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Challenges and Adaptive Solutions in Managing Artificial Intelligence-Based Learning in Elementary Schools

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Abstract

Artificial Intelligence has become an important educational innovation, yet its sustainable implementation in elementary schools remains constrained by various organizational and pedagogical challenges. Existing studies have predominantly examined AI from the perspectives of technology adoption and instructional effectiveness, while limited attention has been given to how schools systematically manage implementation challenges. This study aims to explore the challenges encountered in managing AI-based learning and to examine the adaptive solutions implemented by SD Negeri Kebonsari 3 Malang. A qualitative case study design was employed using interviews, observations, and document analysis. Data were analyzed through the interactive model of Miles et al., while trustworthiness was established using Lincoln & Guba's criteria. The findings reveal five interconnected dimensions of adaptive AI-based learning management: (1) infrastructure challenges addressed through strategic resource optimization; (2) teacher readiness strengthened through collaborative professional learning within the Kedai Kosaga Program; (3) student readiness fostered through responsible AI use and continuous pedagogical guidance; (4) institutional policies that integrate leadership support, professional development, and stakeholder collaboration; and (5) adaptive school management strategies that transform implementation challenges into opportunities for continuous organizational learning. These findings contribute to the literature by proposing adaptive school management as an organizational framework that supports the sustainable implementation of AI-based learning in elementary education.

Keywords: adaptive school management; artificial intelligence; elementary education; learning management; professional learning community

1. Introduction

Artificial Intelligence (AI) has emerged as one of the most transformative innovations in contemporary education, reshaping instructional design, classroom interaction, assessment practices, and educational decision-making. The rapid development of generative AI and intelligent educational technologies has enabled teachers to prepare instructional materials more efficiently, personalize learning experiences, provide immediate feedback, and support students with diverse learning needs. Consequently, AI is increasingly recognized not merely as a technological innovation but as a strategic educational resource capable of improving learning quality when integrated through appropriate pedagogical and organizational practices (Holmes et al., 2022; Zawacki-Richter et al., 2019; Crompton & Burke, 2023). Nevertheless, educational benefits cannot be achieved solely through technological adoption; they also depend on schools' ability to organize, regulate, and continuously improve AI implementation within everyday teaching and learning activities (Luckin & Cukurova, 2019; Holmes et al., 2022).

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Although AI offers considerable educational potential, its implementation in elementary schools remains far from straightforward. Schools frequently encounter interconnected challenges related to digital infrastructure, teachers' technological competence, students' readiness, ethical concerns regarding AI use, and unequal parental support for technology-assisted learning. These challenges are particularly significant in elementary education because younger learners require closer pedagogical guidance and supervision than students at higher educational levels. Therefore, successful AI implementation should not be viewed merely as a matter of technological availability but as a process requiring adaptive organizational capacity, collaborative professional learning, and sustainable institutional support (Luckin & Cukurova, 2019; Crompton & Burke, 2023; Casal-Otero et al., 2023; Selwyn, 2022).

Previous studies have extensively investigated AI integration from various educational perspectives. Existing literature has primarily focused on teachers' digital literacy, technology acceptance, AI-assisted instructional media, personalized learning, and the effectiveness of AI-supported instruction in improving students' learning outcomes (Zawacki-Richter et al., 2019; Holmes et al., 2022; Casal-Otero et al., 2023). Other studies have highlighted professional development programs that enhance teachers' competence in utilizing AI for instructional purposes (Crompton & Burke, 2023; Casal-Otero et al., 2023; Luckin & Cukurova, 2019). These studies have substantially enriched current understanding of educational AI adoption; however, they predominantly explain how AI is used rather than how schools manage the challenges arising from its implementation. Consequently, AI is often positioned as an instructional tool rather than as an organizational innovation requiring systematic educational management.

Moreover, previous research generally discusses implementation challenges as independent obstacles such as inadequate infrastructure, insufficient teacher competence, limited technological resources, or students' digital readiness (Casal-Otero et al., 2023; Crompton & Burke, 2023; Selwyn, 2022). These studies rarely explain how school leadership, collaborative professional learning, institutional policies, continuous mentoring, and stakeholder collaboration interact to transform implementation challenges into opportunities for organizational improvement. As a result, empirical evidence explaining how elementary schools strategically respond to AI implementation challenges through adaptive management practices remains limited (Holmes et al., 2022; Luckin & Cukurova, 2019; Zawacki-Richter et al., 2019). This limitation indicates that existing literature has not sufficiently explained the organizational processes enabling schools to sustain AI-based learning despite facing multiple implementation constraints.

This study addresses the above gap by adopting an adaptive school management perspective to examine how implementation challenges are systematically managed within an elementary school context. Rather than viewing challenges as barriers that merely hinder technology integration, this study conceptualizes them as catalysts for organizational learning that encourage schools to develop adaptive responses through professional collaboration, leadership support, institutional policies, infrastructure improvement, teacher mentoring, and stakeholder engagement. Using SD Negeri Kebonsari 3 Malang as an empirical case, this research demonstrates that the sustainability of AI-based learning depends on the school's capacity to continuously align organizational management with emerging technological and educational demands. This perspective extends previous AI studies by shifting attention from

technological adoption toward the adaptive organizational processes that sustain educational innovation.

Accordingly, this study aims to explore the challenges encountered in managing Artificial Intelligence-based learning and to examine the adaptive solutions implemented by SD Negeri Kebonsari 3 Malang. Specifically, the study investigates five interrelated aspects: (1) infrastructure challenges and adaptive support; (2) teacher readiness and professional learning; (3) student readiness and responsible AI use; (4) institutional policies for sustainable AI-based learning; and (5) adaptive school management strategies that enable the sustainable implementation of AI in elementary education.

2. Method

This study employed a qualitative approach using a single-case study design to obtain an in-depth understanding of the challenges encountered in managing Artificial Intelligence (AI)-based learning and the adaptive solutions implemented within a real educational context. A case study was considered appropriate because it enables researchers to investigate contemporary educational phenomena holistically while preserving the complexity of interactions among leadership, teachers, organizational practices, and learning environments (Yin, 2018).

The research was conducted at SD Negeri Kebonsari 3 Malang, Indonesia, one of the elementary schools that has systematically developed AI-based learning through the Kedai Kosaga Program, a school-based Professional Learning Community). The school was selected purposively because it has continuously integrated AI into teacher professional development before implementing AI-supported learning in classrooms. This unique characteristic provided a suitable setting for examining adaptive school management in response to AI implementation challenges.

Research participants consisted of the principal, curriculum coordinator, and classroom teachers who were directly involved in planning, organizing, implementing, monitoring, and evaluating AI-based learning management. These participants were selected purposively based on their responsibilities and direct involvement in the Kedai Kosaga Program, enabling the study to capture multiple perspectives regarding organizational adaptation and school management practices.

Data were collected through semi-structured interviews, non-participant observations, and document analysis. Interviews explored participants' experiences regarding challenges, adaptive responses, school policies, and professional learning activities. Observations focused on collaborative activities within the Kedai Kosaga Program and school practices related to AI-supported learning management. Documentary evidence, including school programs, meeting reports, teacher development documents, and institutional records, was used to strengthen data credibility through triangulation.

Data analysis followed the interactive model proposed by Miles et al. (2014), consisting of data collection, data condensation, data display, and conclusion drawing and verification. Throughout the analysis, interview transcripts, observation notes, and documentary evidence were continuously compared to identify recurring themes concerning implementation challenges and adaptive management strategies. This iterative analytical process enabled the

development of comprehensive explanations regarding how the school responded to various organizational and pedagogical challenges during AI implementation.

To ensure research trustworthiness, the study adopted the criteria proposed by Lincoln & Guba (1985), including credibility, transferability, dependability, and confirmability. Credibility was strengthened through source triangulation, methodological triangulation, prolonged engagement, and member checking with research participants. Transferability was supported through detailed contextual descriptions of the research setting. Dependability was ensured by maintaining a transparent research process, while confirmability was achieved by documenting analytical decisions and maintaining consistency between empirical findings and research interpretations.

3. Results and Discussion

3.1 Result

The findings of this study demonstrate that managing Artificial Intelligence (AI)-based learning in elementary schools involves a series of interconnected organizational processes that enable schools to respond adaptively to implementation challenges. Rather than viewing technological constraints as isolated problems, SD Negeri Kebonsari 3 Malang developed various adaptive strategies through professional learning, institutional support, collaborative practices, and continuous improvement. To present these findings systematically, the results are organized into five themes corresponding to the research objectives: (1) infrastructure challenges and adaptive support, (2) teacher readiness and professional learning, (3) student readiness and responsible AI use, (4) institutional policies for sustainable AI-based learning, and (5) adaptive school management strategies.

3.1.1 Infrastructure Challenges and Adaptive Support

The findings revealed that the initial challenge encountered by the school was the limited availability of technological infrastructure to support AI-based learning. Although several classrooms had been equipped with Interactive Flat Panels (IFPs), the availability of digital facilities was not yet evenly distributed across all learning environments. Internet connectivity occasionally became unstable during classroom activities, and not every student possessed equal access to digital devices outside school. Differences in students' access to technology at home also influenced the continuity of AI-supported learning activities.

To address these challenges, the school gradually strengthened its technological infrastructure by optimizing available digital facilities, improving internet accessibility, and maximizing the use of existing educational technology. Rather than waiting for complete technological readiness, teachers were encouraged to utilize AI applications flexibly according to available resources and classroom conditions. The school also emphasized that AI should function as instructional support rather than becoming the primary learning medium, allowing teachers to adjust instructional strategies according to students' technological readiness.

Another adaptive response involved collaboration with parents to ensure that students received appropriate support when AI-assisted learning activities required the use of digital devices outside school hours. Communication between teachers and parents enabled schools to identify students who experienced technological limitations and to adjust learning activities

accordingly. This adaptive approach minimized inequalities in technology access while maintaining students' opportunities to participate in AI-supported learning.

3.1.2 Teacher Readiness and Professional Learning

The findings indicate that teacher readiness became one of the primary factors influencing the implementation of AI-based learning management at SD Negeri Kebonsari 3 Malang. Teachers demonstrated varying levels of digital competence and prior experience in utilizing AI applications, requiring the school to establish a structured professional learning process before AI was integrated into classroom instruction. Rather than expecting teachers to independently master emerging technologies, the school positioned teacher readiness as a continuous developmental process supported through collaborative learning.

Professional learning was facilitated through the Kedai Kosaga Program, which functioned as the school's Professional Learning Community. Within this program, teachers regularly participated in collaborative discussions, shared instructional experiences, exchanged best practices, and explored various AI applications relevant to elementary education. These activities enabled teachers to collectively identify appropriate instructional strategies while gradually increasing their confidence in utilizing AI as an instructional support tool.

The findings further revealed that the professional learning process extended beyond introducing AI applications. Teachers received continuous mentoring to understand the pedagogical functions of AI, evaluate its suitability for different learning objectives, and adapt technological tools to students' developmental characteristics. Through collaborative exploration, teachers became familiar with various AI-supported applications and digital learning platforms that could assist lesson preparation, instructional media development, assessment, and classroom interaction. This process encouraged teachers to select technologies critically rather than adopting AI indiscriminately.

Another important finding was that professional learning fostered a collaborative culture among teachers. Participants perceived the Kedai Kosaga Program not merely as a training activity but as an ongoing learning community where members continuously reflected on classroom experiences, discussed implementation challenges, and developed practical solutions together. Such collaborative interactions strengthened teachers' confidence, reduced resistance toward technological innovation, and encouraged continuous professional improvement in response to the evolving development of AI technologies.

3.1.3 Student Readiness and Responsible AI Use

The findings revealed that students' readiness played an essential role in determining the effectiveness of AI-based learning implementation. Teachers found that students demonstrated different levels of digital literacy, learning independence, and technological confidence, requiring instructional adjustments according to students' developmental characteristics. Consequently, AI was not introduced uniformly but was implemented selectively based on students' readiness, learning objectives, and classroom contexts.

Teachers utilized AI as a supporting instructional resource rather than allowing students to depend directly on AI-generated outputs. AI-assisted applications were primarily employed

to enrich classroom learning through interactive media, digital quizzes, visual learning materials, and creative instructional activities. Students were encouraged to participate actively in learning processes while teachers maintained responsibility for facilitating understanding, guiding discussions, and monitoring learning progress. This approach ensured that technology complemented rather than replaced meaningful teacher–student interaction.

The findings also showed that teachers continuously emphasized the responsible use of AI during classroom activities. Students were guided to use digital technologies ethically, verify information critically, and understand that AI-generated content should be reviewed rather than accepted without evaluation. Classroom learning therefore incorporated discussions about appropriate technology use alongside subject content, helping students gradually develop digital responsibility while utilizing AI-supported learning resources.

Differences in students' access to technology outside school further influenced the implementation of AI-based learning. Teachers responded by designing flexible learning activities that did not require continuous access to AI applications beyond the classroom. When home-based digital activities were assigned, teachers adjusted task complexity according to students' available resources and communicated with parents when additional support was needed. These adaptive practices enabled students with different technological backgrounds to participate meaningfully in AI-supported learning without creating unnecessary disparities in learning opportunities.

3.1.4 Institutional Policies for Sustainable AI-Based Learning

The findings revealed that the sustainability of AI-based learning at SD Negeri Kebonsari 3 Malang was strongly supported by institutional policies established by the school leadership. Rather than implementing AI through isolated classroom initiatives, the school incorporated AI integration into its broader educational development agenda. This institutional commitment provided teachers with a clear direction for gradually adopting AI while maintaining alignment with the school's educational vision and instructional objectives.

The principal played a central role in initiating and sustaining AI-based learning by encouraging continuous innovation, facilitating professional development, and creating an environment that supported experimentation with educational technologies. Teachers were given opportunities to explore emerging AI applications while remaining responsible for ensuring that technological use aligned with pedagogical considerations and students' learning needs. This leadership approach promoted a shared commitment to educational innovation rather than imposing mandatory technology adoption.

Institutional support was further demonstrated through the allocation of resources for teacher development and the provision of technological facilities required to support AI implementation. The school continuously encouraged participation in the Kedai Kosaga Program, provided access to digital learning resources, and facilitated collaborative activities that enabled teachers to improve their instructional competence. These institutional efforts ensured that professional learning became an integral component of school development rather than a temporary initiative.

The findings also indicated that sustainable AI implementation relied on collaboration among multiple stakeholders. School leaders, teachers, students, and parents each contributed

to maintaining the continuity of AI-supported learning according to their respective roles. Parents were involved through ongoing communication regarding students' technology use, while teachers and school leaders collaboratively evaluated implementation challenges and adjusted school programs when necessary. This collaborative governance enabled the school to sustain AI-based learning despite differences in technological readiness and resource availability.

3.1.5 Adaptive School Management Strategies

The findings revealed that the successful management of AI-based learning at SD Negeri Kebonsari 3 Malang was not determined by technological sophistication alone but by the school's capacity to continuously adapt its organizational practices to changing educational and technological demands. Rather than implementing AI through fixed procedures, the school adopted a flexible management approach that enabled continuous adjustments according to available resources, teachers' competencies, students' characteristics, and emerging implementation challenges.

Adaptive management was reflected in the integration of planning, collaborative organization, professional learning activities, continuous monitoring, and institutional support into a coherent management process. Each management function was interconnected, allowing feedback obtained during implementation to become the basis for subsequent improvements. Consequently, challenges encountered during AI implementation were treated as opportunities for organizational learning rather than obstacles that hindered innovation.

The findings further demonstrated that collaborative decision-making became an essential characteristic of adaptive school management. Teachers actively shared classroom experiences, discussed implementation difficulties, and developed practical solutions collectively through the Kedai Kosaga Program. School leaders facilitated this collaborative process by encouraging experimentation, providing professional support, and allowing teachers sufficient flexibility to modify instructional strategies according to classroom conditions. Such collaboration enabled the school to respond more effectively to technological changes while maintaining consistent educational objectives.

Another important finding was that adaptive school management emphasized gradual and sustainable improvement instead of rapid technological transformation. AI implementation developed incrementally through continuous teacher capacity building, periodic program evaluation, infrastructure enhancement, and stakeholder collaboration. This gradual approach reduced resistance to educational innovation and enabled the school to sustain AI-supported learning despite variations in technological readiness and resource availability.

Overall, the findings indicate that adaptive school management functioned as the integrating mechanism connecting technological resources, teacher professional learning, student readiness, institutional policies, and collaborative leadership into a sustainable AI-based learning ecosystem. Through this adaptive organizational approach, the school continuously adjusted its management practices in response to implementation challenges while maintaining the quality and continuity of AI-supported learning.

3.2 Discussion

3.2.1 Infrastructure Challenges and Adaptive Support

The findings indicate that technological infrastructure should not be understood merely as the availability of digital devices but as an enabling organizational resource that determines the sustainability of AI-based learning. Although SD Negeri Kebonsari 3 Malang experienced limitations in internet connectivity, unequal access to digital facilities, and disparities in students' access to technology outside school, these constraints did not prevent the school from implementing AI-supported learning. Instead, the school adopted an adaptive approach by optimizing existing facilities, adjusting instructional practices to available resources, and ensuring that AI complemented rather than dominated the learning process. This finding suggests that the effectiveness of AI integration depends not only on technological readiness but also on the school's capacity to manage infrastructural limitations through adaptive educational practices.

This interpretation extends the growing body of literature arguing that technological infrastructure remains one of the fundamental prerequisites for educational AI implementation. Kasneci et al. (2023) emphasized that while generative AI has enormous potential to transform teaching and learning, inadequate technological ecosystems continue to hinder meaningful classroom adoption. Similarly, Grassini (2023) argued that the educational benefits of AI cannot be realized unless schools possess sufficient technological capacity to support both teachers and learners. However, the present findings demonstrate that infrastructure should not be interpreted as a fixed prerequisite that must be fully achieved before AI can be introduced. Rather, schools may progressively strengthen technological capacity while simultaneously implementing AI in pedagogically appropriate ways.

Another important interpretation emerging from the findings concerns the role of instructional flexibility in overcoming infrastructural constraints. Instead of postponing AI implementation until complete technological readiness had been achieved, teachers continuously adjusted instructional strategies according to classroom conditions and students' technological access. Such flexibility reflects the concept of adaptive educational innovation, whereby technological implementation evolves alongside organizational learning rather than following a rigid sequence of technological investment. Lee & Kwon (2024) similarly argued that successful educational AI implementation requires flexible pedagogical adaptation because technological conditions vary considerably across educational institutions. Likewise, Chen et al. (2024) highlighted that sustainable AI integration depends on schools' ability to redesign instructional practices according to contextual needs rather than adopting standardized technological solutions.

The findings also reveal that infrastructural challenges extend beyond physical facilities to include inequalities in students' opportunities to access technology outside school. This condition required teachers to modify learning activities, communicate with parents, and ensure that AI-supported learning remained accessible to all students regardless of their technological background. Such evidence reinforces previous arguments that digital equity constitutes a central consideration in AI-supported education. Casal-Otero et al. (2023) noted that unequal access to digital resources may widen learning disparities if schools fail to provide adaptive instructional support. Similarly, Selwyn (2022) argued that educational technology should always be examined within broader social and organizational contexts because

inequalities in access frequently influence educational outcomes more strongly than the technologies themselves.

An additional contribution of the present findings lies in demonstrating that infrastructure adaptation is not solely a technical responsibility but also an organizational management process. School leaders and teachers collaboratively identified infrastructural limitations, prioritized available resources, and continuously refined implementation strategies according to emerging needs. Consequently, infrastructure became a dynamic organizational resource that evolved through continuous evaluation and collaborative problem-solving rather than remaining a static indicator of technological readiness. This perspective broadens previous AI implementation studies, which have predominantly emphasized technological provision, by illustrating how adaptive organizational management enables schools to sustain AI-supported learning even when technological conditions remain imperfect.

Collectively, these findings contribute to the emerging literature on AI-based education by demonstrating that infrastructure should be reconceptualized as an adaptive organizational capability rather than merely a technological asset. Sustainable AI implementation in elementary schools is therefore determined not by the completeness of technological facilities alone but by the school's capacity to continuously align available infrastructure with pedagogical needs, collaborative decision-making, and equitable learning opportunities. This adaptive perspective expands existing discussions on educational AI by positioning infrastructure management as a strategic organizational process that supports long-term educational innovation rather than simply facilitating technology adoption.

3.2.2 Teacher Readiness and Professional Learning

The findings suggest that teacher readiness for AI-based learning is not an individual competence acquired independently but a collective capacity developed through continuous professional learning. At SD Negeri Kebonsari 3 Malang, teacher preparedness evolved through the Kedai Kosaga Program, where collaborative discussions, peer mentoring, classroom reflection, and joint exploration of AI applications enabled teachers to gradually strengthen their pedagogical and technological competence. This indicates that sustainable AI implementation depends less on teachers' initial digital expertise than on the availability of organizational structures that facilitate continuous professional growth.

This interpretation aligns with the growing body of research emphasizing that successful AI integration requires sustained professional learning rather than isolated technology training. Holmes et al. (2022) argued that teachers need opportunities to develop pedagogical understanding alongside technological competence so that AI can support meaningful learning rather than simply automate instructional tasks. Likewise, Luckin & Cukurova (2019) contended that teachers' capacity to critically evaluate AI applications is essential because educational value emerges from informed pedagogical decision-making rather than technological functionality alone. The present findings reinforce these arguments by demonstrating that professional competence develops progressively through collaborative organizational learning rather than through one-off training activities.

Another significant finding concerns the role of the Kedai Kosaga Program as a Professional Learning Community (PLC). Rather than functioning as a conventional workshop,

the program created a collaborative environment in which teachers continuously exchanged classroom experiences, discussed implementation challenges, evaluated instructional practices, and jointly identified appropriate AI-supported learning strategies. Such collaborative interactions enabled teachers to build confidence while reducing uncertainty associated with emerging technologies. This finding corresponds with the broader literature on Professional Learning Communities, which identifies collaborative inquiry, shared reflection, and collective responsibility as critical mechanisms for improving instructional quality and sustaining educational innovation (DuFour & Fullan, 2013; Hord, 2009; Stoll et al., 2006).

The findings further indicate that professional learning contributed to teachers' ability to make pedagogically appropriate decisions regarding AI use. Instead of introducing AI applications indiscriminately, teachers became more capable of selecting technologies according to curriculum objectives, students' developmental characteristics, and classroom conditions. This demonstrates that professional learning enhanced teachers' pedagogical judgment rather than merely expanding their technological repertoire. Similar conclusions were reported by Mishra & Koehler (2006), who emphasized that effective technology integration requires the integration of technological, pedagogical, and content knowledge (TPACK), allowing teachers to determine when and how technology should support learning rather than dominate instructional processes.

Importantly, the findings extend previous studies by illustrating that teacher readiness should be viewed as an adaptive organizational outcome instead of an individual characteristic. Throughout the Kedai Kosaga Program, teachers continuously learned from one another, reflected on instructional experiences, and collectively solved implementation problems. Consequently, professional competence emerged from ongoing organizational interaction rather than from personal technological proficiency alone. This organizational perspective broadens existing AI literature, which has predominantly examined teachers' digital competence at the individual level, by demonstrating how collaborative professional learning can strengthen schools' adaptive capacity to respond to technological change.

Collectively, these findings contribute to the literature by demonstrating that teacher readiness for AI-based learning is best understood as a product of continuous organizational learning rather than individual technological competence. Professional Learning Communities such as the Kedai Kosaga Program function not merely as professional development initiatives but as adaptive organizational mechanisms that enable teachers to transform implementation challenges into collaborative learning opportunities. This perspective expands current discussions on AI integration by positioning sustained professional learning as a strategic management process that underpins the long-term sustainability of AI-based learning in elementary schools.

3.2.3 Student Readiness and Responsible AI Use

The findings demonstrate that students' readiness for AI-based learning extends beyond their ability to operate digital technologies. At SD Negeri Kebonsari 3 Malang, readiness was developed through a gradual instructional process in which teachers continuously guided students to use AI as a learning support tool while maintaining active engagement in classroom activities. Rather than allowing students to rely uncritically on AI-generated outputs, teachers emphasized understanding, discussion, reflection, and ethical technology use. This indicates

that students' readiness is fundamentally a pedagogical process requiring continuous teacher facilitation rather than a consequence of technological exposure alone.

This interpretation reinforces recent discussions suggesting that the educational value of AI depends on learners' ability to interact critically with intelligent technologies. Casal-Otero et al. (2023) argued that students require not only digital competence but also critical thinking and self-regulated learning skills to benefit from AI-supported instruction. Similarly, Lee & Kwon (2024) emphasized that AI should foster active learning, creativity, and responsible decision-making instead of encouraging passive dependence on automated systems. The present findings extend these arguments by demonstrating that elementary students' readiness develops through structured teacher guidance that gradually cultivates responsible learning behaviors alongside technological competence.

An important finding emerging from this study concerns the role of teachers in mediating students' interaction with AI. Rather than positioning AI as an autonomous source of knowledge, teachers intentionally designed learning activities that required students to evaluate information, discuss alternative ideas, and verify AI-generated responses before incorporating them into classroom tasks. Such pedagogical mediation reflects the growing international concern regarding the responsible educational use of generative AI. Kasneci et al. (2023) highlighted that although AI offers significant opportunities to enhance learning, students must be supported in developing critical judgment to avoid overreliance on automatically generated content. Likewise, Kohnke et al. (2023) argued that responsible AI integration requires teachers to actively scaffold students' interactions with AI so that technology strengthens rather than replaces meaningful learning processes.

The findings further reveal that differences in students' access to technology outside school required adaptive instructional decisions to maintain equitable learning opportunities. Teachers modified learning activities according to students' technological conditions and collaborated with parents whenever additional support was necessary. This adaptive practice demonstrates that responsible AI implementation also involves consideration of educational equity. Research by Holmes et al. (2021) suggested that equitable AI implementation requires schools to recognize contextual differences among learners rather than assuming equal technological access. Likewise, Crompton & Burke (2023) emphasized that inclusive AI integration depends on teachers' ability to adapt instructional strategies to learners' diverse needs and learning environments.

Another noteworthy contribution of the present findings is the recognition that responsible AI use constitutes a shared educational responsibility involving teachers, students, and parents. Students learned appropriate technology use through continuous classroom guidance, while parents supported the continuity of AI-assisted learning beyond school hours. Consequently, responsible AI implementation emerged as a collaborative educational practice rather than merely an individual student competency. This broader perspective extends previous AI studies that primarily emphasize students' digital skills by highlighting the importance of collaborative educational ecosystems in cultivating responsible AI use during the early stages of schooling.

Collectively, these findings contribute to the emerging literature by demonstrating that student readiness for AI-based learning should be conceptualized as a pedagogically mediated process that integrates digital competence, critical thinking, ethical awareness, and

collaborative support. Sustainable AI implementation in elementary schools therefore depends not only on students' technological capabilities but also on teachers' instructional guidance and parental involvement, positioning responsible AI use as a collective educational responsibility rather than an individual learner attribute.

3.2.4 Institutional Policies for Sustainable AI-Based Learnin

The findings demonstrate that institutional policies played a pivotal role in sustaining AI-based learning beyond individual classroom initiatives. Rather than relying solely on teachers' personal motivation to adopt AI, SD Negeri Kebonsari 3 Malang embedded AI integration within its broader school development agenda through leadership commitment, continuous professional learning, resource allocation, and collaborative governance. This institutional approach transformed AI implementation from an isolated instructional innovation into a coordinated organizational strategy that could be sustained over time.

This finding supports the growing recognition that educational innovation requires institutional commitment rather than isolated technological interventions. Spillane (2006) argued that instructional improvement is more sustainable when leadership functions are distributed across organizational members rather than concentrated solely in formal leadership positions. Similarly, Fullan (2016) emphasized that sustainable educational change emerges from coherent organizational policies that align professional development, leadership, and instructional practices toward shared educational goals. The present findings reinforce these perspectives by demonstrating that AI implementation became sustainable because school leadership continuously integrated technological innovation into routine organizational development rather than treating it as a temporary project.

An important aspect emerging from the findings is the principal's role in creating organizational conditions that encouraged teachers to experiment with AI while maintaining pedagogical responsibility. Rather than mandating the use of specific technologies, school leaders provided strategic direction, facilitated professional learning opportunities, and supported teachers in adapting instructional innovations according to classroom realities. This leadership approach reflects instructional leadership that prioritizes capacity building over administrative control. Hallinger (2011) suggested that effective instructional leaders influence educational improvement primarily by fostering teachers' professional growth and creating supportive learning environments. Likewise, Leithwood et al. (2020) argued that leadership contributes to school improvement indirectly by strengthening teachers' instructional capacity and organizational collaboration.

The findings further indicate that institutional policies promoted organizational coherence by integrating infrastructure development, teacher professional learning, classroom implementation, and continuous evaluation into a unified management framework. Such coherence enabled the school to respond adaptively to emerging implementation challenges while maintaining consistency with its educational vision. This observation corresponds with Bryk et al. (2015), who argued that sustainable school improvement depends on coherent organizational systems in which leadership, professional capacity, instructional guidance, and collaborative culture operate as interconnected components rather than separate initiatives. The present study demonstrates that institutional policies functioned precisely as the mechanism connecting these organizational elements to support AI-based learning.

Another noteworthy contribution concerns stakeholder collaboration as an institutional strategy for sustaining AI implementation. The findings reveal that school leaders actively encouraged communication among teachers, students, and parents to address implementation challenges collectively. Rather than perceiving AI integration as the responsibility of teachers alone, the school developed shared institutional responsibility through continuous dialogue and collaborative problem-solving. This organizational practice extends previous discussions of educational AI by illustrating that institutional sustainability depends not only on internal school leadership but also on productive partnerships with families and other educational stakeholders.

Collectively, these findings contribute to the literature by demonstrating that institutional policies should be understood as adaptive governance mechanisms that sustain AI-based learning through organizational coherence, distributed leadership, professional capacity building, and stakeholder collaboration. The study therefore extends previous AI implementation research by positioning institutional policy not merely as administrative regulation but as a strategic organizational process that enables schools to continuously respond to technological and pedagogical change while maintaining the long-term sustainability of educational innovation.

3.2.5 Adaptive School Management Strategies

The findings collectively demonstrate that the sustainability of AI-based learning in elementary schools cannot be explained by isolated factors such as infrastructure availability, teacher competence, student readiness, or institutional policies alone. Instead, these elements operate as interconnected organizational components that continuously influence one another throughout the implementation process. This study reveals that AI integration should therefore be understood as an adaptive organizational process in which schools continuously adjust management practices in response to evolving technological, pedagogical, and contextual challenges. Such a perspective shifts the discussion from technology adoption toward organizational adaptability as the primary driver of sustainable educational innovation.

This interpretation complements contemporary perspectives on educational change, which emphasize that innovation becomes sustainable only when organizations possess the capacity to learn and adapt continuously. Senge (2006) argued that learning organizations continuously refine their practices through collective reflection, shared learning, and systems thinking rather than relying on static organizational procedures. Similarly, Argyris & Schön (1996) proposed that organizational learning enables institutions to modify existing routines in response to new challenges while simultaneously improving future decision-making. The present findings support these perspectives by illustrating how SD Negeri Kebonsari 3 Malang continuously adapted its management practices through collaborative reflection, professional learning, leadership support, and ongoing evaluation during AI implementation.

An important contribution emerging from this study concerns the dynamic interaction among management functions. Rather than functioning as separate administrative activities, planning, organizing, implementation, monitoring, and institutional policy formed an integrated adaptive management cycle. Information generated during implementation and evaluation informed subsequent planning decisions, while collaborative professional learning enabled teachers to continuously improve instructional practices according to students'

learning needs and technological developments. This iterative process reflects the characteristics of adaptive management described by Heifetz et al. (2009), who argued that organizations confronting complex change should prioritize continuous learning, collaborative problem-solving, and flexible decision-making over predetermined procedural solutions.

The findings further suggest that adaptive school management is particularly relevant for AI implementation because educational technologies evolve more rapidly than formal institutional regulations. Consequently, schools cannot rely solely on fixed policies or standardized implementation models. Instead, sustainable AI integration requires organizational flexibility that allows leadership, teachers, and stakeholders to continuously reinterpret emerging challenges and redesign instructional practices accordingly. This observation extends previous studies of AI implementation, which have primarily emphasized technological readiness or teacher competence, by demonstrating that long-term sustainability depends on the school's capacity to maintain organizational responsiveness under changing educational conditions.

Another important implication concerns the transformation of implementation challenges into opportunities for organizational improvement. Throughout the Kedai Kosaga Program, infrastructural limitations, varying teacher competence, differences in students' readiness, and institutional constraints were not perceived as barriers preventing AI integration. Rather, these challenges became catalysts for continuous organizational learning that encouraged collaborative innovation, professional reflection, and strategic adaptation. Such findings broaden current discussions of educational AI by illustrating that organizational resilience emerges not from the absence of implementation challenges but from schools' collective capacity to respond constructively to those challenges through adaptive management practices.

Collectively, this study advances the literature by proposing adaptive school management as an integrative perspective for understanding sustainable AI implementation in elementary education. Unlike previous studies that predominantly examine infrastructure, teacher competence, leadership, or technology adoption as separate determinants, the present study demonstrates that sustainable AI-based learning emerges from the continuous interaction among organizational learning, collaborative professional development, adaptive leadership, institutional support, and context-responsive decision-making. Accordingly, adaptive school management provides a broader conceptual framework for explaining how elementary schools transform implementation challenges into sustainable educational innovation in rapidly evolving technological environments.

4. Conclusion

This study demonstrates that the successful management of Artificial Intelligence (AI)-based learning in elementary schools is determined not merely by the availability of digital technology but by the school's capacity to manage implementation challenges through adaptive organizational practices. The first finding reveals that infrastructure limitations were addressed through strategic resource optimization, collaborative technology sharing, and gradual improvement of digital facilities. Rather than preventing AI integration, infrastructural constraints encouraged schools to develop flexible support mechanisms that enabled teachers to continue implementing AI-assisted learning within existing institutional capacities.

The second finding indicates that teacher readiness was strengthened through continuous professional learning conducted within the Kedai Kosaga Program. Collaborative learning communities provided opportunities for teachers to exchange experiences, develop pedagogical competence, and continuously adapt AI utilization according to classroom needs. Simultaneously, students' readiness emerged not only from their ability to use digital technologies but also from sustained pedagogical guidance that fostered responsible AI use, critical thinking, and active learning. These findings demonstrate that sustainable AI implementation depends on the continuous development of both teacher professionalism and students' responsible engagement with intelligent technologies.

The third finding highlights the importance of institutional policies and school leadership in sustaining AI-based learning. Leadership commitment, professional learning support, infrastructure development, and stakeholder collaboration functioned as integrated organizational mechanisms that maintained the continuity of AI implementation. Rather than positioning AI adoption as an individual teacher initiative, institutional policies embedded AI within the school's broader educational development strategy, ensuring that technological innovation remained aligned with pedagogical objectives and long-term school improvement.

The fourth finding demonstrates that implementation challenges should not be perceived as barriers to educational innovation but as opportunities for organizational learning. Infrastructure constraints, varying teacher competence, students' diverse readiness, and institutional limitations collectively stimulated schools to continuously refine management practices through reflection, collaboration, and adaptive decision-making. This adaptive process enabled the school to respond effectively to changing technological and educational demands while maintaining the sustainability of AI-based learning.

Overall, this study contributes to the growing body of literature by proposing adaptive school management as a comprehensive framework for understanding the sustainable implementation of AI in elementary education. Unlike previous studies that primarily emphasize technology adoption or teacher competence as isolated determinants, this study demonstrates that sustainable AI-based learning emerges through the continuous interaction among adaptive leadership, collaborative professional learning, responsible student engagement, institutional support, and organizational learning. Accordingly, the findings extend current discussions of educational AI by positioning adaptive school management as a strategic organizational approach capable of transforming implementation challenges into continuous educational innovation within elementary school contexts.

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