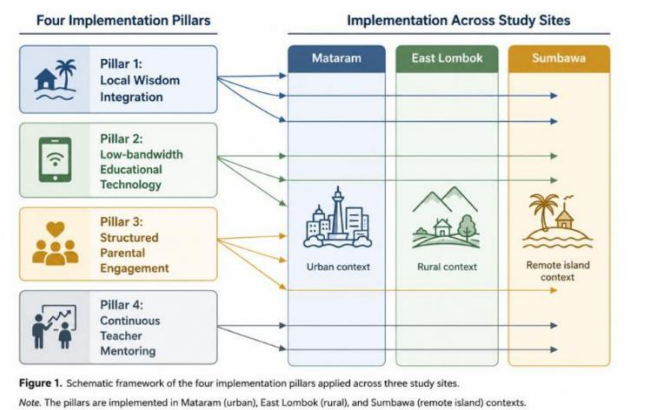


Figure 2. LENTAS Four-Pillar Implementation Framework Across Three Pilot Sites

Note. The four pillars are local-wisdom integration, low-bandwidth educational technology, structured parental engagement, and continuous teacher mentoring across urban, rural, and remote ECE settings.

Table 3. Consolidated thematic summary of barriers, enabling conditions, and preliminary outcomes.

Theme and subtheme	Representative finding	Evidence
Barriers: Teacher capacity	Pre-service training lacks play-based numeracy focus; rural/remote teachers report lower confidence.	Survey, interviews, FGDs
Barriers: Infrastructure & materials	Deficits in manipulatives; electricity/internet reliability is uneven.	Survey, observations
Barriers: Parental engagement	Lower home-numeracy stimulation in remote sites; livelihood constraints.	Survey, FGDs, interviews
Barriers: Cultural-linguistic fit	Distance between central curriculum and local NTB context.	Qualitative sources
Enablers: Local-wisdom integration	Games, woven patterns, and market role-play support engagement.	Interviews, FGDs
Enablers: Educational technology	Offline-first tablet applications complement teacher-led activities.	Interviews, observations
Enablers: Structured parent programmes	Sustained workshops reinforce home practice.	FGDs, survey
Enablers: Multi-stakeholder coordination	Active coordination reduces implementation bottlenecks.	Interviews
Outcomes: Child engagement & basic skills	Counting-to-ten performance rose descriptively from approximately 50% to 80% in the most disadvantaged site.	Pre-post assessment
Outcomes: Teacher confidence	Teachers reported increased repertoire and confidence.	FGDs, interviews
Outcomes: Parent participation	Parents reported increased home practice and confidence.	FGDs, survey

Declarations

Author Contributions

Conceptualization, M.A. Muazar Habibi and Ika Rachmayani; methodology, M.A. Muazar Habibi; software, M.A. Muazar Habibi; validation, M.A. Muazar Habibi, Ika Rachmayani and Abdul Kadir Jaelani; formal analysis, M.A. Muazar Habibi; investigation, Ika Rachmayani; resources, Ika Rachmayani and Abdul Kadir Jaelani; data curation, Ika Rachmayani; writing—original draft preparation, M.A. Muazar Habibi; writing—review and editing, M.A. Muazar Habibi, Ika Rachmayani and Abdul Kadir Jaelani; visualization, M.A. Muazar Habibi; supervision, Abdul Kadir Jaelani; project administration, M.A. Muazar Habibi; funding acquisition, M.A. Muazar Habibi. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

De-identified data supporting the findings are available from the corresponding author on reasonable request, subject to institutional ethics and participant-confidentiality requirements. The data are not publicly deposited because the qualitative transcripts and child-level records contain contextual information that could enable participant or site identification.

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Institutional Review Board Statement

The study received ethical approval from the Research Ethics Committee of Universitas Mataram before recruitment and data collection. The research involved adult participants and children in surveys, interviews, focus groups, and an embedded educational

pilot. Participant confidentiality and data minimization procedures were applied throughout the study.

Informed Consent Statement

Written informed consent was obtained from all adult participants. Parents or legal guardians provided written consent for participating children.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. The authors confirm that the research was conducted with integrity and that there were no financial, personal, institutional, or other relationships that could have influenced the research, its analysis, interpretation, or publication. All relevant ethical considerations, including plagiarism, informed consent, research misconduct, data fabrication and/or falsification, duplicate publication or submission, and redundant publication, have been fully observed and addressed by the authors.

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Appendix A

Abbreviations

ECE Early Childhood Education

FGD Focus Group Discussion

LENTAS Locally Contextualized Early Numeracy with Technology Support

LPPM Institute for Research and Community Service

NTB West Nusa Tenggara

PAUD Pendidikan Anak Usia Dini (Early Childhood Education)