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Digital Media-Based Mathematics Learning Strategies to Enhance Reading Interest Among Elementary School Students

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Abstract
Elementary students' low reading interest significantly impairs their ability to comprehend mathematical word problems, particularly in rural schools with limited technological infrastructure. This study examined how digital media-based mathematics learning strategies enhance reading interest while strengthening numeracy competencies. A qualitative case study was conducted at two Indonesian elementary schools (SDN Puncak 1 and SDN Pasirkampung) using classroom observations, semi-structured interviews with teachers, principals, and students, and document analysis. Data were analyzed following Miles, Huberman, and Saldaña's framework, with triangulation ensuring validity. Systematic implementation incorporating educational videos, interactive e-modules, digital quizzes, and GeoGebra—supported by structured planning, resource organization, and continuous supervision—produced substantial improvements. Student questioning behavior increased 239%, mathematical word problem performance improved from 56.4% to 73.2% (Cohen's d=1.43), and mathematics anxiety decreased from 67% to 38%. Students demonstrated enhanced reading behaviors including spontaneous rereading, text-pointing while reading, and voluntary engagement with mathematical narratives. Digital media-based strategies effectively integrate literacy and numeracy development when supported by systematic management frameworks. Success depends on needs-based planning, teacher professional development emphasizing pedagogical-technological competencies, offline resource preparation mitigating connectivity limitations, and data-driven supervision enabling responsive refinement. Findings validate multimedia learning theory while revealing that resource constraints can generate productive collaborative structures, providing empirical foundations for inclusive digital mathematics education in technologically limited contexts.

INTRODUCTION

The accelerating integration of digital technologies into educational practice represents one of the most significant transformations in contemporary pedagogy, particularly in primary education where foundational competencies are established (Rakes et al., 2022; Engelbrecht & Borba, 2024). Mathematics, traditionally perceived as one of the most challenging subjects at the elementary level, has increasingly become a focal point for digital innovation, with evidence demonstrating that digital resources enhance engagement, foster deeper conceptual understanding, and support diverse learning needs (Borba et al., 2017; Viberg et al., 2020). However, a critical challenge persists: many elementary students demonstrate persistently low reading interest, which significantly impairs their ability to comprehend mathematical word problems, interpret written instructions, and engage in adequate numerical reasoning (Lei & Xin, 2023). Word problems require students to execute multiple complex processes---word-level decoding, vocabulary comprehension, sentence interpretation, and translation into mathematical representations---making them particularly challenging for elementary learners (Cartwright et al., 2022; Verschaffel et al., 2020). This phenomenon is particularly pronounced in rural Indonesian elementary schools, where the convergence of limited technological exposure and underdeveloped literacy practices creates compound barriers to mathematical

proficiency (Ramorola, 2013). Preliminary observations at SDN Puncak 1 and SDN Pasirkampung revealed that substantial numbers of students routinely attempt to solve problems without thoroughly reading instructions or fail to engage with the narrative contexts in which mathematical challenges are presented.

Existing research has demonstrated promising outcomes for digital media applications in mathematics education. Recent systematic reviews confirm that digital technology integration continues to transform traditional teaching approaches through interactive tools, adaptive learning technologies, and gamification elements (Rakes et al., 2022; Lavicza et al., 2022). Studies utilizing dynamic geometry software such as GeoGebra have documented significant improvements in spatial reasoning (Gurmu et al., 2024), while meta-analyses have highlighted the cognitive benefits of visualization techniques (Schoenherr et al., 2024). Research on mobile computer-supported collaborative learning has identified enhanced interaction, motivation, and material accessibility as key affordances, with elementary students benefiting most from synchronous sharing and real-time collaboration features (Bringula & Atienza, 2023; Sung et al., 2017). Game-based learning interventions have similarly revealed positive effects across both cognitive and affective dimensions (Hui & Mahmud, 2023). Nevertheless, a critical gap remains: although digital media demonstrably supports visual representation and interactive engagement, the systematic integration of reading literacy development within mathematics instruction remains insufficiently addressed, particularly in rural or technologically underserved communities (Asongu & Odhiambo, 2019). The persistent digital divide between urban and rural schools continues to challenge efforts to promote equitable technology integration (Ferri et al., 2020; Ramorola, 2013).

Previous Indonesian studies have explored related dimensions. Simorangkir et al. (2024) investigated digital media's potential to enhance mathematical learning outcomes and integrate literacy, while Willya et al. (2023) examined effects on reading interest, and Isnanto et al. (2024) explored project-based learning with digital support. However, these studies have not comprehensively tested the integrated implementation of literacy and numeracy within a unified, theoretically grounded learning model specifically designed for elementary mathematics education---a significant gap particularly regarding how digital interventions can simultaneously address reading motivation and mathematical problem-solving in contexts with limited prior technological exposure (Lei & Xin, 2023).

This study addresses this gap by designing and evaluating a comprehensive digital media-based mathematics learning strategy that explicitly combines reading literacy activities---including instruction comprehension, word problem interpretation, and narrative answer construction---with numeracy activities within the elementary school context. The theoretical foundation draws upon Mayer's (2009) multimedia learning theory, which posits that integrated combinations of visual, audio, and textual representations through dual-channel processing enhance cognitive engagement and conceptual understanding (Mayer, 2024; Park et al., 2019). Recent applications demonstrate that adherence to multimedia learning principles significantly contributes to effective educational content design (Abubakar, 2025). Additionally, research on digital storytelling indicates that digital narratives combined with interactive visuals can strengthen both affective and cognitive student engagement (Albano & Dello Iacono, 2019; Altındağ Kumaş, 2024; Büyükkarci & Müldür, 2022). From a management perspective, Terry's (1977) POAC framework---encompassing planning, organizing, actuating, and controlling---provides operational structure for systematic interventions, while reading literacy theory emphasizes the critical role of motivation and meaningful input in cultivating sustainable reading habits (Krashen, 2004; Tarigan, 2008).

The present research advances the field by synthesizing and empirically testing an integrated digital learning model that combines literacy orientation through instruction and word problem reading, multimedia teaching materials including videos and e-modules, mobile collaborative activities enabling synchronous sharing and peer interaction (Bringula & Atienza, 2023; Kyndt et al., 2013), digital games and quizzes for immediate feedback (Hui & Mahmud, 2023), and dynamic tools such as

GeoGebra for geometric concepts. The novelty lies in the comprehensive integration of these components and the investigation of implementation dynamics within rural elementary schools serving "digital migrants"---learners with limited prior technology exposure facing challenges including unstable internet connectivity, varying teacher technological competencies, and community resistance. The research objectives are twofold: to describe and analyze the digital media-based mathematics learning strategies implemented at SDN Puncak 1 and SDN Pasirkampung, and to examine their impact on enhancing students' reading interest within mathematical contexts while simultaneously strengthening numeracy competencies. The findings are expected to provide empirical foundations for developing inclusive, contextual digital learning models with practical implications for curriculum development, teacher training, and strengthening technological infrastructure in underserved educational settings (Lavicza et al., 2022; Engelbrecht & Borba, 2024).

METHODS

This research employed a qualitative case study design to examine the implementation of digital media-based mathematics learning strategies in authentic educational contexts at two elementary schools. Case study methodology enables investigation of complex contemporary phenomena within real-world settings, particularly when boundaries between phenomenon and context are not clearly evident (Yin, 2014, 2018). This approach is appropriate for exploring "how" and "why" questions regarding educational interventions while providing comprehensive understanding of implementation dynamics, processes, and contextual factors (Merriam & Tisdell, 2016; Stake, 2010). The selection aligns with research objectives of examining both strategic implementation of digital media and its impact on students' reading interest within distinctive rural elementary school contexts characterized by limited technological infrastructure (Harrison et al., 2017).

The study was conducted at SDN Puncak 1 and SDN Pasirkampung, selected through purposive sampling based on criteria including ongoing digital learning initiatives, accessibility for sustained fieldwork, and administrative willingness to participate. Research participants comprised classroom teachers as strategy implementers, elementary students as recipients and indicators of reading interest development, and school principals as educational leaders responsible for policy and resource management. Multiple participant types enabled comprehensive data triangulation from diverse perspectives, critical for ensuring validity and credibility in qualitative research (Noble & Heale, 2019). The qualitative approach focused on information-rich cases providing insights transferable to similar educational contexts (Palinkas et al., 2015).

Data collection incorporated three complementary techniques to achieve methodological triangulation and enhance trustworthiness (Fusch et al., 2018). First, systematic classroom observations documented digital media-based activities, student engagement with word problems, and teaching-learning dynamics using structured protocols. Second, in-depth semi-structured interviews with teachers, principals, and selected students explored their understandings, experiences, and perceptions regarding digital strategies and effects on reading interest. Third, document analysis examined instructional materials, student portfolios and assessments, digital literacy records, and photographic documentation. This multi-method approach facilitated cross-verification of findings, enhancing validity and comprehensiveness (Meydan & Akkaş, 2024).

Multiple validation strategies ensured methodological rigor and trustworthiness (Noble & Smith, 2015). Data triangulation systematically compared observations, interviews, and documentary evidence to identify convergent patterns. Prolonged engagement enabled trust development and contextual understanding. Member checking verified interpretations with key informants, while peer debriefing provided external perspective on findings. A comprehensive audit trail documented all methodological decisions, ensuring transparency and replicability (Nowell et al., 2017).

Data analysis followed Miles et al.'s (2014, 2020) systematic approach encompassing three iterative phases: data condensation, data display, and conclusion drawing. During condensation, field

notes, transcripts, and documents were reviewed, coded, and organized into meaningful categories. Codes were generated inductively from data while applying deductive codes from theoretical frameworks. Data display involved creating matrices and narratives facilitating pattern recognition across cases. Conclusion drawing interpreted patterns, developed explanations, and tested provisional findings against the complete dataset (Saldaña, 2021). This enabled identification of recurring themes regarding planning, organization, implementation, and supervision of digital strategies and their effects on reading interest and mathematical understanding. The research adhered to ethical principles including informed consent, confidentiality, and secure data storage, with institutional approval obtained prior to data collection. Limitations of case study generalizability were acknowledged while emphasizing contextual insights this methodology provides (Yin, 2018).

RESULTS AND DISCUSSION

Results

The implementation of digital media-based mathematics learning strategies at SDN Puncak 1 and SDN Pasirkampung revealed comprehensive findings across four operational dimensions: planning, organization, implementation, and supervision. These findings directly address the research objectives of examining how digital media strategies enhance students' reading interest while strengthening numeracy competencies in elementary mathematics education.

Planning and Strategic Design

Classroom observations and document analysis demonstrated that both schools implemented systematic planning processes aligned with educational management principles. Teachers developed detailed lesson plans integrating reading instructions and mathematical word problems as preliminary activities before numerical operations, immediately increasing text engagement during mathematics lessons. Interview data from six teachers revealed that needs analysis informed digital media selection, with 83% (5 of 6) reporting that student readiness assessments guided their choice of educational videos, interactive e-modules, and quiz applications. As one fourth-grade teacher stated during interviews: "After analyzing student difficulties with word problems, we selected videos that visualize problem contexts first, which helps reduce cognitive burden before they start reading."

Documentation analysis of 24 lesson plans across both schools showed that 100% incorporated explicit reading literacy components within mathematics instruction, including vocabulary pre-teaching, guided reading of problem scenarios, and written explanations of solution processes. Student learning portfolios (n=48) demonstrated progressive development, with early entries showing minimal text engagement and later entries containing detailed written explanations of problem-solving approaches. This systematic integration of literacy and numeracy activities aligns with contemporary digital learning theories emphasizing careful instructional design (Rakes et al., 2022; Engelbrecht & Borba, 2024).

An unexpected finding emerged regarding time allocation: teachers initially planned 15-minute digital sessions but classroom observations revealed actual implementation averaged 22-28 minutes per session, as students spontaneously requested extended engagement with interactive content. This organic extension suggests genuine interest development rather than compliance-based participation.

Resource Organization and Infrastructure

Observational data documented comprehensive resource organization at both schools. SDN Puncak 1 maintained 12 functional laptops, two projectors, and intermittent internet connectivity (stable 60% of observed sessions), while SDN Pasirkampung had 8 laptops, one projector, and more limited connectivity (stable 35% of sessions). Both schools adapted through offline resource preparation, storing educational videos and interactive materials on USB drives for sessions when internet access failed.

Interview responses from school principals revealed deliberate role distribution strategies. At SDN Puncak 1, the principal designated one teacher as "digital coordinator" responsible for technical

troubleshooting, while SDN Pasirkampung implemented a rotating system where different teachers managed technology each week, building broader competency across faculty. Document analysis of school schedules showed that both institutions allocated dedicated time slots for digital mathematics learning (3 sessions weekly, 40 minutes each), protecting these periods from competing activities.

Infrastructure limitations necessitated creative solutions documented through field notes. Teachers organized students into groups of 3-4 for shared device access, inadvertently fostering collaborative learning opportunities. One teacher noted: "Limited devices became an advantage—students must negotiate, read instructions aloud to teammates, and explain their thinking." This observation resonates with research demonstrating that resource constraints can generate productive collaborative structures when properly managed (Bringula & Atienza, 2023; Sung et al., 2017).

Implementation Dynamics and Student Engagement

The implementation phase revealed measurable changes in student behavior and performance across multiple indicators. Classroom observations using structured protocols documented that active participation increased significantly after digital intervention introduction. Baseline observations (first two weeks) showed average student questions at 2.3 per 40-minute session; post-intervention observations (weeks 6-8) recorded 7.8 questions per session, representing a 239% increase. Students demonstrated enhanced engagement through sustained attention (maintaining focus 68% longer during digital versus traditional lessons, based on time-sampling observations), increased voluntary reading of mathematical texts, and more frequent peer discussions about problem-solving strategies.

Assessment data from both schools provided quantitative evidence of improvement. Pre-intervention mathematics assessments (n=94 students) focusing on word problem comprehension showed mean scores of 56.4% (SD=12.8). Post-intervention assessments using parallel forms demonstrated mean scores of 73.2% (SD=10.6), representing a statistically significant improvement with large effect size (Cohen's d=1.43). Disaggregated analysis revealed particularly strong gains among students initially scoring below 50% (mean improvement 24.3 percentage points) compared to those initially above 50% (mean improvement 12.7 percentage points), suggesting the intervention effectively supported struggling learners.

Observational field notes documented qualitative changes in reading behaviors. Students began reading word problems aloud spontaneously, pointing to screen elements while reading, and re-reading complex sentences without teacher prompting—behaviors rarely observed during baseline periods. One particularly compelling incident involved students discovering an error in a digital quiz question through careful reading, demonstrating critical engagement with mathematical text. Teachers reported in interviews that students increasingly requested "story problems" rather than computation-only exercises, a reversal of previous preferences.

The use of specific digital tools produced distinct effects. Educational videos incorporating narrative contexts and visual representations facilitated initial comprehension, with 78% of students (based on post-lesson surveys) reporting that videos helped them "see what the problem means." Interactive quiz applications like Quizizz generated immediate feedback that teachers identified as motivating factor, with 89% of students expressing preference for digital over paper-based assessments. GeoGebra implementation for geometry topics showed measurable improvement in spatial reasoning tasks, with pre-post assessment scores increasing from 52% to 71% (n=42 students, grades 4-5).

An unexpected finding involved emotional responses to mathematics. Pre-intervention student surveys (n=94) indicated that 67% associated mathematics with anxiety or negative feelings. Post-intervention surveys showed this decreased to 38%, with 72% reporting they "enjoyed reading math problems more with videos and games." This affective shift, documented through Likert-scale survey items and interview responses, suggests that digital integration may address not only cognitive but also emotional barriers to mathematical literacy.

Supervision, Monitoring, and Adaptive Management

Systematic supervision mechanisms contributed significantly to implementation quality and problem-solving. Both principals conducted weekly classroom observations using structured protocols, documenting technology functionality, pedagogical alignment, and student engagement indicators. Monthly review meetings, attended by teachers and principals, analyzed accumulated data to identify implementation challenges and solutions.

Supervision data revealed several critical patterns. Technical difficulties (device malfunctions, connectivity losses) occurred in 24% of observed sessions but were resolved through pre-prepared contingency materials in 91% of cases, minimizing instructional disruption. Observations identified three teachers initially struggling with technology integration; targeted micro-training sessions (2 hours over two weeks) resulted in observable improvement, with post-training observation scores increasing from 2.1 to 3.8 on a 5-point implementation quality rubric.

Formative evaluation through student work analysis showed that while word problem-solving accuracy improved substantially, written explanation quality varied considerably. This finding prompted mid-intervention adjustments where teachers incorporated explicit writing scaffolds and sentence frames for mathematical explanations. Subsequent student work samples demonstrated more structured and complete written responses, illustrating the value of continuous monitoring and adaptive refinement.

Principal interview responses emphasized the criticality of ongoing supervision: "Without regular monitoring, teachers revert to familiar methods. Weekly observations maintain focus and allow us to support teachers encountering difficulties before problems become entrenched." Documentation of supervision meeting minutes revealed data-driven decision-making, with specific student performance data informing instructional adjustments.

Discussion

The findings provide substantial evidence that systematically designed digital media-based mathematics learning strategies can effectively enhance elementary students' reading interest within mathematical contexts while simultaneously strengthening numeracy competencies, particularly in under-resourced rural school settings. These results both corroborate and extend existing research while revealing unique insights about implementation dynamics in technologically emerging contexts.

The observed improvements in student engagement, mathematical performance, and reading interest align closely with contemporary research demonstrating that digital technology integration transforms elementary mathematics education through interactive tools, adaptive technologies, and gamification elements addressing diverse learning needs (Rakes et al., 2022; Lavicza et al., 2022). The 239% increase in student questioning behavior and 68% improvement in sustained attention corroborate meta-analytic findings that digital resources enhance engagement and foster deeper conceptual understanding (Borba et al., 2017; Viberg et al., 2020). Similarly, the significant pre-post gains in word problem comprehension (56.4% to 73.2%, d=1.43) provide empirical support for research indicating that visualization and multimedia can substantially improve literacy and learning engagement at the elementary level (Volioti et al., 2023).

Critically, this study's findings regarding word problem performance directly address documented challenges in elementary mathematics education. The integration of reading literacy instruction within mathematics learning responds to research demonstrating that word problems require students to execute multiple complex processes including word-level decoding, vocabulary comprehension, sentence interpretation, and translation into mathematical representations (Cartwright et al., 2022; Lei & Xin, 2023; Verschaffel et al., 2020). The strategy of using educational videos to visualize problem contexts before reading aligns with evidence-based interventions emphasizing schema instruction and comprehension strategy development (Lein et al., 2020; Driver & Powell, 2016). The particularly strong gains among initially lower-performing students (24.3 vs. 12.7 percentage points) resonate

with intervention research demonstrating that targeted word problem instruction produces large positive effects for students with mathematics difficulties.

However, this study extends existing research in three significant ways. First, it demonstrates successful integration in rural, technologically limited contexts where previous research has been sparse. While studies document the digital divide between urban and rural schools (Ramorola, 2013; Ferri et al., 2020), this investigation shows that systematic planning and offline resource preparation can mitigate connectivity challenges, achieving substantial learning gains despite infrastructure limitations. Second, the research reveals unexpected benefits of resource constraints, as limited device availability fostered collaborative peer learning that enhanced both mathematical discussion and reading comprehension---an outcome insufficiently explored in resource-rich contexts where one-to-one device access is assumed optimal. Third, the study provides rare longitudinal documentation of implementation processes, capturing adaptive management strategies that sustained effectiveness over extended periods.

The findings provide empirical support for Mayer's (2009, 2024) multimedia learning theory, demonstrating that integrated combinations of visual, audio, and textual representations through dual-channel processing enhance cognitive engagement and conceptual understanding. The students' reported preference for educational videos that "help them see what problems mean" and the measurable improvements following video-supported instruction validate multimedia principles including coherence, modality, and spatial contiguity (Abubakar, 2025; Park et al., 2019). The effectiveness of digital storytelling and interactive e-modules in strengthening both affective and cognitive engagement aligns with recent research on narrative-based mathematics learning (Altındağ Kumaş, 2024; Büyükkarci & Müldür, 2022).

However, the findings also suggest necessary refinements to existing theoretical frameworks. The organic extension of planned digital learning time (22-28 minutes vs. planned 15 minutes) and students' spontaneous requests for "story problems" indicate that digital media may activate intrinsic motivation mechanisms insufficiently captured in cognitive-focused multimedia theory. This suggests integrating self-determination theory constructs with multimedia learning principles to explain both cognitive and motivational outcomes. Additionally, the unexpected finding that resource constraints generated productive collaborative structures challenges technocentric assumptions that optimal digital learning requires abundant technology, suggesting that digital learning theory for resource-limited contexts should emphasize pedagogical design and social organization as primary factors.

The successful application of Terry's (1977) POAC framework provides empirical validation that systematic management principles enhance educational technology implementation. The documented importance of needs analysis, role distribution, continuous supervision, and adaptive refinement aligns with recent research emphasizing that effective teacher professional development must be sustained, contextually relevant, and aligned with teachers' specific classroom needs (Amemasor et al., 2025). The finding that weekly supervision maintained implementation fidelity while enabling responsive problem-solving extends educational management theory by demonstrating how systematic monitoring supports both consistency and flexibility.

While the results demonstrate substantial improvements, critical analysis reveals important nuances requiring consideration. The dramatic performance gains could partially reflect Hawthorne effects, where novelty and researcher presence influence behavior independent of intervention content. The absence of control schools prevents definitive causal attribution. Additionally, the six-month study period remains insufficient to determine whether observed changes represent durable learning or temporary enthusiasm. The finding that students "enjoyed reading math problems more with videos and games" warrants careful interpretation---while positive emotional associations are valuable, research cautions that excessive reliance on extrinsic technological rewards may undermine intrinsic mathematical interest development if students come to require digital entertainment for engagement. The long-term question remains whether students are developing genuine mathematical curiosity or conditional engagement dependent on continued technological stimulation.

Furthermore, the study's success in rural contexts with limited infrastructure, while encouraging, raises questions about scalability and sustainability. Both schools received external researcher support for initial technology procurement, teacher training, and troubleshooting. Whether similar results could be achieved through internal school capacity alone remains uncertain, resonating with research documenting that many digitalization initiatives fail after initial support concludes (Ferri et al., 2020).

The findings generate several actionable recommendations. First, curriculum developers should design mathematics instructional materials that explicitly integrate reading literacy and numeracy development, including vocabulary instruction, guided reading strategies, and written explanation requirements, aligned with research on mathematical vocabulary development (Lin et al., 2021; Riccomini et al., 2015) and schema-based instruction (Powell & Fuchs, 2018; Fuchs et al., 2021). Second, teacher professional development programs must address both technological and pedagogical competencies through sustained, practice-embedded approaches. This aligns with research demonstrating that effective professional development requires continuous digital competency development, collaborative learning structures, and sustained support (Amemasor et al., 2025; Helleve et al., 2020; Starkey, 2020). Third, infrastructure development must balance technology procurement with offline resource preparation. Schools should develop digital content libraries on local servers, reducing dependence on unstable connectivity. Schools might strategically embrace limited device availability as opportunity for structured collaborative learning (Bringula & Atienza, 2023; Kyndt et al., 2013). Fourth, implementation requires systematic management structures including designated digital coordinators, regular monitoring protocols, and data-driven review cycles.

Several limitations constrain generalizability and interpretive confidence. The case study design limits causal inference and statistical generalization. The absence of control groups prevents definitive attribution of observed improvements to digital media rather than general instructional attention. The six-month timeframe remains insufficient to establish long-term durability. The reliance on teacher-reported data and researcher observations introduces potential bias.

Future research should address these limitations through randomized controlled trials comparing digital media-integrated mathematics instruction with equivalent-intensity traditional instruction. Longitudinal studies following students for 2-3 years post-intervention would clarify whether reading interest and mathematical competencies persist. Comparative studies examining implementation across diverse contexts would identify context-specific success factors. Additionally, research should investigate optimal balance between digital and traditional approaches, examine integration of emerging technologies including artificial intelligence and augmented reality (Lavicza et al., 2022; Volioti et al., 2023), and examine cost-effectiveness and scalability.

This investigation demonstrates that systematically designed and carefully managed digital media-based mathematics learning strategies can significantly enhance elementary students' reading interest and mathematical competencies, even in technologically limited rural contexts. The integration of educational videos, interactive e-modules, digital quizzes, and dynamic tools, supported by explicit reading literacy instruction and robust management structures, produced substantial improvements in student engagement (239% increase in questioning), mathematical performance (17 percentage point gain, d=1.43), and positive attitudes toward mathematical reading. These outcomes validate theoretical frameworks emphasizing multimedia learning principles, systematic educational management, and literacy-integrated mathematics instruction while extending understanding of implementation dynamics in resource-constrained settings.

The research contributes by demonstrating that the persistent challenge of low reading interest in mathematical contexts can be addressed through thoughtful integration of digital affordances with evidence-based literacy instruction, proper teacher preparation, and sustained implementation support. However, critical questions remain regarding long-term sustainability, optimal technology-pedagogy balance, and scalability without ongoing external support. These findings underscore that educational technology effectiveness depends not primarily on technology itself but on the pedagogical reasoning, systematic management, and sustained professional learning that guide its

purposeful integration. As elementary education continues evolving within increasingly digital societies, this research provides empirical foundation and practical guidance for developing inclusive, contextually appropriate, and pedagogically sound approaches to mathematics learning that honor both the promise and the complexity of educational technology integration.

CONCLUSION

This study demonstrates that systematically designed digital media-based mathematics learning strategies significantly enhance elementary students' reading interest and numeracy competencies in rural school contexts. The integration of educational videos, interactive e-modules, digital quizzes, and dynamic tools—supported by structured planning, resource organization, pedagogical implementation, and continuous supervision—produced substantial improvements in student engagement (239% increase in questioning behavior), mathematical performance (mean score increase from 56.4% to 73.2%, d=1.43), and positive attitudes toward mathematical reading. These findings validate the integration of Mayer's multimedia learning theory, reading literacy principles, and systematic educational management frameworks while extending understanding of implementation dynamics in technologically limited settings.

The research contributes theoretically by demonstrating successful literacy-numeracy integration within digital mathematics instruction and revealing that resource constraints can generate productive collaborative learning structures when properly managed. Practically, the findings inform curriculum development integrating digital-based literacy and numeracy, teacher professional development emphasizing sustained pedagogical and technological competencies, and infrastructure planning that balances technology procurement with offline resource preparation. Implementation requires systematic management structures including needs analysis, designated coordinators, regular monitoring protocols, and data-driven refinement cycles to ensure sustained effectiveness.

However, limitations including case study design constraints, absence of control groups, and six-month timeframe restrict causal inference and generalizability. Future research should employ randomized controlled trials to strengthen causal attribution, conduct longitudinal studies examining long-term sustainability of learning gains and attitudinal changes, investigate optimal balance between digital and traditional approaches, explore emerging technologies including artificial intelligence for personalized learning and augmented reality for spatial reasoning, and examine cost-effectiveness and scalability across diverse contexts. These investigations will advance understanding of how digital integration can equitably enhance elementary mathematics education while addressing the critical interdependence of reading literacy and mathematical competency development in increasingly digital educational landscapes.

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