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The Construction of an AI-Based Curriculum and Learning Management System in Rural Private Madrasah Ibtidaiyah in Indonesia

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ABSTRACT

The era of digitalization demands technological adaptation across all sectors of education, including Islamic private school *(Madrasah Ibtidaiyah*/MI) in Indonesia. This study aims to construct a contextual Artificial Intelligence (AI)-based curriculum and learning management system for rural private MI. The research employs mixed methods sequential explanatory design, integrating a Systematic Literature Review (SLR) and a single qualitative case study conducted at the pilot MI Ulul Albab in Prayungan Village, Sawoo, Ponorogo. Data were collected through literature review, in-depth interviews with the principal and teachers, and field observations. The findings reveal a significant gap between the theoretical potential of AI in education and the realities of limited digital infrastructure in rural *madrasahs*. Nevertheless, the urgency of AI adoption remains high, particularly in supporting teachers' administrative tasks and facilitating more personalized learning. Infrastructure constraints are partially offset by the strong enthusiasm and local agency of school leaders and teachers. Based on these findings, this study proposes the concept of "Adaptive Innovation Based on Local Agency," an approach that emphasizes mobile-first, lightweight, and low-cost AI solutions.

KEYWORDS

Artificial Intelligence, Islamic Learning, Rural Madrasah, Innovation in Education, Curriculum Management

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Introduction

The era of digital disruption has transformed various sectors of life, including education, which now requires institutional adaptation and technological integration to enhance learning quality (Haleem et al., 2022; Haleem, Javaid, & Qadri, 2022). In recent developments, this transformation has shifted from general educational digitalization toward the implementation of Artificial Intelligence in Education (AIEd). Globally, AIEd is viewed as having the potential to improve educational management efficiency, personalize learning processes, and enable data-driven decision-making. However, recent scholarship also highlights critical debates regarding equitable access, collaborative relationships between teachers and technology, and infrastructural readiness in countries of the Global South (Zawacki-Richter et al., 2019; Selwyn, 2022). Thus, AI integration in education should not be understood merely as a technological agenda but also as a pedagogical, ethical, and social issue.

In the Indonesian context, digital transformation in education continues to face significant disparities between urban and rural areas. Schools in rural regions frequently encounter limited ICT infrastructure, unstable internet access, and uneven levels of teachers' digital literacy (Rahayu et al., 2022; Siahaan, 2023). This condition becomes particularly significant when related to rural private Madrasah Ibtidaiyah (MI), which, on the one hand, operate with limited resources, yet on the other hand, play a strategic role in providing Islamic elementary education, character formation, and the strengthening of moderate Islamic values from an early age (Maarif, 2019). In practice, limited access to modern educational innovations risks widening the quality gap between rural private MI and other schools with greater resource support (Junaedi, 2021).

The urgency of this issue aligns with the direction of national education policy. The *Merdeka Belajar* (Freedom to Learn) policy emphasizes curriculum flexibility, differentiated instruction, and the strengthening of institutional capacity to respond adaptively to students' needs. In parallel, the national digital transformation agenda encourages schools and madrasahs to develop more effective and responsive learning governance systems. Within this framework, AI becomes particularly relevant as it offers functions beyond general digitalization. While digitalization typically involves the use of devices, platforms, or digital content, AI enables learning needs analysis, content personalization, instructional strategy recommendations, and the automation of teachers' administrative tasks (Chen et al., 2020; Rahman, 2022; Portela, 2025). At the elementary level, such functions are especially important, as learning at this stage

requires close attention to diverse abilities, learning paces, and students' developmental needs.

Research on AI implementation in education has grown rapidly worldwide. Several studies indicate that AI can support adaptive learning, administrative efficiency, and data-driven curriculum development, particularly in higher education or schools in developed and urban contexts (Baker & Smith, 2019; Zawacki-Richter et al., 2019). Nevertheless, research specifically addressing the construction of AI-based curriculum and learning management systems in rural private Madrasah Ibtidaiyah in Indonesia remains very limited (Hidayah, 2022). Most studies focus on the general technical aspects of AI or on macro-level policy discussions, leaving insufficient attention to the complexity of implementation within religious-based educational institutions characterized by distinct social, cultural, and infrastructural contexts (Fadli & Kusuma, 2023). This gap underscores the need for research that not only highlights the normative potential of AI but also formulates a contextual and realistic implementation framework for rural madrasahs.

Based on this context, this article aims to analyze the urgency of and construct a conceptual framework for an AI-based curriculum and learning management system for rural private Madrasah Ibtidaiyah in Indonesia. Specifically, the study seeks to: (1) identify the potential benefits of AI in improving curriculum management efficiency and learning effectiveness; (2) analyze the challenges and barriers to its implementation; and (3) formulate adaptive and sustainable AI integration strategies. The central argument of this article is that AI utilization in rural private MI should not be viewed merely as a complementary digital innovation, but rather as a strategic necessity to address resource limitations while enhancing the quality of educational services. However, its implementation must be designed contextually, implemented gradually, and position teachers as the primary actors in collaboration with technology.

Literature Review

This literature review is developed to establish a conceptual foundation regarding the urgency of integrating artificial intelligence into curriculum and learning management in rural private *Madrasah Ibtidaiyah* (MI). Specifically, the discussion focuses on six major themes: Artificial Intelligence in Education (AIEd), AI applications in curriculum management, the characteristics of curriculum management in madrasahs, challenges in implementing AI in rural MI, adaptive learning, and the limitations of AI in local-religious contexts.

2.1 Artificial Intelligence in Education (AIEd)

AIEd is a field of study that examines the use of intelligent technologies to support learning, improve administrative efficiency, and create more personalized learning experiences (Chen et al., 2020). Its scope includes intelligent tutoring systems, learning analytics, recommendation systems, and predictive analytics (Baker & Smith, 2019). Recent literature indicates a shift from primarily administrative functions toward deeper pedagogical roles, including learning personalization, formative feedback, identification of learning gaps, and the adjustment of materials based on students' abilities (Zawacki-Richter et al., 2019; Hwang et al., 2020).

Nevertheless, global AIEd studies emphasize that the use of AI is not without challenges. Ethical dimensions, equity of access, and collaborative relationships between teachers and technology must be carefully maintained (Selwyn, 2022). Ideally, AI should function as a support system that strengthens teachers' capacities rather than replacing their role. This perspective is particularly crucial for institutions in the Global South, where infrastructural limitations and institutional capacity constraints remain significant (Pedro et al., 2019).

2.2 AI Applications in Curriculum Management

Within the domain of curriculum management, AI can support data-driven planning, monitoring, and evaluation. AI has the potential to assist in analyzing learning outcomes, mapping students' needs, and identifying curriculum components that require adjustment through data mining and predictive analysis (Selwyn, 2022; Luckin, 2018). In the context of MI, AI can help analyze the continuity between the national curriculum and religious content, support evidence-based decision-making, and detect material redundancies (Hidayah, 2022; Baker & Smith, 2019). Thus, the application of AI in curriculum management is not merely a matter of digitalization, but rather a means of strengthening institutional capacity to design adaptive and relevant curricula.

2.3 Curriculum Management in Madrasahs

Curriculum management is a systematic process that includes the planning, implementation, evaluation, and continuous development of educational programs (Oliva, 2018). In madrasahs, this process is more complex because it must integrate the national curriculum with religious content (Ministry of Religious Affairs, 2020). In many rural MI, curriculum management practices are still conducted manually, relying on face-to-face coordination and physical documentation, which makes the process slow and less data-driven (Junaedi, 2021; Fadli & Kusuma, 2023). This condition risks

creating a mismatch between learning objectives and the demands of twenty-first-century competencies. Therefore, educational renewal cannot rely solely on administrative digitalization but requires a more adaptive and data-informed approach (Rahayu et al., 2022).

2.4 Challenges of AI Implementation in Rural MI

The implementation of AI in rural private MI faces three major barriers. First, in terms of digital infrastructure, there are limitations related to stable internet access, low network quality, limited device availability, and, in some cases, inadequate electricity supply (Siahaan, 2023). Second, in terms of human resources, there are low levels of digital literacy, limited competence in Technological Pedagogical Content Knowledge (TPACK), and resistance to change (Rahayu et al., 2022). Third, from the perspective of financial resources, limited fiscal space hinders investment in devices, training, licensing, and sustainable system maintenance (Hidayah, 2022). These three obstacles indicate that AI models developed for urban contexts cannot be directly adopted. Instead, a gradual, lightweight, and low-cost approach is required, including mobile-first or offline-supported solutions (Fadli & Kusuma, 2023).

2.5 Adaptive Learning

Adaptive learning uses intelligent algorithms to tailor content, levels of difficulty, learning sequences, and feedback based on each student's progress and achievement (Peng et al., 2019). Such systems dynamically analyze students' responses in order to optimize their learning pathways (Hwang et al., 2020). This concept enables personalization at scale, which is highly relevant for MI with considerable diversity in students' abilities (Selwyn, 2022). In practical terms, adaptive principles in rural madrasahs can be implemented through automated question banks, recommendations for reinforcement materials, or rapid feedback mechanisms, without necessarily depending on complex platforms (Chen et al., 2020).

2.6 Limitations of AI in Local Contexts

The use of AI in rural MI also has critical limitations. Data bias is a fundamental issue: AI systems trained predominantly on urban data may generate recommendations that are not relevant to rural students and may even reproduce inequality (Baker & Smith, 2019; Selwyn, 2022). In addition, general AI systems often lack sensitivity to religious contexts and local wisdom, such as madrasah curricula, *tahfidz* practices, or the nuances of local *fiqh* traditions (Hidayah, 2022). Therefore, the implementation of AI in madrasahs requires a human-in-the-loop approach that positions teachers as the primary guides and controllers of technology (Pedro et al.,

2019). AI should be understood as a supportive tool that serves educational goals grounded in local values, rather than as a mechanism that replaces the teacher's central role (Fadli & Kusuma, 2023).

Method

3.1 Research Design and Site

This study employed mixed methods sequential explanatory design, combining a Systematic Literature Review (SLR) in the first phase and a single qualitative case study in the second phase (Creswell & Creswell, 2018). The research site was the pilot project of MI Ulul Albab, located in Prayungan Village, Sawoo District, Ponorogo Regency, East Java, Indonesia. This site was purposively selected because it represents a rural private madrasah that is attempting to undertake digital adaptation amid infrastructural limitations and constrained institutional capacity. The madrasah was treated as an instrumental case for understanding the broader dynamics of AI adoption in the context of rural Islamic elementary education.

3.2 Data Sources and Participants

Secondary data was obtained through a systematic review of journal articles, academic books, conference proceedings, and policy documents related to AIEd, the digital divide, curriculum management, and adaptive learning. Primary data were collected in the field through interviews, observations, and document analysis. Participants were selected using purposive sampling and consisted of six individuals: one foundation administrator, one madrasah principal, two teachers (representing general and religious subjects), and two representatives of the madrasah committee/parents.

3.3 Data Collection

The first phase (SLR) was conducted through searches in Scopus, Web of Science, and Google Scholar using the following keyword combinations: "artificial intelligence" OR "AIEd" AND "curriculum management" OR "adaptive learning" AND "madrasah" OR "Islamic school" AND "rural" OR "Global South." The selection process followed the PRISMA protocol (Page et al., 2021) and was limited to publications from 2018 to 2024 discussing AI in education, learning personalization, the digital divide, teacher competence, and algorithmic justice. The SLR findings generated preliminary analytical themes that were then used to develop case study instruments.

The second phase (case study) employed three techniques:

1) Semi-structured in-depth interviews with all participants (45-60 minutes each, audio-recorded with consent);
2) Passive participant observation of learning activities, administrative practices, and curriculum coordination; and
3) Document analysis, including the Madrasah Operational Curriculum, teaching materials, evaluation reports, and ICT infrastructure data.

All participants received a clear explanation of the purpose of the study, and their identities were anonymized in accordance with confidentiality principles.

3.4 Data Analysis and Points of Integration

The SLR data were analyzed through descriptive mapping (distribution of studies by year, region, and focus) and thematic synthesis to identify key concepts and research gaps (Xiao & Watson, 2019). The primary data were analyzed using the thematic analysis approach of Braun and Clarke (2006), following an iterative process of transcription, initial coding, theme clustering, refinement, and narrative construction. The coding process was facilitated by NVivo 12 software.

Integration between the two phases was conducted at two points of mixing. First, at the instrument development stage, where the SLR findings were directly used to construct the interview guide and observational focus. Second, at the final interpretation stage, through a joint display to identify confirmation, modification, or correction between assumptions derived from the literature and the field findings. This process generated meta-inferences as the basis for model construction.

3.5 Trustworthiness

The credibility of the study was ensured through: 1) Source triangulation, by comparing the perspectives of the foundation administrator, principal, teachers, and committee representatives; 2) Method triangulation, through the combination of interviews, observations, and document analysis; 3) Limited member checking, to confirm interpretations with key informants; and 4) An audit trail consisting of systematic documentation of the entire research process. A sufficiently rich contextual description is also provided to enable assessment of the transferability of the findings to other similar rural madrasah contexts.

In the following section, the author presents Figure 1: Research Flowchart. This diagram provides a clear and concise visual overview of the entire research process, structured into the following stages. *Stage 1 (SLR):* Systematic Literature Review (SLR) - detailing the procedural steps (Database Identification → Criteria-Based Selection → Thematic Analysis). Point of Integration: *"Case Study Instrument Development"* -

indicating that the findings of the SLR were utilized to construct the interview guidelines and observational framework. *Stage 2 (Case Study)*: A single case study conducted at the pilot project of MI Ulul Albab, employing three data collection techniques (Interviews, Observations, and Document Analysis). Analysis and Outcomes: *"Analysis and Integration of Findings"* - encompassing *Thematic Analysis* and *Data Triangulation*, which ultimately culminated in the *Model Construction and Formulation of Recommendations*. The following is the visualization of the research flow diagram.

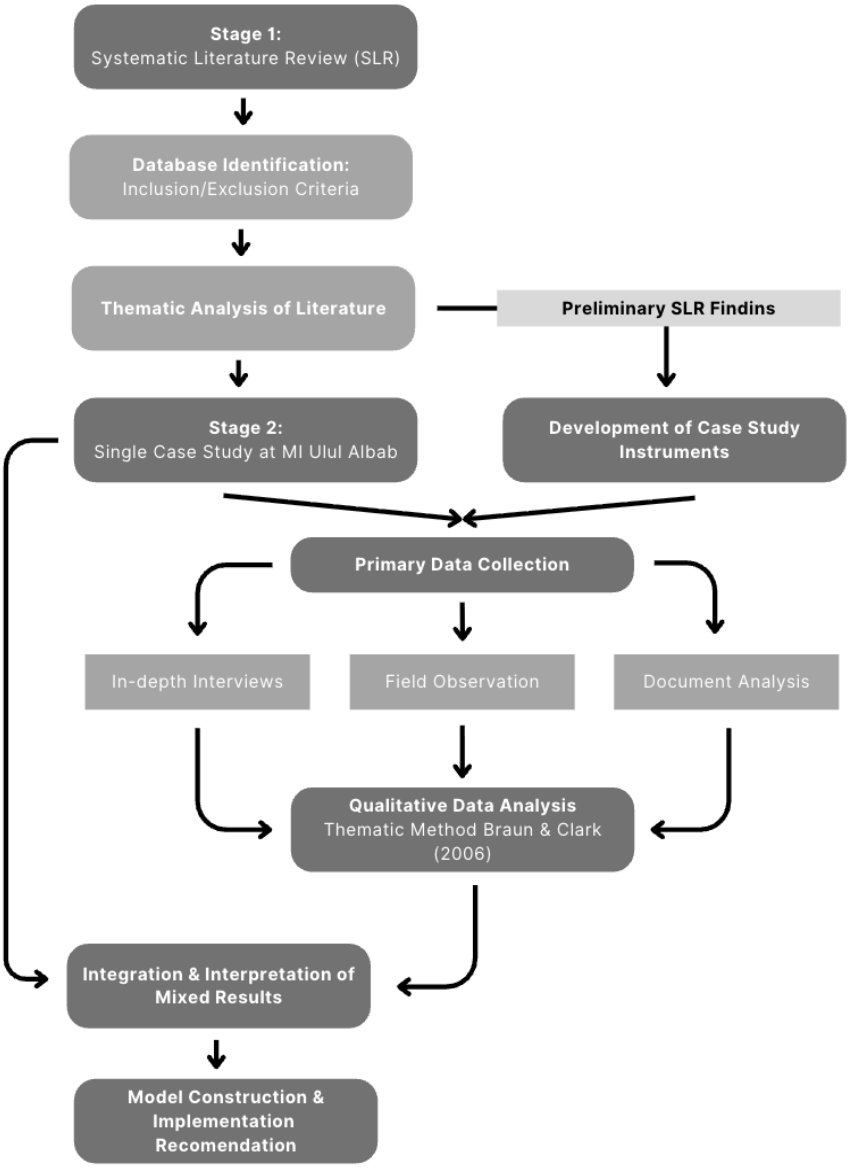

Figure 1 Chart oF Mixed Method Research Flowchart: SLR + Qualitative Single Case

Results

The findings are organized into three thematic clusters: (1) the digital infrastructure gap, (2) the realities of curriculum and learning management, and (3) the potential for adaptive learning grounded in local agency.

4.1 Digital Infrastructure Gap and Structural Constraints

Data from the Central Bureau of Statistics (BPS, 2023) and the Ministry of Religious Affairs (Kemenag, 2023) confirm significant infrastructure disparities. More than 93% of MI in Indonesia operate as private institutions, with a high concentration in rural areas. Only 35% of rural private MI in underdeveloped regions possess functional computer laboratories, and stable internet access is available in only approximately 48% of rural MI, compared to more than 90% in urban areas. The SLR findings affirm that this disparity is part of the broader issue of educational technology marginalization in the Global South (Pedro et al., 2019), further compounded by extremely low network speeds - below 5 Mbps - rendering real-time cloud-based AI systems effectively inoperable.

At the pilot MI Ulul Albab, field observations and document analysis revealed that the madrasah possesses only a single shared computer unit for all administrative needs. Internet connectivity depends entirely on the principal's personal mobile data subscription, with no institutional Wi-Fi network in place. All six participants accessed the internet via personal smartphones using self-funded data plans, and only two reported feeling comfortable using internet-based applications for instructional purposes. The principal stated: *"We are planning to install a good internet network. However, at the moment, due to limited funds, we have had to postpone even purchasing a router, let alone a server or paid applications."*

This limitation reflects layered structural vulnerability: not merely the absence of devices, but also the lack of a supporting ecosystem, including maintenance budgets and technical personnel (Selwyn, 2022).

Table 1. Technology Access Disparities between Urban and Rural MI

Indicator	Urban MI	Rural MI	Implications for AI Implementation
Stable internet access	>90% (BPS, 2023)	<50% (Kemenag, 2023)	Offline-first or hybrid AI models are required
Average network speed	>20 Mbps	<5 Mbps	Cloud-based AI systems risk being non-optimal

Device availability (student ratio)	High (1:5)	Low (1:30)	Solutions must rely on teachers' personal mobile devices
Teacher digital literacy	High	Moderate–Low (Rahayu et al., 2022)	Simple interfaces and contextual training are needed
Use of adaptive AI platforms	Available/piloted	Not yet available	Opens opportunity for introducing simple, directly actionable AI tools

Source: Synthesis of BPS (2023), Kemenag (2023), Rahayu et al. (2022), and Pedro et al. (2019)

4.2 Realities of Curriculum and Learning Management

Field observations and document analysis demonstrated that all curriculum management processes at MI Ulul Albab are conducted entirely manually. Schedule preparation, task distribution, grade recapitulation, and reporting are carried out using handwritten records and basic spreadsheets. The Madrasah Operational Curriculum (*Kurikulum Operasional Madrasah*/KOM) document had not been updated for more than one year, with no evidence of data-based evaluation records. Inter-teacher coordination occurs informally during recess periods, without any formal, data-driven mechanism.

Two teachers acknowledged spending several hours per week on administrative tasks, which correspondingly reduced their time for creative lesson preparation and individual student interaction. The foundation administrator remarked: "*We are very open to technology, but for now, the most realistic option is to manage what we already have as best we can."* The principal added: "*I have seen on YouTube that there is AI that can generate exam questions. But we need step-by-step training."* One teacher noted: "*Sometimes I must stay late just to write up reports. If something could help, even just a little, it would already mean a great deal."*

These conditions reflect the administrative burden identified in literature as a key inhibitor of pedagogical quality (Luckin, 2018). The gap between this manual reality and the potential of AI to automate scheduling, reporting, and student achievement analysis indicates that administrative automation represents the most realistic entry point - a *low-hanging fruit* - for AI integration in rural madrasahs.

4.3 Potential for Adaptive Learning Grounded in Local Agency

Despite these constraints, the case study identified emergent forms of innovation driven by local initiative. Two of the four teachers independently used their personal smartphones to access free online quiz applications, share materials via WhatsApp, and utilize generative AI tools to draft assessment questions. The first teacher stated: *"I use Google Forms for daily quizzes. It is free, and the results are immediately available."*

The second teacher added: *"I have tried using ChatGPT to generate questions. It was quite helpful, but I am not sure whether the output aligns with the madrasah curriculum."* During one observed session, a teacher played a pre-downloaded YouTube video during instruction - in anticipation of internet disruption during cloudy weather or power outages - a spontaneous adaptation that reflects the principle of offline-supported learning.

From the community side, two committee members expressed willingness to support teacher technology training through independent fundraising. One stated: "*If there is training that can help teachers teach better, we are willing to help raise the funds from the parents."* This statement confirms that local community agencies constitute a genuine and tangible form of social capital that can be strategically mobilized.

These findings suggest that the foundation for AI implementation at MI Ulul Albab is not entirely absent, but rather present in the form of social capital and adaptive willingness, rather than physical infrastructure. Teachers' patterns of using simple technology reflect principles of adaptive learning that are responsive to contextual needs (Hwang et al., 2020; Selwyn, 2022). Nevertheless, the transferability of these findings must be understood contextually. Madrasahs with higher levels of geographic isolation or weaker community capacity may require different approaches. Accordingly, these findings are better understood as analytical propositions rather than directly replicable formulas.

The integration of findings from the SLR and the single case study demonstrates that AI can begin to bridge learning gaps even under conditions of minimal resources, provided that the strategy is appropriately designed — namely, by focusing on micro-level needs, utilizing existing devices, and empowering teachers as the frontline actors of implementation. **Figure 2** illustrates the Framework for Gradual AI Integration in Rural MI (Based on the Synthesis of Findings).

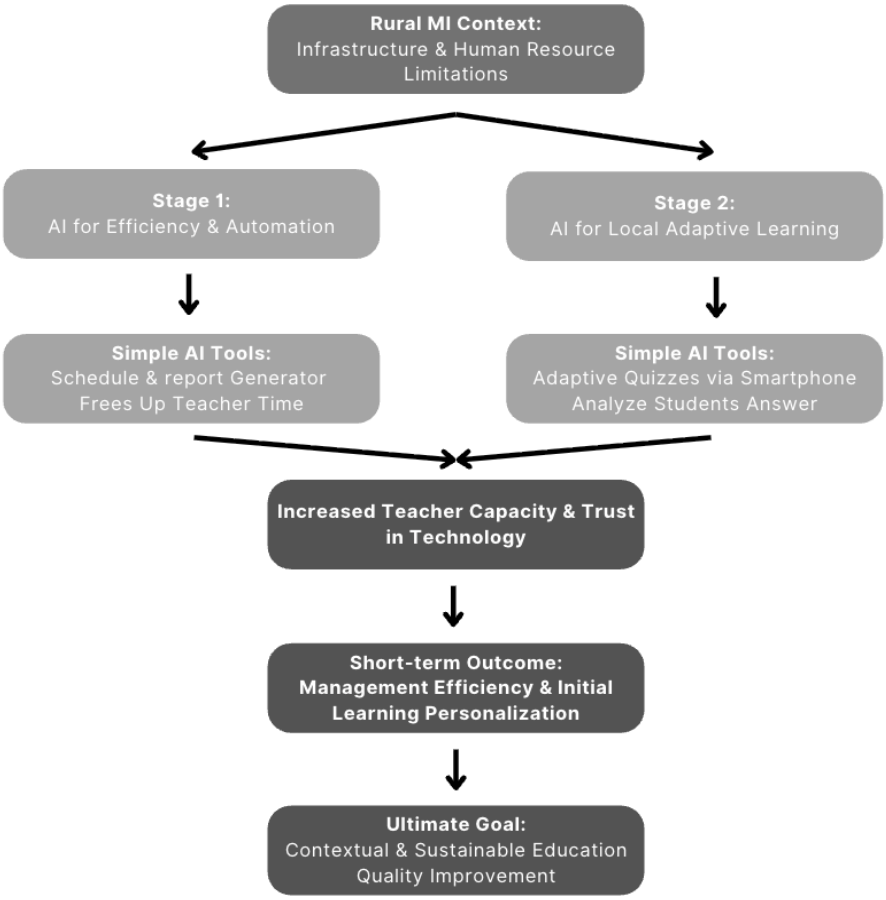

Figure 2. Framework for Gradual AI Integration in Rural MI (Based on Synthesis of Findings)

Discussions

This section presents an in-depth interpretation of the research findings, elaborates on the urgency of AI adoption in rural private MI, and formulates the theoretical and practical implications relevant to madrasah education policy and practice.

5.1 Summary of Research Findings

This study reveals a critical paradox in the context of Islamic elementary education in rural Indonesia. On one hand, there exists a significant digital infrastructure gap between the theoretical potential of AIEd and the realities of rural private MI, characterized by unstable internet access, minimal hardware availability, low teacher digital literacy, and constrained institutional budgets. On the other hand,

it is precisely within these conditions of limitation that a strong urgency for AI adoption emerges - particularly as a response to teachers' inefficient administrative burdens and the pressing need for more personalized and differentiated learning for students.

The key findings of this study demonstrate that lightweight, mobile- or web-based, low-cost AI solutions focused on resolving specific problems possess substantially higher potential for adoption and sustainability than large-scale, complex AI platforms. Furthermore, this study finds that structural barriers do not necessarily extinguish opportunities for innovation. On the contrary, local teacher agency and community support within the madrasah proved to be driving forces capable of compensating for the limitations of physical infrastructure.

5.2 Distinguishing Contributions in Relation to Existing Literature

The findings regarding digital infrastructure challenges align with a body of global research on the digital divide in rural and developing-country contexts (Pedro et al., 2019; Selwyn, 2022). However, this study makes a distinguishing contribution by shifting the discourse from a focus on enhancement in technology-rich environments toward a focus on necessity in resource-constrained settings. While much of the AIEd literature concentrates on algorithmic sophistication and complex systems integration (Baker & Smith, 2019; Zawacki-Richter et al., 2019), this study finds that the primary value of AI in rural contexts lies in its most fundamental capabilities - namely, administrative automation and basic personalization that can directly alleviate teacher burdens.

Comparative analysis with AIEd practices in socio-economically similar regions further corroborates these findings. In rural South Asia, particularly in Bangladesh and India, several AIEd programs have been successfully implemented using low-tech AI approaches that rely on simple mobile devices and minimal connectivity, with a focus on improving basic literacy and providing formative feedback for teachers (Peng, Ma, & Spector, 2019). In Sub-Saharan Africa, research demonstrates that successful AI adoption in rural schools did not originate from sophisticated platforms, but from simple SMS-based or offline-capable tools operable even without active internet connectivity (Pedro et al., 2019). These patterns are highly relevant to the Indonesian rural MI context, as they demonstrate that infrastructural limitations are not absolute barriers, but rather conditions that determine the design of appropriate solutions.

The dimension of local teacher and community agency identified in this study represents a distinguishing factor that has received insufficient attention in the mainstream AIEd literature. Most AIEd studies position teachers solely as recipients or users of technology, rather than as actors who actively adapt and shape technology

use in accordance with their contextual needs. The findings of this study, by contrast, reveal that teachers at MI Ulul Albab are not passive subjects but adaptive agents who independently explore simple technological solutions within the constraints of their environment.

Table 2 Research Positioning: Comparison with Existing Literature

Dimension	Dominant AIEd Literature (Urban/Well-Resourced)	This Study's Findings (Rural Private MI)
Primary focus	Enhancement and innovation	Basic efficiency and equity
Technological approach	Complex, integrated platforms	Simple, specific modules (micro-AI)
Primary challenges	Data integration, ethics, security	Basic infrastructure, digital literacy, budget
Teacher role	Facilitator and AI collaborator	Adaptive agent and frontline implementer
Adoption model	Top-down, structured	Bottom-up, adaptive, and incremental
Social context	Urban, institutionally established	Rural, community-centric, high social capital

5.3 Theoretical Justification: Foundations of the "Adaptive Innovation Based on Local Agency" Concept

The concept of "Adaptive Innovation Based on Local Agency" proposed in this study does not emerge from a theoretical vacuum but rests on a well-established and academically defensible set of theoretical foundations.

First, this concept draws on the Theory of Diffusion of Innovations (Rogers, 2003), which asserts that the adoption of innovations within communities is not uniform but depends on perceptions of relative advantage, compatibility, and trialability. The findings of this study show that teachers at MI Ulul Albab have instinctively operated according to this logic: they gravitate toward applications that are immediately useful, free of charge, and can be trialed without significant risk. The implication is that AI adoption programs for rural MI must be designed to fulfill these three criteria, rather than simply offering technically sophisticated technology.

Second, the concept is reinforced by the perspective of critical pedagogy (Freire, 1970), which emphasizes the importance of positioning local communities not as objects of development but as active subjects who shape solutions to their own

problems. The engagement of the madrasah community - including committee members ready to mobilize funding for teacher training - reflects this spirit. AI integrated into the madrasah ecosystem must not arrive as a technology imposed from above, but must grow from the needs, capacities, and values embedded within the community.

Third, this concept aligns with the community-based design approach (Sanders & Stappers, 2008), which holds that sustainable solutions must be built *with* the communities that will use them, not merely designed *for* them. In the context of this research, such an approach means that the development of AI systems for rural MI ideally involves teachers, principals, and community members from the design stage onward, not only at the point of implementation.

5.4 Risks of AI Adoption: Privacy, Algorithmic Bias, and Teacher Deskilling

While this study generally argues for the urgency of AI adoption in rural MI, it is essential to critically discuss the potential risks accompanying this process, to avoid uncritical technological optimism.

First, the risk of data privacy warrants serious attention. Many free and easily accessible mobile AI applications operate with non-transparent privacy policies, collecting user data for commercial purposes. In the madrasah context, where users are young students and teachers who may not fully understand the implications of data use, this risk becomes more concrete. Frameworks such as the UNESCO AI Competency Framework for Teachers (UNESCO, 2022) affirm that literacy regarding data privacy and security constitutes a minimum competency that teachers must possess before integrating AI into instruction. Accordingly, AI training programs for rural madrasah teachers must not focus solely on tool operation but must also encompass data security awareness.

Second, the risk of algorithmic bias cannot be overlooked. As reviewed in the literature, most AI models are trained on data predominantly derived from urban student profiles or specific socio-economic contexts. When deployed in rural MI, the resulting recommendations may be irrelevant or even inequitable for students from different backgrounds (Selwyn, 2022; Baker & Smith, 2019). In the madrasah context, which encompasses specific religious content, this bias may be further amplified - for instance, when AI fails to recognize the pedagogical relevance of Islamic studies materials or produces assessments inconsistent with madrasah values. Therefore, AI implementation in madrasahs must be accompanied by local validation mechanisms that enable teachers to evaluate and correct AI output in accordance with their context.

Third, there is the risk of deskilling - the erosion of teachers' pedagogical skills and autonomy resulting from excessive reliance on AI in instructional decision-making. Although AI can enhance efficiency, over-dependence risks undermining teachers' capacity for independent and reflective pedagogical judgment (Selwyn, 2022). In the madrasah context, where teacher-student relationships are not only academic but also religious and moral in character, this risk becomes particularly sensitive. The appropriate approach, therefore, is to position AI strictly as a supportive tool, with teachers remaining the primary subjects in all pedagogical decisions - a human-in-the-loop orientation.

5.5 Interactions between Local Institutions and Systemic Constraints

The findings of this study cannot be fully understood without examining how MI Ulul Albab, as a local institution, interacts with broader systemic constraints. At least three dimensions of systemic constraint shape the opportunities and limitations of AI adoption in rural madrasahs.

First, from the perspective of funding, rural private MI occupies a structurally disadvantaged position. Although the government, through the Ministry of Religious Affairs, provides the Madrasah School Operational Assistance (*Bantuan Operasional Sekolah*/BOS), the allocation for technology-related needs is frequently insufficient to cover digital device procurement, software licensing, or sustained teacher training. Dependence on community contributions makes funding unpredictable and difficult to plan for in the long term. Under these conditions, AI solutions based on free or freemium software that require no new infrastructure become the only realistic option.

Second, from the perspective of teacher training policy, rural madrasah teachers frequently lack equitable access to professional development programs relevant to educational technology. Existing training programs tend to be top-down, standardized, and insufficiently attentive to the initial capacity and specific needs of teachers in remote areas. The findings of this study show that teachers at MI Ulul Albab are more responsive to contextual, incremental, and practice-based training rather than generic and theoretical instruction. This implies that digital literacy training policies for madrasah teachers must be redesigned to account for the diversity of conditions on the ground.

Third, from the perspective of national curriculum standards, AI adoption in madrasahs must simultaneously align with two curriculum systems: the *Kurikulum Merdeka* from the Ministry of Education, Culture, Research, and Technology, and the religious curriculum from the Ministry of Religious Affairs. This complexity presents a

distinctive challenge for developing relevant AI systems, as such systems must accommodate two complementary yet distinct competency frameworks. Generic AI tools that are not designed for religious content will struggle to achieve full acceptance within the madrasah community.

5.6 Proposed Research Model

The findings of this study affirm that a one-size-fits-all approach to educational digitalization is no longer adequate, particularly when applied to contexts that differ significantly from the dominant assumptions of the AIEd literature in terms of infrastructure, culture, and institutional character. This finding signals the need for a transition - from equity policies focused solely on physical procurement (hardware) toward approaches that integrate infrastructure strengthening, human capacity development, and the development of genuinely contextual software.

Based on the synthesis of these findings, this study proposes the concept of "**Adaptive Innovation Based on Local Agency**" as an orientational framework for the development and implementation of AI systems in rural private MI. This concept rests on three foundational principles.

First, contextuality: AI solutions must be designed or selected based on their fit with the madrasah's infrastructural conditions, human resource capacity, and socio-cultural characteristics - not merely on global technological trends.

Second, incrementality and sustainability: AI implementation need not occur all at once or comprehensively. A more realistic model is phased adoption, beginning with the most pressing need - administrative automation - and progressing toward more complex functions such as adaptive learning and curriculum analytics.

Third, local agency as the driving force: the success of AI implementation is determined not solely by the sophistication of the technology, but by the extent to which teachers, principals, and communities are positioned as primary actors who possess control, understanding, and the capacity to adapt technology to their own needs.

Figure 3 visualizes the **Tiered Adaptive AI Adoption Model for Rural Private MI**, constructed from the synthesis of research findings. This model depicts three progressive tiers of adoption: Tier 1, basic administrative automation using simple digital tools; Tier 2, data-supported learning through lightweight mobile platforms; and Tier 3, integrated adaptive learning systems grounded in analytics - all of which can be built incrementally as infrastructure and human resource capacity are strengthened.

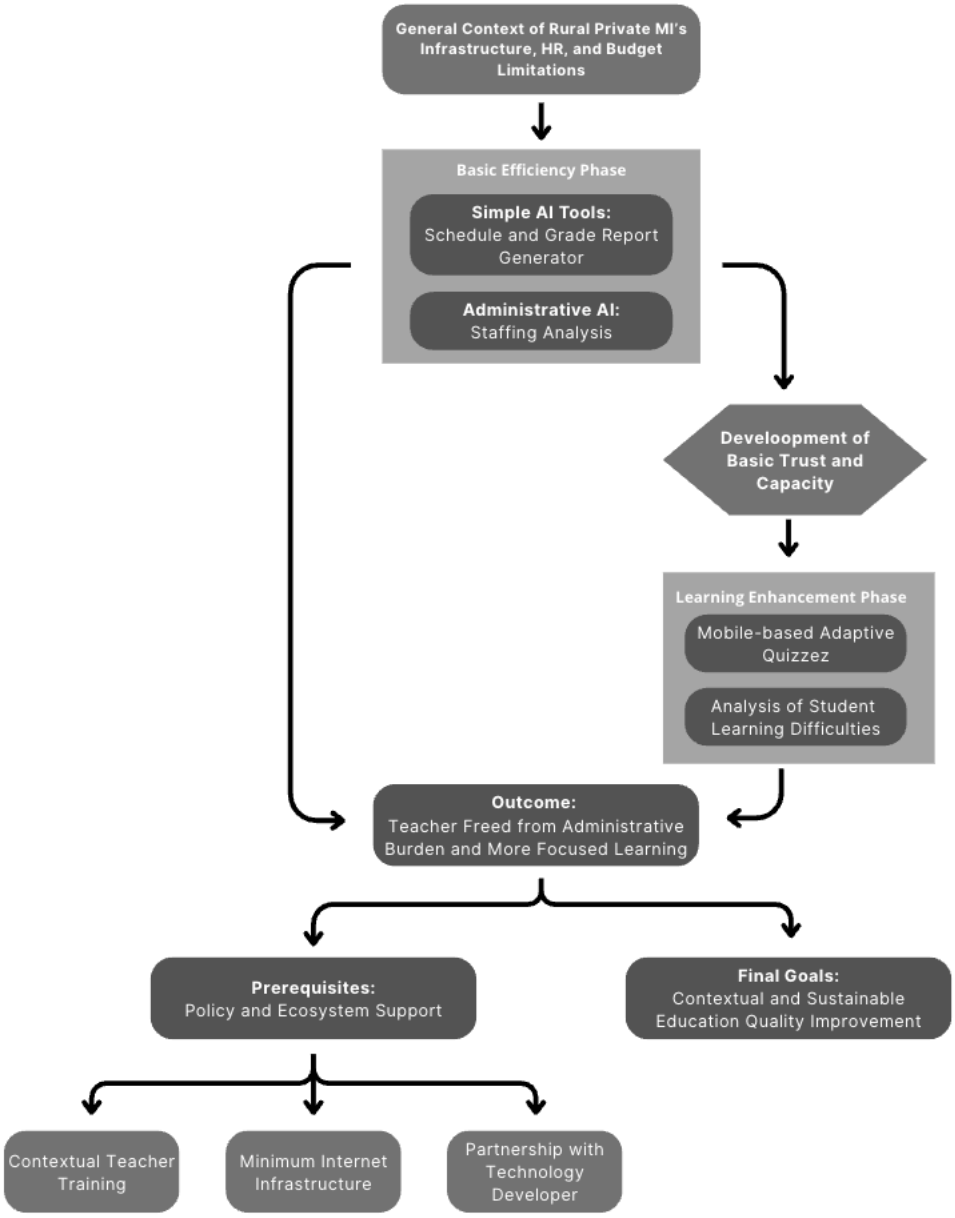

Figure 3 Tiered Adaptive AI Adoption Model for Rural Private MI

The findings of this study carry distinct implications for each category of stakeholders. For policymakers - both the Ministry of Religious Affairs and the Ministry of Education, Culture, Research, and Technology - the primary implication is the need to shift orientation away from promoting complex AI platforms toward the development and dissemination of lightweight, low-cost, user-friendly AI tools capable of operating under conditions of limited infrastructure (low-bandwidth or offline-first).

Relevant policy measures could take the form of digital aid packages encompassing internet subsidies, standardized teacher training modules, and a curated list of educational AI applications validated for rural madrasah contexts.

For teacher training institutions, the findings imply a need to shift from generic digital literacy training toward functional digital literacy training that directly equips teachers with skills to use simple AI tools for resolving everyday administrative and pedagogical challenges. Contextual, incremental, and practice-based training will be substantially more effective than generic, theory-heavy instruction.

For rural private MI themselves, the findings indicate that strategic investment in improving basic internet connectivity will yield faster and more measurable impact than large-scale investment in expensive hardware. The most realistic initial step is to begin with administrative automation using freely available digital tools, then progress incrementally toward more complex AI functions as teacher capacity and infrastructure are strengthened.

5.8 Configuration and Dynamics of the Findings

The configuration of the findings in this study is the product of a dynamic interaction between structural factors and local agency. Structural factors - encompassing policy gaps, economic disparities, and digital infrastructure limitations - create real and tangible constraining conditions. Yet within these conditions, local agency - manifested in the principal's transformational will, teachers' adaptive spirit, and community support - emerges as a force that cannot be disregarded.

This dynamic reinforces the argument that the success of AI adoption in rural MI is not determined solely by the availability of technology, but by the capacity of local actors to adapt technology in accordance with their needs and capabilities. A dense curriculum, heterogeneous student abilities, and teachers' time constraints generate genuine pressure that drives the need for efficient solutions. AI, even in its simplest form, offers a responsive potential that manual and conventional approaches have consistently been unable to fulfill.

5.9 Recommendations

Based on the entirety of the foregoing discussion, this study formulates three principal recommendations:

First, from a practical standpoint, further testing and validation of AI-based curriculum management system prototypes and adaptive learning modules specifically designed for rural MI contexts are required. Longitudinal intervention studies should

be conducted to measure the actual impact on teacher workload, operational efficiency, and student learning outcomes.

Second, from a policy standpoint, structured dialogue should be established between the Ministry of Religious Affairs, the Ministry of Communication and Information Technology, and educational technology developers to create a supportive digital ecosystem. This dialogue should be directed toward formulating minimum digital infrastructure standards for madrasahs, developing a national platform containing curated AI tools, and providing incentives for madrasahs that pioneer AI adoption.

Third, from the standpoint of future research, similar studies should be conducted across diverse geographical locations and socio-cultural contexts to strengthen the external validity of the proposed model. Future research could also explore the development of AI content that more deeply integrates local wisdom values and Islamic educational content, thereby rendering the technology more authentically relevant to the madrasah community.

5.10 Adaptive AI Implementation Roadmap for Rural Private MI (2025–2030)

As an operational synthesis of the foregoing discussion, this study formulates an implementation roadmap intended as a guide for stakeholders. The roadmap is organized into six progressive and mutually reinforcing annual phases.

Table 3 Adaptive AI Implementation Roadmap for Rural Private MI (2025–2030)

Year	Key Targets and Activities	Phase
2025	Mapping of 100 pilot MI; formulation of AI education technical standards	Preparation and standardization
2026	5 simple AI tool prototypes ready for testing; basic teacher training modules available	Tool and module development
2027	200 teachers trained; pilot testing in 25 pilot MI	Initial training and small-scale piloting
2028	500 teachers trained; implementation model validated	Model validation and capacity building
2029	40% of rural MI digitalized; AI toolkit distributed to 15 provinces	Expansion and mass digitalization
2030	60% of rural MI digitalized; policy support system permanently operational	Target achievement and sustainability

Source: Synthesis of research findings

This roadmap is operationalized through four core strategies: (1) a phased and contextual approach; (2) mobile-first and offline-first principles; (3) tiered training based on actual needs; and (4) continuous evaluation that is adaptive to evolving field conditions.

5.11 Strategic Recommendation Matrix

To complement the roadmap, the following matrix presents more detailed recommendations for each primary stakeholder group.

Table 4 AI Implementation Recommendation Matrix for Rural Private MI

Stakeholder	Short-Term (1–2 Years)	Medium-Term (3–5 Years)	Success Indicators
Ministry of Religious Affairs	Formulate minimum digital infrastructure standards; develop basic AI training modules	Build a national platform of curated AI tools; provide incentives for pioneer madrasahs	40% of rural MI accessing basic AI tools by 2027
Local Government	Provide stable internet access in remote and underserved areas; establish digital education innovation centers	Allocate dedicated funds for madrasah digitalization; build partnerships with higher education institutions	60% of districts with madrasah digitalization programs by 2028
Technology Developers	Design lightweight mobile-first applications; adopt offline-first principles	Build an integrated AI tool ecosystem; develop contextual rural content	10 AI education applications certified for rural MI by 2026
Rural Private MI	Establish school digitalization teams; initiate basic administrative automation	Integrate AI tools into instruction; build a culture of data-informed decision-making	30% of teachers will be using AI tools regularly by 2028

Source: Synthesis of research findings

5.12 Synthesis: Toward Empowering AI

The entirety of the discussion in this section converges on a single fundamental conclusion: the urgency of AI in rural private MI does not lie in the sophistication of its

technology, but in its capacity to serve as an instrument of empowerment - one that addresses structural limitations through solutions that are adaptive, contextual, and sustainable. The success of its implementation is not measured by the technical sophistication of the systems adopted, but by the extent to which the technology is capable of: 1) Liberating teachers from administrative burdens that erode pedagogical time and energy; 2) Enabling basic learning personalization within conditions of limited resources; 3) Strengthening local capacity through a sustainable bottom-up approach; and; 4) Reducing the digital divide without creating new forms of dependency.

The tiered adoption model proposed in this study offers a realistic and contextual framework. However, its implementation requires the collective commitment of all stakeholders, each fulfilling a strategic role commensurate with their capacity and authority. In doing so, this study contributes not only to the advancement of academic inquiry into AIEd in marginalized contexts but also offers an operational roadmap for achieving equitable quality education through technology that is inclusive, adaptive, and genuinely oriented toward community empowerment.

Conclusion

6.1 Principal Findings

This study reveals a paradigm shift in understanding the urgency of AI adoption in rural MI. The impetus for adoption of AI does not arise from ambitions of enhancement, but rather from the pragmatic necessity of addressing administrative inefficiency and human resource limitations. This finding challenges the assumption that sophisticated infrastructure is an absolute prerequisite for AI adoption. Social capital - in the form of enthusiasm, local agency, and community support - proves to be a more determinant lever. On this basis, the concept of "**Adaptive Innovation Based on Local Agency"** is proposed as a framework more appropriate to this context than top-down and infrastructure-centric adoption models.

6.2 Research Contributions

Conceptually, this study operationalizes "Adaptive Innovation Based on Local Agency," which complements the predominantly tech-centric global AIEd discourse with a human- and context-centric perspective, in alignment with UNESCO's (2022) call for equity in AI utilization. Methodologically, this study demonstrates the relevance of the Mixed Methods Sequential Explanatory Design in addressing the complexity of educational issues in marginalized regions, where the combination of SLR and

qualitative case study functions as an active dialectical process - yielding holistic understanding that is practically relevant.

6.3 Limitations

Several limitations must be acknowledged. *First*, the single case study design limits direct generalization; the findings are more appropriately understood as analytical propositions requiring further empirical testing. *Second*, six participants from a single institution reflect the specific dynamics of MI Ulul Albab, which may not be uniformly applicable to other madrasahs. *Third*, the study is confined to the phase of urgency identification and has not entered the stage of empirical implementation; the effectiveness of the proposed solutions therefore awaits verification. *Fourth*, the rapid pace of AI development renders some findings time-sensitive, necessitating periodic re-examination.

6.4 Directions for Future Research

Three directions for future research are recommended. *First*, the development and testing of mobile-first AI tool prototypes through intervention studies - whether action research or quasi-experimental designs - to measure the empirical impact on teacher efficiency and student learning outcomes. *Second*, multi-site studies across provinces examine the transferability of the "Adaptive Innovation Based on Local Agency" model across diverse geographical and cultural contexts. *Third*, longitudinal research on AI adoption among madrasah teachers to understand the development of digital literacy and pedagogical capacity over time. This study opens a space for deeper inquiry toward achieving equitable quality education through technology that is inclusive, adaptive, and genuinely oriented toward the madrasah community.

Disclosure Interest

We declare no conflict of interest.

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Author Contribution

Mulyono conceptualized the study, performed the data collection and analysis, and drafted the article. The author critically revised the manuscript and bears full responsibility for its entire content.

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