



Driving Elementary Digital Literacy: Technology-Based Principal Leadership in Resource-Constrained Schools

Annisa Ilmeira Queen^{1*}, Aspin Aspin², Ishak Bagea³, Feni Febrianti⁴, Ainul Basyirah⁵

¹Administrasi Pendidikan, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Muhammadiyah Kendari, Kendari, Indonesia; ²Pendidikan Dasar, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia; ³Administrasi Pendidikan, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Muhammadiyah Kendari, Kendari, Indonesia; ⁴Pendidikan Guru Sekolah Dasar, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Bima Internasional MFH, Bima, Indonesia; ⁵Manajemen Pendidikan, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

*Corresponding author: Annisa Ilmeira Queen, Administrasi Pendidikan, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Muhammadiyah Kendari, Kendari, Indonesia. Email: annisailmeira26@gmail.com

Abstract

The imperative for digital transformation within primary education has highlighted the strategic role of educational leadership in driving technological integration and cultivating student competencies. However, empirical understanding of how technology-focused principal management directly fosters foundational digital literacy among elementary students in resource-constrained contexts remains limited. This study examined the operationalization of technology-based principal leadership management and evaluated its direct role in strengthening student digital literacy at SDN Lalosabila. Utilizing a qualitative single-case study design, empirical data were gathered through semi-structured interviews, non-participant classroom observations, and institutional document analysis involving the school principal, instructional staff, and elementary students. Data was processed iteratively using thematic analysis coupled with method and source triangulation to ensure analytical rigor. The findings demonstrate that technology-driven principal leadership operates across five core operational dimensions: strategic planning, pedagogical oversight through e-supervision, administrative evaluation, human capital development, and culture creation. Furthermore, principal-led initiatives catalyzed a transition from passive technology consumption to active engagement, enhancing student digital literacy across technical, cognitive, and ethical domains. Nevertheless, systemic barriers, including internet bandwidth fluctuations and device shortages, continue to constrain optimal implementation. This study concludes that transformational, adaptive digital leadership is essential for bridging digital divides in primary education. Practically, the results offer actionable frameworks for educational administrators seeking to optimize digital infrastructure, design continuous teacher mentoring programs, and build resilient, ethically grounded digital learning cultures in emerging educational environments.

Keywords: Principal Leadership, Digital Management, Digital Literacy, Primary Education, Educational Technology



Introduction

The digitization of the contemporary knowledge economy has fundamentally transformed primary education, elevating digital literacy from an advantageous auxiliary skill to an indispensable foundational competency (Kalyani, 2024; Zou et al., 2025). Within primary school settings, digital literacy extends well beyond rudimentary technical operational skills, encompassing critical cognitive capabilities, information evaluation, media awareness, and ethical engagement within digital ecosystems (Audrin & Audrin, 2022; Sajidan et al., 2023). Cultivating these complex digital competencies at an early age is particularly crucial given the heightened exposure of young learners to online environments, where unguided navigation poses substantial risks regarding data security, cyber threats, and misinformation (Purnama et al., 2021; Reddy et al., 2023). Consequently, educational institutions face mounting institutional pressure to systematize technology integration across administrative and pedagogical domains (Timotheou et al., 2022).

Achieving meaningful technological transformation within primary education depends significantly on the strategic agency of educational leadership (Alajmi, 2022; Yang et al., 2025). Traditional supervisory approaches centered on administrative maintenance are increasingly inadequate for navigating the complexities of modern digital classrooms (Berkovich & Hassan, 2023). Instead, effective technology integration requires transformational digital leadership, wherein school principals serve as strategic visionaries, resource facilitators, and instructional innovators (Karakose et al., 2021; Schmitz et al., 2023). Extant empirical research demonstrates that principal leadership directly influences teachers' self-efficacy, technological adoption, and pedagogical innovation (Luo et al., 2024; Zeng et al., 2025). When school leaders establish cohesive digital visions, provide targeted professional support, and implement structured e-supervision, teachers exhibit greater readiness to incorporate interactive learning tools and foster critical digital literacy among students (Devisa et al., 2023; Mushadi et al., 2025).

Despite the growing body of literature examining digital leadership in secondary and tertiary educational contexts, a notable empirical gap persists regarding the operationalization of technology-driven principal management within primary schools situated in resource-constrained or developing regions (Basuki et al., 2024; Hidayat & Patras, 2024). Much of the existing scholarship remains either conceptually abstract or heavily dependent on quantitative metrics that aggregate leadership behaviors without capturing localized operational mechanics (Akram et al., 2022; Ofita et al., 2024). Specifically, there is limited qualitative evidence explaining how primary school principals navigate systemic infrastructure deficits, bridge generational digital competence divides among instructional staff, and translate high-level digital policies into actionable student literacy outcomes (Abdurrohman & Hidayati, 2024; Robandi et al., 2025). Understanding these localized managerial dynamics is essential, as primary schools in developing contexts often operate under unique socio-technical constraints that modulate technology adoption (Abu et al., 2025; Suwanto et al., 2022).

To address these empirical limitations, this study investigates the operationalization of technology-based principal leadership management and its direct influence on student digital literacy development at SDN Lalosabila. Framed through the Swales (2004) Create a Research Space (CARS) model, this inquiry systematically analyzes how strategic leadership practices intersect with pedagogical execution to strengthen student digital competencies. Specifically, this paper addresses three core objectives:

1. To examine how the school principal conceptualizes and executes technology-based leadership across strategic planning, administrative supervision, and instructional development.
2. To evaluate the specific pedagogical mechanisms and student-level practices through which principal-led digital initiatives enhance digital literacy skills.
3. To identify the critical contextual enabler and structural barriers that influence the sustained implementation of technology-based management in an elementary school context.

By addressing these research objectives, this study makes a distinct theoretical and practical contribution to the field of educational management. Conceptually, it refines transformational

leadership models by providing qualitative, empirically grounded insights into the specific operational behaviors that link principal digital stewardship to student learning outcomes in primary education. Practically, the findings offer actionable frameworks for school administrators, policymakers, and curriculum designers seeking to optimize digital infrastructure, design continuous teacher development programs, and build resilient, ethically grounded digital learning cultures in emerging educational environments.

Methods

Research Design

This study adopts a qualitative single-case study design to conduct an in-depth investigation into technology-based principal leadership management and its operational role in strengthening student digital literacy. A qualitative case study framework is particularly suitable for examining contemporary, context-bound phenomena within real-world educational environments, especially where the boundaries between organizational leadership practices and instructional outcomes are highly intertwined. By centering on a specific elementary school setting, this approach facilitates a holistic exploration of social interactions, managerial strategies, and pedagogical dynamics that cannot be captured adequately through standardized quantitative metrics.

Data Sources

The investigation was conducted at SDN Lalosabila, a public elementary school that has systematically initiated digital technology integration within its administrative structures and classroom instruction. Data sources were selected using a purposive sampling strategy to ensure the gathering of rich, relevant, and contextually grounded information. Primary data sources comprised three distinct participant groups chosen based on their strategic roles within the school ecosystem:

1. The school principal ($n = 1$), serving as the central institutional policymaker, administrator, and visionary driver of digital initiatives.
2. Elementary classroom and ICT teachers ($n = 4$), representing the instructional staff responsible for executing digital pedagogies and embedding media tools into daily learning.
3. Elementary school students ($n = 8$), representing the primary beneficiaries who experience leadership-driven literacy programs directly.

Secondary data sources encompassed official institutional documentation, including school development plans, digital infrastructure inventory logs, teacher lesson plans, and instructional evaluation records.

Data Collection and Instruments

Data were collected through a multi-method triangulation approach comprising semi-structured interviews, non-participant classroom observations, and document analysis.

- **Semi-Structured Interview Protocols:** Flexible, semi-structured interview guides were developed to query the principal and teaching staff regarding digital leadership vision, resource allocation, professional development frameworks, and pedagogical challenges. Student perspectives were gathered through age-appropriate focus group discussions designed to assess their operational, critical, and creative interactions with digital technology.
- **Observation Protocols:** Field observation checklists were utilized during active school hours to document administrative technology practices, e-supervision routines, physical infrastructure conditions, and direct teacher-student interactions during technology-enhanced lessons.
- **Documentary Checklists:** Document analysis guides were constructed to systematically evaluate administrative records, official policies, curriculum blueprints, and student digital assignment artifacts.

The data collection process unfolded across three sequential phases to ensure structural rigor and field integrity:

1. Preliminary Phase: Formal administrative access was secured, and ethical permissions were granted by the school authority. Initial exploratory visits were conducted to build rapport with staff and familiarize participants with the research objectives.
2. Fieldwork Execution Phase: In-depth semi-structured interviews were conducted individually with the principal and teaching staff in quiet, private administrative settings. Subsequently, non-participant classroom observations were carried out across multiple instructional sessions to capture real-time pedagogical execution. Student focus group discussions were organized in supportive, low-pressure environments under the guidance of class teachers.
3. Document Verification Phase: Institutional artifacts, teaching records, and digital logs were systematically compiled, cross-referenced with observational data, and archived for analytical processing.

Data Analysis

Qualitative enquiry, measurement pertains to establishing conceptual trustworthiness, interpretive validity, and qualitative rigor rather than numerical metrics. To ensure high analytical credibility, this study implemented strict trustworthiness criteria comprising credibility, transferability, dependability, and confirmability:

- Credibility: Methodological and source triangulation was systematically executed by cross-verifying interview accounts with observational field notes and institutional documents. Member-checking was performed with the principal and teacher participants to confirm that interview transcripts accurately represented their expressed views.
- Transferability: Comprehensive thick descriptions of the institutional context, participant demographics, and managerial interventions were documented to allow scholars to judge applicability to similar primary education contexts.
- Dependability and Confirmability: A rigorous audit trail detailing field logistics, analytical decisions, and preliminary coding frameworks was maintained throughout the research process.

Qualitative data were systematically processed and analyzed following the thematic analysis framework articulated by Miles, Huberman, and Saldana (2014). The analysis involved three concurrent streams of activity:

1. Data Reduction: Raw interview transcripts, observation notes, and document summaries were transcribed verbatim, cleaned, and categorized. Initial inductive coding was performed to condense raw data into meaningful conceptual units related to digital leadership strategies, instructional modifications, and structural obstacles.
2. Data Display: Coded data were organized into structured thematic matrices and comparative tables to illuminate relationships, operational patterns, and functional dependencies across participant groups.
3. Conclusion Drawing and Verification: Emerging themes were evaluated iteratively against existing theoretical frameworks on educational leadership and digital literacy. Preliminary conclusions were continuously verified against the broader data corpus until stable thematic saturation was established.

Findings

The empirical data collected from interviews, non-participant classroom observations, and institutional document analyses at SDN Lalosabila reveal that technology-based principal leadership operates as a crucial catalyst for enhancing elementary student digital literacy. The findings are organized around three central thematic categories: the operational dimensions of technology-based principal leadership, the pedagogical mechanisms strengthening student digital literacy, and the structural enablers and systemic barriers influencing program execution (Figure 1).

Operational Dimensions of Technology-Based Principal Leadership

The principal's leadership practices manifested across five distinct managerial domains: strategic planning, pedagogical oversight, administrative evaluation, human capital development, and culture creation. Institutional document analysis of the school development plan (RKS) confirmed that digital transformation objectives were formally integrated into long-term organizational goals rather than treated as peripheral activities. The principal allocated specific budget proportions toward maintaining digital hardware and securing internet connectivity.

In terms of pedagogical oversight and evaluation, the principal shifted from traditional physical classroom walk-throughs to integrated e-supervision methods. Observational data showed that lesson plans (RPP/Modul Ajar) were submitted and evaluated through shared cloud platforms, allowing real-time feedback on ICT integration. As the principal noted during an interview:

"Digital leadership requires moving beyond verbal encouragement. We incorporated digital metrics into our internal supervisory routines to ensure every teacher systematically utilizes multimedia resources in their weekly instructional delivery."

Human capital development was prioritized to address varying technical competencies among instructional staff. Document logs showed that four internal workshops were conducted during the academic year, supplemented by peer-mentoring partnerships where tech-savvy teachers assisted colleagues in operating educational software and cloud management systems. This structured support fostered an adaptive school culture, reducing technological anxiety among senior teaching staff.

Pedagogical Mechanisms Strengthening Student Digital Literacy

The leadership initiatives directly influenced classroom practices, driving student digital literacy across technical, cognitive, and ethical dimensions. Classroom observations across multiple subjects demonstrated a transition from passive, teacher-led lecture modes to active, technology-enhanced learning environments. Teachers regularly incorporated interactive educational videos, digital quizzes, and web-based open educational resources to increase student engagement.

Student digital literacy was cultivated through three primary pedagogical pathways:

1. **Information Access and Evaluation:** Teachers routinely assigned guided web-research tasks. Observation records revealed that teachers explicitly instructed students on assessing source credibility, checking publication details, and distinguishing factual content from opinion. During a focus group discussion, a fifth-grade student remarked:

"We are taught not to copy everything from the internet immediately. Our teacher shows us how to look at different websites to make sure the information is correct before we use it in our group presentations."

2. **Digital Artifact Creation:** Students were encouraged to move beyond information consumption toward creative digital production. Instructional records confirmed that students utilized basic software tools to construct multimedia presentations, digital posters, and simple video reports. These project-based tasks strengthened technical operation skills while fostering peer collaboration and communication.
3. **Co-Curricular and Ethical Enrichment:** Beyond core subjects, the school established computer interest clubs and basic media literacy sessions. These activities emphasized cyber safety, personal data protection, and respectful communication in digital spaces.

Structural Enablers and Systemic Barriers

The sustained execution of technology-based management at SDN Lalosabila was governed by an interplay between facilitating internal conditions and persistent operational challenges. **Supporting Factors:** The primary enabling factor was the principal's clear transformational vision, supported by high teacher readiness and shared institutional commitment. Observational data confirmed that strong peer-collaboration networks enabled teachers to troubleshoot technical issues collectively during lesson execution. Furthermore, positive administrative policies created a safe climate for teachers to experiment with new digital pedagogical methods without fear of technical failure.

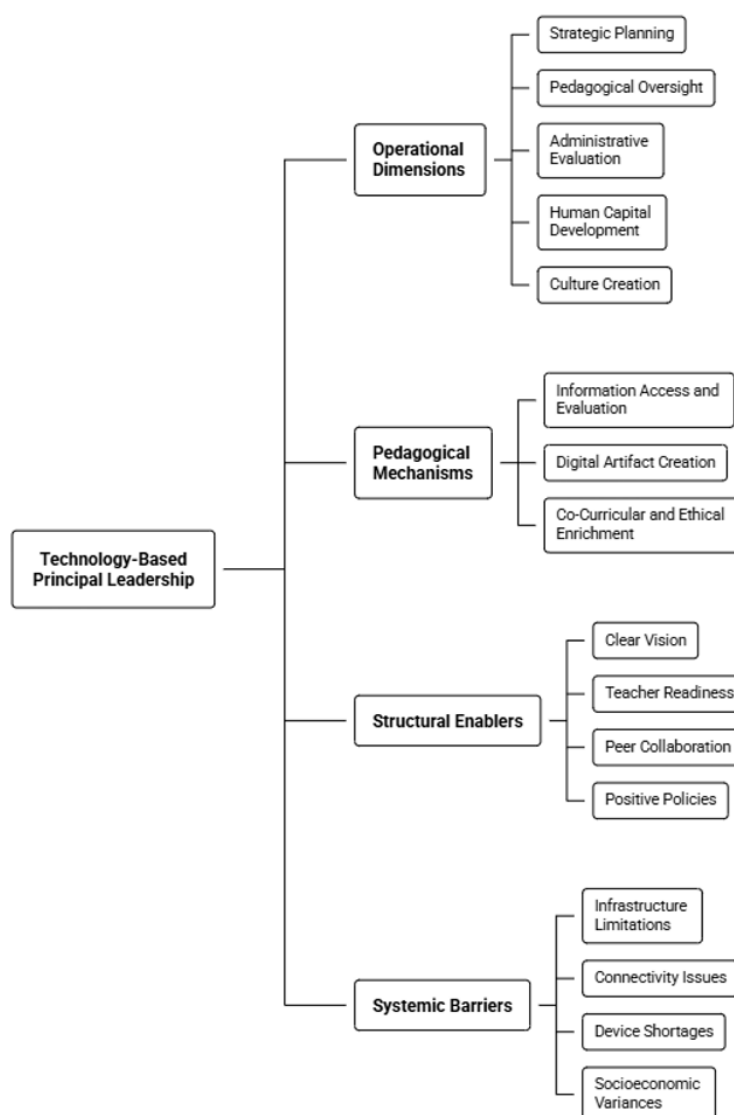
Inhibiting Barriers: Despite strategic planning, physical infrastructure limitations presented ongoing obstacles. Connectivity logs indicated periodic internet bandwidth fluctuations, which

occasionally disrupted planned online activities. Additionally, an inventory audit revealed a device-to-student ratio that required students to work in shared groups rather than individually. Variances in student socioeconomic backgrounds also meant that home access to digital devices remained unequal, limiting the scope of home-based digital assignments. As one classroom teacher highlighted during an interview:

"While our internal motivation and leadership support are strong, network instability and hardware shortages remain our primary bottlenecks. When internet bandwidth drops during a lesson, we must quickly adapt to offline digital resources."

In summary, the findings demonstrate that visionary principal leadership effectively transforms primary school management and elevates student digital competencies. However, achieving optimal outcomes requires continuous investments in physical infrastructure and strategic strategies to bridge remaining digital divides.

Figure 1: Technology-Based Principal Leadership and Student Digital Literacy



Discussion

The integration of digital technology into primary education has shifted from an innovative pedagogical alternative to an essential organizational requirement (Kalyani, 2024; Zou et al., 2025). Within elementary school settings, cultivating digital literacy requires more than technical instruction; it demands systemic organizational stewardship capable of aligning institutional vision, teacher development, and physical infrastructure (Timotheou et al., 2022). This study investigated how technology-based principal leadership management operates within an

elementary school context and evaluated its direct role in strengthening student digital literacy. The primary research questions examined the specific managerial mechanisms deployed by the school leader, the resulting pedagogical transformations at the student level, and the contextual enablers and structural barriers influencing sustained implementation.

A critical finding of this inquiry is that technology-based principal leadership at SDN Lalosabila functions as a multi-dimensional, transformational endeavor rather than a series of isolated administrative tasks. Granular analysis of empirical data reveals that leadership practices systematically permeated five interconnected domains: strategic planning, pedagogical oversight, administrative evaluation, human capital development, and culture creation. Document analysis of the institutional development plan (RKS) verified that digital goals were embedded within core financial and operational strategies rather than treated as ad-hoc projects. Specifically, the deliberate allocation of budgetary resources toward hardware maintenance and cloud infrastructure directly enabled classroom-level technical stability.

Furthermore, the shift from traditional physical supervisory walk-throughs to cloud-based e-supervision provided the principal with granular, continuous oversight of lesson planning and ICT utilization. This structural mechanism replaced sporadic evaluations with ongoing feedback loops, directly encouraging teachers to incorporate interactive media, video modules, and digital quizzes into weekly instruction. These empirical observations support the theoretical framework proposed by Schmitz et al. (2023), who argued that transformational leadership drives deeper technological integration when leaders establish clear expectations alongside structural support mechanisms. The results also align with the empirical conclusions of Luo et al. (2024), demonstrating that principal technology leadership combined with instructional e-supervision significantly enhances teacher professional competence and fosters an adaptive digital culture.

At the student level, the empirical data demonstrate that principal-led structural interventions catalyzed a shift from passive technology consumption toward active, creative, and critical digital engagement. Granular classroom observations revealed that student digital literacy developed across three distinct pathways: information access and evaluation, digital artifact creation, and ethical enrichment. Rather than utilizing computers solely for rote drill activities, students were systematically guided through internet research protocols where they evaluated source credibility, cross-checked publication dates, and distinguished verified facts from digital opinion.

These findings align with the theoretical formulations of Audrin and Audrin (2022), who asserted that genuine digital literacy requires higher-order cognitive evaluation rather than simple operational fluency. The observation that primary students engaged in digital artifact creation, such as multimedia presentations and digital posters, reinforces the empirical work of Jordan et al. (2025) and Yasa et al. (2024), who documented that inquiry-based digital tasks significantly improve critical thinking, peer collaboration, and creative expression.

An unexpected outcome of this study relates to the resilience of teacher collaboration networks in mitigating physical infrastructure deficits. Standard educational technology literature frequently assumes that severe bandwidth throttling or hardware shortages lead directly to instructional failure or teacher avoidance behavior (Akram et al., 2022; Basuki et al., 2024). However, the granular qualitative data from SDN Lalosabila revealed that when faced with network instability, teachers routinely deployed offline digital repositories and engaged in real-time peer troubleshooting. Rather than abandoning digital lessons, instructional staff adapted their pedagogical delivery due to a high sense of digital self-efficacy and psychological safety cultivated by the principal.

This nuance offers a critical perspective that partially contrasts with traditional deterministic models of technology adoption, which often position physical infrastructure as an absolute prerequisite for digital engagement (Alieto et al., 2024). While infrastructure deficits undoubtedly restrict operational efficiency, strong transformational leadership and collaborative peer cultures can create psychological buffers that sustain technological practices even in resource-constrained environments.

The observed success of digital literacy integration at SDN Lalosabila can be explained through the lens of Distributed Leadership Theory and the Technology Acceptance Model (TAM). By providing targeted workshops, structured peer-mentoring, and e-supervision, the principal

effectively lowered perceived complexity while increasing the perceived usefulness of educational technology among teachers. This dual mechanism enhanced teacher readiness, which subsequently translated into structured learning experiences for students. Based on these findings, it is reasonable to hypothesize that in primary educational settings, the effect of principal digital leadership on student literacy outcomes is fully mediated by teacher digital self-efficacy and the presence of collaborative professional learning communities.

Nevertheless, scholarly caution must be exercised when interpreting these empirical results. Because this study relied on a single-case qualitative design, the findings reflect the unique institutional, cultural, and interpersonal dynamics of SDN Lalosabila. Generalizing these outcomes to all primary schools must be done carefully, particularly when comparing urban educational institutions with rural schools that face vastly different socioeconomic and technical conditions.

The theoretical implications of this study highlight the need to re-conceptualize school leadership models in emerging digital economies. Digital leadership must no longer be viewed as an isolated technical skill set, but as an integrated management philosophy that unifies strategic resource allocation, continuous human capital development, and active culture building. For policymakers and educational administrators, these findings suggest that leadership training programs must shift away from abstract policy management toward practical competencies in e-supervision, digital resource curation, and strategic technology budgeting.

To advance this line of inquiry, future research should employ multi-site comparative case designs and mixed-method longitudinal studies across diverse geographical and socioeconomic regions. Quantitative investigations examining the precise mediating pathways between principal digital leadership, teacher pedagogical competency, and standardized student digital literacy metrics would provide valuable empirical validation. Furthermore, future studies should explore how emerging technologies, such as generative artificial intelligence and adaptive learning platforms, can be ethically and strategically managed by elementary school leaders in developing nations.

Conclusion

This study investigated the operationalization of technology-based principal leadership management and evaluated its direct role in strengthening student digital literacy in an elementary school setting. The empirical findings demonstrate that when principal leadership transitions from routine administrative oversight to visionary, transformational digital stewardship, substantial improvements occur across instructional practices, teacher capacity, and student digital engagement. By embedding digital strategy within institutional development plans, implementing cloud-based e-supervision, supporting continuous professional development, and establishing collaborative peer networks, the principal effectively created an environment conducive to early digital literacy acquisition. At the student level, these principal-led initiatives catalyzed a shift from passive technology consumption to active, critical, and creative engagement, cultivating essential competencies in information evaluation, multimedia artifact creation, and ethical online behavior.

The theoretical and practical implications of these findings provide meaningful guidance for educational leaders, policy architects, and curriculum designers. Conceptually, the results refine transformational leadership models in primary education by highlighting the specific operational behaviors through which principal stewardship influences student learning outcomes. Practically, the study underscores that sustainable digital transformation cannot rely solely on physical hardware procurement; rather, it demands structured investments in human capital, continuous teacher mentoring, and resilient operational strategies that can withstand persistent infrastructure limitations. Educational policymakers must prioritize equitable digital infrastructure distribution while designing targeted leadership programs that equip school administrators with actionable skills in e-supervision, digital resource curation, and strategic technology management.

Ultimately, cultivating digital literacy in elementary education represents a fundamental societal imperative in an increasingly interconnected world. While technical and structural barriers remain persistent challenges in emerging educational landscapes, adaptive, human-

centered, and visionary principal leadership serves as the indispensable cornerstone for bridging digital divides and empowering young learners to navigate the complex digital future with confidence, critical awareness, and social responsibility.

Ethics approval

The study was conducted in compliance with the Declaration of Helsinki. Informed consent was obtained from all individual participants involved in the study, and parental consent was secured for all elementary school student participants.

Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Declaration of artificial intelligence use

This study used artificial intelligence (AI) tools and methodologies in the following capacities: Manuscript writing support: AI-based language models were employed for language refinement (improving grammar, sentence structure, and readability of the manuscript).

We confirm that all AI-assisted processes were critically reviewed by the authors to ensure the integrity and reliability of the results. The final decisions and interpretations presented in this article were solely made by the authors.

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