Journal of Nonformal Education
Vol. 12, No. 2 (2026): 380-393

p-ISSN 2442-532X | e-ISSN 2528-4541
https://journal.unnes.ac.id/journals/jone

Community-Based Artificial Intelligence for Enhancing Productive Digital Literacy in Nonformal Education: An Integrative Conceptual Framework

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Submitted: July 7, 2026. Revised: August 2, 2026. Accepted: August 22, 2026

Abstract

Background – Artificial intelligence (AI) can support personalization, feedback, and knowledge creation, yet educational AI research remains concentrated in formal institutions and commercially connected settings. Indonesian Community Learning Activity Centers (PKBM) and Learning Activity Studios (SKB) require models that address local knowledge, uneven access, adult learning, and community authority over data.

Research Urgency – Current literature often treats AI access as equivalent to inclusion. It pays less attention to who curates knowledge, controls data, evaluates AI outputs, and determines locally relevant learning outcomes in nonformal education.

Research Objectives – This article develops a Community-Based AI–Project-Based Learning (Cb-AI-PjBL) framework for strengthening productive digital literacy in Indonesian nonformal education and specifies its theoretical basis, governance requirements, implementation stages, and evaluation indicators.

Research Method – The study uses an integrative conceptual review rather than a systematic literature review. A purposive corpus of 47 scholarly sources published mainly in 2023–2026 was examined across AI in education, community and Indigenous data governance, digital literacy, adult and nonformal education, and PjBL. Iterative thematic comparison produced four problem–solution categories. Two UNESCO AI competency frameworks were used as policy benchmarks.

Research Findings – The synthesis produced four interdependent design pillars: community-curated knowledge repositories, culturally responsive adaptive pathways, multimodal access and digital-literacy bridges, and participatory governance and ethical oversight. PjBL functions as the pedagogical connector. The present review did not conduct field trials. As external contextual support reported an N-Gain of 0.43 and an 82.7% validation score for a PjBL productive-digital-literacy model; these results support the PjBL component but do not validate the integrated Cb-AI-PjBL framework.

Research Conclusion – Cb-AI-PjBL offers a testable design proposition for shifting from AI delivered to communities toward AI designed and governed with communities. Its feasibility and effectiveness still require pilot testing in PKBM and SKB settings.

Research Novelty/Contribution – The contribution lies in contextually integrating established community AI, data-justice, multimodal-access, and PjBL principles for Indonesian PKBM and SKB, not in claiming invention or empirical validation of those concepts.

Keywords: community-based artificial intelligence; productive digital literacy; nonformal education; project-based learning; participatory governance; PKBM; SKB

How to Cite:

Multazam, M., Miftahudin, A., Qutni, D., Rimayati, E., & Isah, M. (2026). Community-based artificial intelligence for enhancing productive digital literacy in nonformal education: An integrative conceptual framework. *Journal of Nonformal Education, 20*(2), 380-393. https://doi.org/10.15294/jone.v12i2.58666

INTRODUCTION

The artificial intelligence (AI) revolution has brought fundamental changes in the global education landscape. Adaptive learning systems, intelligent tutoring, automated feedback, learning analytics, and generative AI tools are now central topics in educational innovation discourses (Bond et al., 2024; Mustafa et al., 2024; Ogunleye et al., 2024; Wu et al., 2025; Irfan et al., 2025). Contemporary literature asserts that AI in education should be grounded in the principles of human agency, inclusion, equity, linguistic diversity, cultural diversity, privacy protection, and pedagogical validation, not just technological novelty (Bond et al., 2024; Taylor et al., 2026; Kashyap et al., 2024; Garcia Ramos & Wilson-Kennedy, 2024). Educational AI research and policy still privilege formal institutions, standardized curricula, and commercially scalable platforms. This emphasis can marginalize lifelong and nonformal education, where learners vary widely in age, schooling experience, language, digital access, livelihood, and learning purpose (Adarkwah, 2025; Ncube & Tawanda, 2025). In these settings, importing institution-centered AI may reproduce exclusion rather than expand learning opportunities.

In Indonesia, this phenomenon is evident in the practice of Community Learning Activity Centers (PKBM) and Learning Activity Studios (SKB). These two institutions are the spearhead of nonformal education that serves groups that are not optimally reached by formal education: students of Package B and Package C programs, marginalized women, migrant workers, school dropouts, and indigenous communities. In this context, the relevant question is not simply "how can AI be adopted in nonformal institutions?" but rather "how can AI be co-designed with communities to strengthen existing learning ecology?". The problem becomes increasingly urgent when it is associated with digital literacy. Although internet penetration in Indonesia is relatively high, the level of digital literacy of the community is still low and the use of digital devices among PKBM and SKB learning citizens is still dominated by entertainment consumption and social media interaction rather than the production of educational content (Afrina et al., 2024; Sudiapermana et al., 2025; Gai Mali et al., 2023). This gap between access and meaningful use shows that the issue of digital literacy is no longer a matter of device ownership, but a matter of the capacity to use technology productively, critically, and responsibly (Novela et al., 2024; Alam & Mohanty, 2023).

Productive digital literacy refers to competencies that enable people to create digital content, construct knowledge, evaluate information critically, collaborate, and use technology for meaningful purposes rather than remain passive consumers (Stolpe & Hallström, 2024; Chan & Hu, 2023; Adarkwah, 2025). As external evidence, Firdaus et al. (2026) reported an N-Gain of 0.43 for a contextual PjBL model implemented with equality-program learners in three PKBM. The present article uses that result only to support the pedagogical relevance of PjBL; it does not treat it as evidence for community AI or for the integrated framework. Meanwhile, the literature on community-based AI offers a more fundamental idea: that AI in nonformal education is not enough to simply adopt existing technologies, but requires a paradigm shift from "AI for the community" to "AI together and by the community" (Moudgalya & Swaminathan, 2024; Perera et al., 2025; Roberts & Montoya, 2023; Wang et al., 2024). The synthesis of the literature places local knowledge repositories, culturally responsive adaptive learning pathways, multimodal access, and participatory governance as the four key pillars of inclusive AI for lifelong learning.

This article integrates two established lines of scholarship: community-based and justice-oriented AI governance, and PjBL for productive digital literacy. It proposes the Cb-AI-PjBL framework as an integrative conceptual model for Indonesian PKBM and SKB. The framework is not presented as an empirically validated intervention. It organizes design propositions that require subsequent co-design, piloting, and evaluation. This article becomes relevant in the context of national policy. The Merdeka Learning Program, the National Movement for Digital Literacy (GNLD), and strengthening the role of PKBM as a "people's university" (Banyu Hikmah et al., 2024; Prasetyo & Kusumawardani, 2025; Dadang et al., 2026) all require a strong pedagogical foundation to integrate AI in a meaningful, inclusive, and ethical manner in Indonesia's nonformal education ecosystem.

p-ISSN 2442-532X | e-ISSN 2528-4541
https://journal.unnes.ac.id/journals/jone

Non-formal education plays a crucial role in the lifelong learning agenda because it reaches learners who are not effectively served by the formal system (Prasetyo & Kusumawardani, 2025; Dadang et al., 2026). In Indonesia, PKBM and SKB organize equality education (Package A, B, C), courses and training, and community empowerment programs (Adeoye et al., 2024; Ambarini et al., 2025). Research by Ilyas et al. (2025) shows that the multimodal technology-based learning model in the equality program is able to increase students' entrepreneurial creativity, while Sari et al. (2024) prove that TPACK-based learning designs that integrate Team Based Project Learning effectively improve the digital literacy skills of learners. The study of Nugroho et al. (2024) and Darmawan et al. (2025) further confirms that the development of community-based digital learning media is able to build digital literacy in marginalized communities, while Kusumawardani et al. (2023) show that competency assessments based on local wisdom can increase the innovation capacity of rural communities. These findings confirm that community learning ecosystems recognize diverse knowledge authorities—elders, artisans, farmers, entrepreneurs, and peers—so community-based AI frameworks should support not only individual learning paths, but also collective memory and local knowledge preservation.

PjBL offers a plausible bridge between productive digital literacy and community-based AI because it organizes learning around relevant problems, collaborative production, reflection, and public presentation (Awamleh, 2024; Busnawir et al., 2025; Kato Nabirye, 2024). Firdaus et al. (2026) developed a six-stage PjBL model comprising problem orientation, project planning, implementation, monitoring and mentoring, evaluation and reflection, and product presentation. Their study reported an 82.7% expert-validation score and an overall N-Gain of 0.43. These data concern the PjBL model alone. They do not constitute validation of the Cb-AI-PjBL framework proposed here. On the other hand, participatory design and ethical AI governance are important prerequisites. The data justice literature highlights the need to move beyond abstract principles toward concrete governance arrangements that redistribute decision-making authority (Taylor et al., 2026; Atenas et al., 2025).

In community-based AI, ethical governance should include informed consent, data minimization, community review, transparent explanations of AI outputs, and recovery mechanisms—including respect for the collective knowledge rights and data sovereignty of indigenous communities (Perera et al., 2025; Roberts & Montoya, 2023). The need for ethical AI policy and literacy frameworks is also increasingly emphasized in the cutting-edge literature (An et al., 2025; Biagini, 2025; Mulaudzi & Hamilton, 2025). Thus, there are three unresolved gaps: (1) lifelong learning and nonformal education have not been studied as distinct domains with their own pedagogical and ethical requirements; (2) the discussion of the digital divide has not addressed the difference between the communities that simply access AI tools and the communities that can shape and govern them; and (3) ethical AI frameworks are often institution-centric rather than practical community governance models. This article answers these three gaps through the integrated framework of Cb-AI-PjBL.

METHODS

This article uses an integrative conceptual review. The approach was selected to connect bodies of literature that use different concepts, methods, and units of analysis: (1) community-based AI, participatory design, data sovereignty, and data justice; (2) AI literacy and culturally responsive educational technology; and (3) PjBL and productive digital literacy in adult and nonformal education. The review develops a theoretically coherent and operationally testable framework; it does not estimate an intervention effect or claim exhaustive systematic coverage.

Sources were identified iteratively through Scopus, Web of Science, ERIC, Google Scholar, and reference chaining. Search combinations included “community-based AI,” “participatory AI,” “data sovereignty,” “AI governance,” “nonformal education,” “lifelong learning,” “productive digital literacy,” “project-based learning,” “PKBM,” and “community learning center.” The conceptual corpus comprised 47 scholarly sources cited in this article, published mainly during 2023–2026, and was supplemented by

UNESCO's 2024 AI competency frameworks for students and teachers. Searches prioritized recent sources because generative AI scholarship changed rapidly after 2022.

Sources were retained when they contributed directly to at least one analytical domain: local knowledge and data control; contextual adaptation; multimodal and low-bandwidth access; participatory accountability; productive digital literacy; or PjBL in nonformal learning. Formal-education studies were included only when their concepts were transferable, and their contextual limits could be stated. Opinion pieces without a clear analytical basis and technology studies without educational or governance relevance were excluded. Because this is an integrative conceptual review, PRISMA registration, exhaustive screening counts, meta-analysis, and study-level risk-of-bias scoring were not applied. This boundary is stated to prevent the review from being interpreted as a registered SLR.

The synthesis proceeded through four transparent steps. First, relevant claims, design requirements, risks, and implementation conditions were extracted from each source. Second, recurring codes were compared across the literature streams. Third, related codes were grouped into four problem–solution categories: knowledge sovereignty and local relevance; contextual personalization; access and participation; and accountability and contestability. Fourth, these categories were translated into four framework pillars and connected through PjBL. Infrastructure, facilitator competence, AI literacy, cybersecurity, regulation, and financial sustainability were retained as cross-cutting enabling conditions rather than additional pillars because they affect every pillar. The coding was interpretive; no statistical inter-coder coefficient was calculated. This limitation is considered when evaluating the framework's transferability.

Table 1. Analytical Path from Recurring Codes to the Cb-AI-PjBL Framework

Analytical category	Illustrative recurring codes	Derived pillar	Boundary
Knowledge sovereignty and local relevance	local knowledge; community curation; consent; data control	Community-curated knowledge repository	Addresses what knowledge enters the system and who authorizes it
Contextual personalization	local language; livelihood relevance; learner choice; culturally responsive pathways	Culturally responsive adaptive pathways	Addresses how recommendations respond to context without stereotyping learners
Access and participation	low bandwidth; shared devices; voice; offline access; multimodality	Multimodal access and digital-literacy bridge	Addresses who can participate and through which modes
Accountability and contestability	explainability; appeal; bias reporting; community oversight; auditability	Participatory governance and ethical oversight	Addresses who can question, correct, suspend, or redesign the system
Cross-cutting enabling conditions	infrastructure; facilitator competence; AI literacy; cybersecurity; regulation; financing; environmental sustainability	Implementation conditions across all pillars	Not treated as a fifth pillar because each condition affects the complete framework

Source: Authors' integrative synthesis of the reviewed literature.

RESULTS AND DISCUSSION

CB-AI-PJBL Framework: Integrated Conceptualization

The literature synthesis resulted in an integrated framework called Community-Based AI for Productive Digital Literacy through Project-Based Learning (Cb-AI-PjBL). This framework consists of four main pillars that reinforce each other and one main pedagogical mechanism (PjBL) that connects all pillars. In contrast to conventional educational AI models that start from available technologies and ask how they can be used in educational settings, the Cb-AI-PjBL framework starts from the ecology of community learning and asks what role AI can legitimately play in it.

p-ISSN 2442-532X | e-ISSN 2528-4541
https://journal.unnes.ac.id/journals/jone

Pillar One: Community-Curated Local Knowledge Repository

The first pillar is the foundation of the entire framework: a dynamic knowledge base built through community participation and managed locally. Participatory and community-based AI scholarship warns that systems trained only on external, generic, or commercially produced content can marginalize local knowledge and community authority (Moudgalya & Swaminathan, 2024; Wang et al., 2024). Relevant lifelong learning should therefore begin with knowledge already held and authorized by the community.

These repositories can include video interviews with local experts, audio recordings of indigenous elders, annotated photos of local practices, translated learning materials, peer-validated tips, community-made tutorials, and verified links to external sources. The AI component does not replace the community knowledge holder, but rather supports indexing, tagging, translation assistance, search, recommendation, and information retrieval.

In the context of PKBM and SKB, these repositories can take the form of a local wisdom-based digital question bank for Package C programs, a community-based vocational skills library for course training, or an archive of local agricultural knowledge that can be accessed through a voice interface. It is important to note that not all knowledge has to be digitized: some cultural knowledge may be sacred, limited, gender-specific, age-specific, or not suitable for open circulation. These repositories therefore require layered access rules and community reviews before content is uploaded, tagged, or recommended.

Table 2. Local Knowledge Repository Components in the Cb-AI-PjBL Framework

Components	Description	Examples in the Context of PKBM/SKB
Local Knowledge Bank	Curated and validated collection of community knowledge	Local organic farming techniques, traditional recipes, craft skills
Multimodal Interface	Access via text, voice, video, and images	Voice search in regional languages, video tutorials for senior citizens
Community Annotation System	Contextual tagging by community members	Labels "validated local farmers" or "limited indigenous knowledge"
Layered Access Rules	Knowledge confidentiality protocols based on community agreement	Open, semi-limited, and member-exclusive content
Contribution Mechanism	Procedures for citizens to add knowledge	Upload via WhatsApp, voice recording, titled photo

Source: Authors' synthesis informed by Moudgalya and Swaminathan (2024) and Firdaus et al. (2026); no table was reproduced verbatim.

Pillar Two: Culturally Responsive Adaptive Learning Pathways

The second pillar concerns how AI recommends learning paths. The reviewed literature cautions against narrow personalization based only on standardized quiz scores, completion rates, or decontextualized competency profiles (Horna-Saldaña et al., 2025; Perera et al., 2025; Chiu, 2024a). Effective personalization requires contextual sensitivity, adaptive support, and meaningful learner engagement (Chiu, 2024b; Mulaudzi & Hamilton, 2025). Accordingly, the proposed pathways consider language preferences, occupation, learning objectives, literacy levels, available devices, cultural norms, and practical application.

Culturally responsive learning paths have three main characteristics. First, prioritizing language accessibility: the system must support local languages, dialects, oral explanations, and translations into simple languages (Nndwamato et al., 2025; Horna-Saldaña et al., 2025). In Indonesia, this means support for Javanese, Sundanese, Bugis, regional Malay, and hundreds of other local languages, not just the standard Indonesian. Second, defining learning progress through contextual indicators. Farmers' learning progress may be

demonstrated through better pest identification or more effective use of weather information. Third, adapt learning modalities as needed: some learners prefer audio due to literacy barriers or work routines, while others prefer video demonstrations, visual guides, peer discussions, or short text messages.

When integrated with PjBL, adaptive pathways guide learners toward resources relevant to their digital projects. For example, a learner developing digital content for a local MSME could receive recommendations on product photography, concise promotional writing, consumer ethics, and platform selection. The learner and facilitator must still be able to inspect, reject, or revise recommendations; contextual adaptation should support agency rather than automate decisions.

Third Pillar: Multimodal Access and Digital Literacy Bridge

The third pillar faces infrastructure and literacy barriers that often prevent underserved communities from the benefits of educational technology. Various studies converge on the identification of similar barriers: unequal internet access, limited device ownership, shared smartphones, low confidence in using apps, limited typing ability, and fear of making mistakes (Garcia Ramos & Wilson-Kennedy, 2024; Gai Mali et al., 2023; Alam & Mohanty, 2023).

The Cb-AI-PjBL framework therefore requires a multimodal access design. AI-powered learning must be accessible through smartphones, community kiosks, shared tablets, low-bandwidth web interfaces, offline content packages, voice-based systems, interactive voice response, community radio integration, and familiar communication platforms such as WhatsApp. Multimodal design prevents AI from becoming a privilege for digitally confident learners (Luo, 2023; Lata & Bhatnagar, 2023).

A critical innovation in this pillar is the concept of a "digital literacy bridge" developed from the PjBL model of Firdaus et al. (2026). In contrast to separate digital literacy curricula that are abstract and detached from immediate needs, this approach integrates digital literacy support directly into the learning system. When citizens learn to find voice search tools, the system explains how to ask questions clearly. When citizens learn to accept recommendations, the system shows why the content is suggested. When citizens learn to upload local knowledge, the system explains consent, privacy, and sharing options. In this way, digital literacy becomes part of meaningful participation rather than a prerequisite that excludes learners (Stolpe & Hallström, 2024; Darmawan et al., 2025).

Table 3. Multimodal Access Strategy in the Framework of Cb-AI-PjBL

Access Modalities	Target Users	Integrated AI Features
Smartphone Android/iOS	Citizens learn with personal devices	Local language chatbots, adaptive content recommendations
E-mail Bot	Users with limited access to the app	Sending materials via messaging, interactive text quizzes
Community Kiosk	Citizens without personal devices	Touchscreen interface, offline access, facilitator assistance
Community Radio	Remote areas, elderly residents	Personalized audio content, SMS questions and answers
Offline Package	Areas without internet connection	Pre-synced material downloads, periodic syncs

Source: Authors' synthesis informed by Horna-Saldaña et al. (2025) no table was reproduced verbatim.

Pillar Four: Participatory Governance and Ethical Oversight of AI

The fourth pillar is strongly emphasized across the reviewed data-governance and community-AI literature. These sources identify transparency about system control, data storage, recommendation logic, and error correction as conditions for accountable participation (Taylor et al., 2026; Roberts & Montoya, 2023;

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Atenas et al., 2025). Risks include misuse of community data, commercial exploitation, cultural misrepresentation, weak oversight, biased recommendations, and extraction of community knowledge without reciprocal value.

The Cb-AI-PjBL framework proposes a Community AI Council as a central governance mechanism. In the Indonesian context, this council can be integrated with existing institutional structures: PKBM administrators, representatives of learning citizens, community leaders, education facilitators, and technical partners. His responsibilities include approval of data collection protocols, review of sensitive content, monitoring of system performance, determination of access levels, handling complaints, and participation in periodic audits. This board shouldn't be symbolic it should have real decision-making authority over data usage, content inclusion, and partnership agreements.

Participatory governance also requires algorithmic recovery mechanisms. Learning citizens and community representatives should be able to flag AI outputs that are inaccurate, biased, inappropriate, or culturally insensitive. The system should provide clear procedures for correction, appeal, and review. In the context of an equality program, this means that learners must be able to question learning path recommendations that are perceived as inappropriate for their real conditions, and the system's response must be understandable and actionable.

PJBL as a Connecting Pedagogical Mechanism

The main contribution of this article is to position PjBL not just as an additional learning method, but as a pedagogical mechanism that connects the four pillars of Cb-AI. Within this framework, digital projects that learners work on serve as an interface between learners and community AI systems.

When PKBM learners work on a thematic blogging project about the local potential of their village, the process automates: (1) accessing and enriching local knowledge repositories (Pillar 1), (2) receiving adaptive and contextual resource recommendations (Pillar 2), (3) using multimodal interfaces according to their device capacity and literacy (Pillar 3), and (4) participating in the decision-making process about how their content is used and shared (Pillar 3 4). Thus, the digital project becomes a unified unit of analysis that activates the entire Cb-AI ecosystem.

This integration also has a deeper pedagogical dimension. Social constructivism and experiential learning assert that learning is most effective when learners are actively engaged in meaningful practice in real social contexts (Busnawir et al., 2025; Ranken et al., 2025). Community-based digital projects are a direct realization of this principle: citizens learn not only to use technology, but also to contribute to the development of community knowledge, which in turn enriches the AI ecosystem they use.

Table 4. PjBL Stage Synthesis with Cb-AI Components

PjBL Stage	Learning Citizen Activities	The Role of Community AI	Activated Cb-AI Pillar
Problem Orientation	Identify real issues in the community	View local contextual data and information	Pillars 1, 2
Project Planning	Designing a digital project plan	Adaptive resource recommendations and templates	Pillars 2, 3
Project Execution	Create collaborative digital content	Technical support, information search, translation	Pillars 1, 2, 3
Monitoring & Mentoring	Evaluate the process with the facilitator	Progress analytics, obstacle detection	Pillars 2, 4
Evaluation & Reflection	Product evaluation and learning process	Questionable algorithmic feedback	Pillar 4

PjBL Stage	Learning Citizen Activities	The Role of Community AI	Activated Cb-AI Pillar
Product Presentation	Share products with the community	Contributions to local knowledge repositories	Pillars 1, 4

Source: Authors' synthesis informed by Firdaus et al. (2026) and Moudgalya and Swaminathan (2024); no table was reproduced verbatim.

Prior Empirical Evidence Supporting the PjBL Component

The integrated Cb-AI-PjBL framework remains conceptual and has not been field-tested as a whole. Prior empirical work by Firdaus et al. (2026) tested a PjBL model for productive digital literacy with 30 equality-program learners in three PKBM in West Bandung Regency. That study provides contextual evidence for selecting PjBL as the pedagogical connector, but it did not test community AI repositories, adaptive pathways, multimodal AI access, or participatory AI governance.

Table 5. Secondary Summary of Increasing Productive Digital Literacy in the Implementation of the PjBL Model

Digital Literacy Aspects	Pretest mean	Posttest mean	N-Gain	Categories
Content evaluation	61.4	76.2	0.41	Moderate
Knowledge construction	59.8	75.5	0.43	Moderate
Digital content creation	58.5	76.3	0.45	Moderate–High
Overall average	59.9	76.0	0.43	Moderate–High

Source: Secondary summary of results reported by Firdaus et al. (2026). These data were not produced by the present review and do not validate the integrated Cb-AI-PjBL framework. Category labels reproduce the terminology used in the source study. Category labels reproduce the terminology used in the source study. Category labels reproduce the terminology used in the source study.

In Firdaus et al. (2026), digital content creation showed the largest pretest–posttest change. This finding is relevant because content production differentiates productive digital literacy from passive technology consumption (Stolpe & Hallström, 2024; Adarkwah, 2025; Chan & Hu, 2023). It should not, however, be interpreted as evidence that AI integration or the complete Cb-AI-PjBL framework is effective. Firdaus et al. (2026) also reported improvement in knowledge construction and an average expert-validation score of 82.7% for their PjBL model. These results support the pedagogical plausibility and design feasibility of the PjBL component. They do not establish the feasibility, acceptability, safety, or effectiveness of the four-pillar community AI framework proposed in this review.

Policy and Practice Implications for Indonesia

The Cb-AI-PjBL framework has far-reaching implications for various stakeholders in Indonesia. First, for policymakers, this study emphasizes that AI policies in education should explicitly include lifelong learning and nonformal education as domains, not just extensions of school or university policies. Investments should prioritize PKBM and SKB as community learning centers, public digital infrastructure, multilingual open education resources, local facilitation, and community data governance mechanisms. The GNLD program needs to be strengthened with a pedagogical framework that ensures digital literacy activities do not stop at the campaign but have an impact on changing practices at the grassroots level (Garcia Ramos & Wilson-Kennedy, 2024; An et al., 2025).

Second, for educational AI developers, this framework implies that educational AI platforms should be modular, explainable, low-bandwidth, multilingual, and locally configurable. Developers should build tools that allow communities to curate content, define access rules, examine recommendation logic, and report

p-ISSN 2442-532X | e-ISSN 2528-4541
https://journal.unnes.ac.id/journals/jone

adverse outputs. Open-source or public interest models may be invaluable when communities need transparency and adaptability (Kashyap et al., 2024; Mulaudzi & Hamilton, 2025).

Third, for adult educators and community facilitators, this framework highlights an expanded role. Educators become mediators between AI systems and community learning needs. They support learners in asking better questions, evaluating AI outputs, documenting local knowledge, protecting sensitive information, and connecting digital resources with practical actions. Firdaus et al. (2026) reported positive learner and tutor responses and observed active participation during its PjBL implementation; this contextual evidence supports facilitative practice but does not establish a causal effect of tutor role. Related literature likewise emphasizes learner agency and community-based digital facilitation (Chiu, 2024a; Darmawan et al., 2025).

Fourth, for researchers, this framework opens up several directions for future research. Longitudinal research is needed to examine how Cb-AI-PjBL affects learning participation, student confidence, livelihood outcomes, language preservation, and collective problem-solving. Comparative studies can explore how this framework operates in various Indonesian cultural, infrastructural and policy contexts. Further research should also investigate sustainable funding models, community-owned data infrastructure, and governance indicators for ethical AI in nonformal education (Biagini, 2025; Zhang et al., 2026).

Table 6. Operational Roadmap for Piloting Cb-AI-PjBL in PKBM and SKB

Stage and lead actors	Core actions	Minimum safeguards	Illustrative indicators
1. Readiness and mandate — PKBM/SKB leaders, learners, facilitators, community representatives	Map learning needs, languages, devices, connectivity, facilitator competence, data practices, and relevant regulation; establish a Community AI Council	Voluntary participation; documented community mandate; baseline risk assessment	Approved governance charter; baseline access and AI-literacy profile; named responsibility holders
2. Co-design and repository building — learners, local experts, facilitators, developers	Select one livelihood-linked project; curate local materials; define metadata, consent, licensing, and correction procedures	Source attribution; consent for sensitive knowledge; copyright and cultural-protocol review	Share of verified resources; local-language coverage; consent completeness; correction turnaround
3. Facilitator preparation and small pilot — facilitators, technical partners, council	Train facilitators in prompting, verification, bias detection, safeguarding, and low-bandwidth alternatives; run a bounded PjBL cycle	Human review of consequential outputs; offline fallback; incident-report channel	Facilitator competency completion; learner participation; project completion; flagged-output rate
4. Monitored implementation — council, learners, facilitators, researchers	Track learning, participation, equity, system errors, appeals, and resource use; revise pathways and repository rules	Regular audit; cybersecurity controls; accessible appeal; suspension threshold	Product-quality rubric; digital-literacy gain; participation gap; appeal resolution; security incidents
5. Evaluation and responsible scaling — local government, PKBM/SKB network, researchers	Assess feasibility, acceptability, learning outcomes, livelihood relevance, cost, energy use, and governance quality before expansion	Independent review; budget and maintenance plan; regulatory compliance check	Feasibility and acceptability rates; cost per learner; energy/data use; sustained local funding; audit compliance

Source: Authors' operationalization of the proposed conceptual framework.

Discussion: From AI for Communities to AI by and with the Community

The synthesis suggests that inclusive AI in nonformal education should be treated as a sociotechnical and adult-learning problem rather than a technology-deployment problem. The proposed framework starts with community purposes, experience, language, livelihood, and governance, then asks which AI functions are justified. This orientation is consistent with adult learning principles that emphasize relevance, prior

experience, participation, and immediate application, while extending them to questions of data authority and algorithmic contestability.

Compared with UNESCO's AI competency frameworks, Cb-AI-PjBL shares a human-centered orientation, ethical responsibility, foundational AI literacy, and progression toward creative participation (Miao et al., 2024; Miao & Cukurova, 2024). Its additional emphasis is institutional: competence alone cannot ensure inclusion when communities lack authority over data, local representation, system correction, and implementation priorities. The four pillars therefore connect individual capability with collective governance.

Compared with existing community and Indigenous AI models, the framework adopts data sovereignty, local knowledge curation, and participatory oversight but adds PjBL as an adult-learning mechanism (Moudgalya & Swaminathan, 2024; Perera et al., 2025; Wang et al., 2024). Projects make governance observable: learners encounter questions of provenance, consent, verification, authorship, and public benefit while producing a concrete digital output. This provides a stronger pedagogical link than treating participation as consultation conducted only before system deployment.

The framework also clarifies a tension in Global South AI governance. Local ownership can increase relevance and accountability, but it does not automatically eliminate unequal power. Community councils may reproduce local hierarchies; donor platforms may retain technical control; local datasets may expose sensitive knowledge; and limited budgets may shift unpaid moderation work to facilitators. Community ownership must therefore be supported by transparent authority, independent review, adequate financing, and the right to refuse or suspend AI use. AI risk management must extend beyond participation and privacy. Algorithmic bias may stereotype learners or languages; hallucinations and misinformation may contaminate local repositories; generated content may violate copyright or community intellectual-property rules; weak authentication may expose personal data; and cyberattacks may compromise shared devices or governance records. Regulatory compliance must cover data protection, child and vulnerable-adult safeguards, accessibility, procurement, and responsibility for harmful outputs. Human verification and accessible non-AI alternatives remain necessary for consequential learning decisions.

Environmental and operational sustainability also constrain implementation. Cloud-based generative AI consumes energy, bandwidth, and financial resources that may be hidden from communities. Local or offline systems reduce some connectivity burdens but require maintenance, security updates, technical support, and replacement planning. Cb-AI-PjBL should therefore be evaluated against educational value, total cost, energy and data use, local maintenance capacity, and opportunity costs. It must not become a low-cost substitute for public investment in facilitators, connectivity, libraries, and inclusive learning infrastructure.

LIMITATIONS

This article has four limitations. First, it is an integrative conceptual review and does not provide exhaustive PRISMA screening or meta-analytic estimates. Second, the framework reflects interpretive synthesis and was not assessed with a formal inter-coder reliability statistic. Third, the literature corpus may underrepresent unpublished community initiatives, non-English scholarship, and studies with null or adverse findings, creating publication and language bias. Fourth, the integrated framework has not been co-designed, piloted, or validated in PKBM or SKB. Its feasibility, acceptability, equity effects, learning outcomes, governance quality, costs, and environmental implications remain propositions for empirical testing.

CONCLUSION

This integrative conceptual review proposes Cb-AI-PjBL as a testable framework for Indonesian nonformal education. Four connected pillars address knowledge curation, contextual adaptation, multimodal participation, and participatory governance, while PjBL links them through community-relevant digital projects. The contribution lies in this contextual integration and operationalization, not in claiming that the

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underlying concepts are new or that the complete framework is already effective. The framework shifts attention from AI delivered to communities toward AI selected, shaped, questioned, and governed with communities. For PKBM and SKB, this requires more than access to tools. It requires facilitator competence, AI literacy, verified local knowledge, accessible alternatives, contestable recommendations, cybersecurity, regulatory compliance, sustainable financing, and clear responsibility for harm.

The present review generated no field-trial data. Firdaus et al. (2026) reported an N-Gain of 0.43 and an 82.7% validation score for a PjBL productive-digital-literacy model in three PKBM. That external evidence supports further investigation of PjBL as the pedagogical connector; it does not validate the AI components or the integrated framework. The next research step is a small, governed co-design pilot followed by independent evaluation using the indicators specified in the roadmap. PKBM and SKB can become important sites for responsible AI experimentation only when participation has decision-making force and non-AI options remain available. Future studies should test whether Cb-AI-PjBL improves productive digital literacy and community agency without increasing surveillance, exclusion, facilitator workload, misinformation, or environmental cost.

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