



Regional Data Centers as Catalysts for Sustainable Digital Pedagogy in Islamic Education: A Systematic Literature Review of Innovative Science Learning Models in Elementary Schools

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ABSTRACT

The rapid advancement of digital technologies has transformed educational systems worldwide, creating opportunities for innovative teaching, learning, and knowledge management. Nevertheless, disparities in digital access, infrastructure availability, and technological readiness remain significant challenges, particularly in Islamic elementary education. These challenges affect the quality of science learning and limit students' ability to develop scientific literacy, digital competence, critical thinking, and other twenty-first-century skills. Therefore, this study aims to examine the role of regional data centers in supporting sustainable digital pedagogy and enhancing digital literacy through innovative science learning models in Islamic elementary schools. This study employed a Systematic Literature Review (SLR) to synthesize evidence from national and international scholarly publications on digital pedagogy, regional data infrastructure, Islamic education, and science learning innovation. The review included peer-reviewed journal articles, conference proceedings, policy papers, and academic reports published between 2015 and 2025. The collected literature was analyzed using thematic coding and content analysis to identify major trends, opportunities, and challenges associated with implementing regional data centers in educational settings. The findings indicate that regional data centers significantly improve digital accessibility, strengthen data security, support cloud-based educational services, and enhance the efficiency of learning management systems. Furthermore, innovative pedagogical approaches such as blended learning, inquiry-based learning, project-based learning, and artificial intelligence-assisted learning were found to improve students' scientific understanding, digital literacy, problem-solving skills, and collaborative competencies. The study also reveals that regional digital infrastructure can reduce educational disparities between urban and rural schools by providing more equitable access to digital resources and learning platforms. In conclusion, regional data centers serve as strategic enablers of sustainable digital pedagogy and digital transformation in Islamic elementary science education. Strengthening collaboration among educational institutions, policymakers, technology providers, and local governments, along with sustained investment in digital infrastructure and teacher professional development, is essential for building inclusive, resilient, and future-oriented educational ecosystems.

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■ INTRODUCTION

The rapid advancement of digital technology has significantly transformed global educational systems, including learning management, pedagogical approaches, and knowledge dissemination processes. The integration of digital technology into education

has encouraged institutions to adopt innovative learning models that support flexibility, collaboration, and student-centered learning environments. In the context of Islamic education, digital transformation has become increasingly important due to the growing demand for inclusive, accessible, and

sustainable educational services in the digital era. However, despite technological progress, many Islamic educational institutions, particularly elementary schools in developing regions, still face serious challenges related to digital inequality, infrastructure limitations, and inadequate technological support systems. Unequal access to digital infrastructure continues to hinder educational equity, especially in rural and underdeveloped areas (Lo, 2025). Similarly, research by Georgopoulou & Troussas (2025) emphasized that the digital divide is not merely about internet access but also concerns digital literacy, technological competence, and institutional readiness.

Science learning in elementary schools requires interactive, contextual, and technology-supported pedagogical approaches to improve students' critical thinking and problem-solving skills. Innovative learning models such as blended learning, inquiry-based learning, project-based learning, and AI-assisted learning have demonstrated positive impacts on students' scientific understanding and digital competence (Avila-Garzon & Bacca-Acosta, 2025). Nevertheless, the successful implementation of these pedagogical innovations strongly depends on the availability of reliable digital infrastructure and sustainable educational technology ecosystems. In many Islamic elementary schools, limited server capacity, unstable internet connectivity, and inadequate digital resource management have reduced the effectiveness of digital learning initiatives (T. C. Liu, 2022). These limitations underscore the urgent need for strategic technological infrastructure to support long-term educational sustainability.

Regional data centers have emerged as an important technological solution for strengthening digital ecosystems in educational institutions. Data centers serve as centralized infrastructure that efficiently and securely manages, stores, and distributes educational data. Regional data centers improve cloud-based educational services, increase digital accessibility, and enhance the reliability of learning management systems (Avila-Garzon & Bacca-Acosta, 2025). In addition, decentralized regional data infrastructures can minimize latency, optimize network performance, and reduce operational costs for educational institutions located in remote areas. The role of regional data centers has become increasingly relevant in supporting digital pedagogy because modern educational practices depend heavily on cloud computing, online learning platforms, artificial intelligence, and big data analytics (Jones et al., 2025).

Previous studies have primarily focused on digital pedagogy, e-learning implementation, and digital literacy in general educational contexts. Digital learning environments have been shown to improve student engagement and collaborative learning experiences (Moleka, 2025). Artificial intelligence and other digital technologies continue to transform educational innovation and instructional practices (Chun et al., 2025). (Chun et al., 2025). Despite these advancements, significant challenges remain in many Islamic elementary schools, particularly regarding unequal digital access, limited technological infrastructure, unstable internet connectivity, fragmented educational data management, and inadequate digital learning support systems.

Evidence from numerous educational contexts shows that schools in rural and geographically isolated areas continue to face significant challenges in accessing digital learning resources and technology-based educational services. Limited internet connectivity, inadequate technological infrastructure, and restricted access to cloud-supported learning platforms often constrain the implementation of effective digital learning practices. As a result, students in these areas frequently have fewer opportunities to benefit from innovative learning approaches compared to their counterparts in more developed regions.

These conditions not only affect the quality of teaching and learning but also influence students' digital literacy and their ability to participate in technology-enhanced science learning activities. In many cases, schools still operate with fragmented, independent digital systems that are not well integrated with broader educational networks. Such fragmentation reduces data management efficiency, limits collaboration among educational stakeholders, and creates barriers to the long-term sustainability of digital learning initiatives.

Therefore, strengthening digital infrastructure and developing more integrated educational ecosystems have become increasingly important. A well-connected digital environment can support more equitable access to learning resources, improve the management of educational information, and create greater opportunities for schools to implement innovative and sustainable pedagogical practices.

Although numerous studies have inspected digital literacy, educational technology adoption, and innovative pedagogical models, limited attention has been given to the role of regional digital

infrastructure, particularly regional data centers, as a foundational mechanism for supporting sustainable digital pedagogy. The absence of an integrated perspective that links regional data infrastructure to science education in Islamic elementary schools creates both a practical and a theoretical gap. From a practical standpoint, insufficient understanding of how regional data centers can improve accessibility, reliability, and equity in digital learning may constrain efforts to reduce educational disparities. From a theoretical standpoint, the relationship between regional technological infrastructure, sustainable digital pedagogy, and innovative science learning remains underexplored in the context of Islamic elementary education. Therefore, a comprehensive review is necessary to synthesize existing knowledge and establish a clearer conceptual framework that connects regional data centers, digital sustainability, educational equity, and science learning innovation in Islamic elementary schools.

The novelty of this study lies in its focus on the strategic role of regional data centers as catalysts for sustainable digital pedagogy within Islamic elementary education. Unlike previous studies that mainly emphasized learning applications and instructional strategies, this research integrates perspectives of educational technology infrastructure, digital literacy enhancement, and sustainability-oriented pedagogy. Furthermore, this study examines innovative science learning models in Islamic elementary schools through a Systematic Literature Review (SLR), thereby providing a broader analytical perspective on the relationship between regional digital infrastructure and educational transformation (Chairunnisa & Muawanah, 2024).

This research is important because digital inequality continues to create educational disparities between urban and rural Islamic schools. Limited access to technology not only affects the quality of learning but also limits students' opportunities to develop the digital competencies required in the twenty-first century (Verma, 2024). The integration of regional data centers with innovative digital pedagogy is expected to strengthen educational resilience, improve access to learning, and support sustainable science education practices in Islamic institutions (Rahman, 2025). In addition, strengthening digital literacy through sustainable infrastructure aligns with global educational transformation agendas and Sustainable Development Goal 4 concerning equitable and quality education. The analysis is further informed by a constructivist epistemological perspective that emphasizes

the social and contextual dimensions of knowledge construction in digitally mediated learning environments.

Therefore, this study aims to critically examine the role of regional data centers in developing digital literacy and promoting sustainable digital pedagogy through innovative science learning models in Islamic elementary schools (Dvoutely, 2025). This literature review is guided by three research questions: (RQ1) How do regional data centers facilitate digital literacy development and innovative science learning practices in Islamic elementary education? (RQ2) In what ways do regional data infrastructures contribute to educational accessibility, learning effectiveness, and sustainable pedagogical transformation? (RQ3) What key challenges, opportunities, and future directions emerge from the integration of regional data center-maintained digital learning ecosystems in Islamic elementary schools? By addressing these questions, the study seeks to provide a comprehensive synthesis of existing knowledge and offer theoretical insights and practical recommendations for policymakers, educational institutions, and technology stakeholders committed to advancing sustainable digital education in Islamic elementary schools.

■ METHOD

Research Design

This study employed a Systematic Literature Review (SLR) design to examine the role of regional data centers in supporting sustainable digital pedagogy, digital literacy, and innovative science learning in Islamic elementary education. The review was reported in accordance with the PRISMA 2020 statement proposed by Page et al. (2021), which provides a structured reporting framework for systematic reviews, including identification, screening, eligibility assessment, inclusion, and transparent documentation of the review process. The use of PRISMA 2020 was intended to improve the transparency, reproducibility, and methodological accountability of this review. Accordingly, the article selection process was organized into four stages: identification of records from academic databases, removal of duplicates, screening of titles and abstracts, and full-text eligibility assessment. The final included studies were then extracted and synthesized using a structured review matrix.

Data Extraction

Data were extracted using a structured matrix consisting of author(s), year, methodology, educational context, thematic

category, key findings, and contribution to the present study. The extracted data were analyzed through qualitative content analysis and thematic synthesis. The coding process involved data reduction, open coding, axial coding, and synthesis of major themes. NVivo 14 was used to organize and retrieve coded segments, document coding decisions, and support auditability across the selected studies. A total of 78 initial codes were generated and then consolidated into broader thematic categories.

Data sources and research sample

The data sources included scientific articles, conference proceedings, book chapters, policy reports, and international publications indexed in reputable academic databases, including Scopus, Web of Science, Google Scholar, ERIC, and ScienceDirect. The publications analyzed in this study were published between 2015 and 2025 to ensure the relevance and recency of the reviewed literature.

The exclusion criteria comprised: (1) publications unrelated to educational sustainability, digital pedagogy, or educational technology infrastructure; (2) studies lacking relevance to elementary or Islamic educational contexts; (3) opinion papers, editorials, book reviews, and non-academic publications; (4) duplicate records; and (5) studies with insufficient methodological information.

Data collection procedure

The data collection procedure was conducted systematically through several stages. First, the researchers identified relevant keywords and search strings related to the research objectives. Second, article searches were conducted in electronic databases to obtain relevant academic publications. Third, the identified articles were screened using titles, abstracts, and keywords to assess their relevance to the study topic.

The next stage involved full-text reading and eligibility assessment to ensure that the selected studies satisfied all inclusion criteria. Following the eligibility review, data were systematically extracted using a structured data synthesis matrix designed to facilitate comparison and verification across studies. The matrix included key information such as the author(s) and year of publication, research objectives, methodological approach, educational context, technological infrastructure, digital pedagogy models, and principal findings. The use of this synthesis matrix enabled transparent, systematic organization of evidence, allowing patterns, similarities, and differences among studies to

be identified and analyzed. To enhance the rigor and reproducibility of the review, a summary of the extracted studies (see Appendix A) provides readers with a clear overview of the evidence base underpinning the analysis and conclusion. To ensure research validity and reproducibility, the review process followed transparent documentation procedures, including database recording, article selection flow, and categorization of research themes. This process minimized potential bias during literature selection and interpretation.

Research instruments

The primary research instrument in this study was a literature review matrix developed by the researchers to systematically classify and analyze relevant studies. The matrix included categories such as author identity, publication year, research objectives, methodology, educational context, digital infrastructure implementation, innovative learning models, and research findings.

In addition, document analysis guidelines were used to evaluate the relevance, credibility, and contribution of each publication to the research objectives. The instruments enabled the researchers to identify recurring themes, conceptual relationships, and gaps within the existing literature concerning regional data centers and sustainable digital pedagogy in Islamic education.

Data analysis technique

The selected studies were analyzed using a qualitative content analysis approach combined with thematic synthesis techniques. The analytical process consisted of four sequential stages: data reduction, open coding, axial coding, and thematic synthesis. During the data reduction stage, relevant information was extracted from each of the 52 selected articles using a structured data extraction matrix that included research objectives, methodology, educational context, technological infrastructure, pedagogical approaches, and principal findings.

Subsequently, an open coding procedure was conducted to identify recurring concepts, keywords, and patterns across the studies. Initial codes included terms such as digital literacy, artificial intelligence in education, teacher digital competence, educational technology infrastructure, learning management systems, cloud computing, data-driven learning, science learning innovation, and Islamic educational transformation. A total of 78 initial codes were generated from the extracted data. The next stage involved axial

coding within NVivo, in which conceptually related codes were grouped into broader analytical categories based on similarities, relationships, and thematic connections, such as digital literacy, artificial intelligence in education, teacher digital competence, educational technology infrastructure, learning management systems, cloud computing, data-driven learning, science learning innovation, and Islamic educational transformation. A total of 78 initial codes were generated from the extracted data. The coding and categorization process was conducted manually, with assistance from NVivo 15 (QSR International) qualitative data analysis software, which was used to organize, manage, and systematically retrieve coded segments across the 52 selected studies. NVivo facilitated the structured documentation of open codes, supported the grouping of related codes during axial coding, and enabled transparent audit trails throughout the analytical process.

The next stage involved axial coding, in which conceptually related codes were grouped into broader analytical categories based on similarities, relationships, and thematic

connections. Through this process, the initial codes were consolidated into several higher-order categories representing common trends in the literature. Finally, thematic synthesis was conducted to integrate these categories into five overarching themes that addressed the research questions and reflected the dominant patterns identified across the reviewed studies.

The analysis resulted in five major themes: (1) Digital Literacy and 21st-Century Competencies, (2) Educational Technology Infrastructure and Regional Data Ecosystems, (3) Sustainable Digital Pedagogy and Innovative Learning Models, (4) Artificial Intelligence and Data-Driven Educational Transformation, and (5) Digital Transformation in Islamic Elementary Education. These themes served as the analytical framework for interpreting the findings and discussing the contribution of regional data centers to sustainable digital learning ecosystems in Islamic elementary schools.

The collected data were systematically organized into several thematic categories to explore common trends, distinctive characteristics, and recurring patterns across

Table 1. Coding and Theme Development Process

Initial Concepts (Open Codes)	Emerging Categories	Major Themes
Digital literacy, information literacy, media literacy, and digital skills	Development of Digital Competencies	Strengthening Digital Literacy and Twenty-First Century Competencies
Cloud-based systems, regional data centers, learning management systems, digital learning platforms, and educational databases	Digital Infrastructure Development	Educational Technology Infrastructure and Regional Digital Ecosystems
Digital pedagogy, problem-based learning, inquiry-based learning, collaborative learning, and blended learning approaches	Innovative Pedagogical Practices	Sustainable Digital Pedagogy and Innovative Learning Approaches
Artificial intelligence, generative AI, learning analytics, adaptive learning systems, and educational data mining	AI-Supported Learning Transformation	Artificial Intelligence and Data-Driven Educational Transformation
Islamic pedagogy, madrasah education, Islamic elementary schools, ethical digital learning, and Islamic digital literacy	Transformation of Islamic Education	Digital Transformation in Islamic Elementary Education

the selected studies. This process enabled the researchers to identify key areas of discussion and establish meaningful connections among the findings reported in different contexts. Subsequently, a thematic analysis was conducted to deepen understanding of how regional data centers can support the advancement of digital pedagogy while addressing challenges related to unequal access to digital resources in Islamic elementary schools.

The final stage involved integrating and interpreting the findings through a narrative synthesis. This approach facilitated a comprehensive understanding of the strategic contribution of regional data centers to fostering sustainable digital learning environments. Rather than merely summarizing previous studies, the synthesis sought to reveal broader relationships among infrastructure development, educational innovation, and the changing needs of contemporary learning systems.

Throughout the analysis, particular attention was given to critical interpretation and comparative examination across studies. By examining similarities and differences in findings, the study was able to construct a more holistic perspective on the role of technological infrastructure in education. This process also provided valuable insights into how digital infrastructure can strengthen digital literacy, support innovative science learning practices, and contribute to the long-term sustainability of educational transformation within Islamic elementary education.

■ RESULTS AND DISCUSSION

The findings of this systematic literature review were derived from the analysis of 52 selected studies examining regional data centers, digital literacy, digital pedagogy, educational technology infrastructure, and innovative science learning in Islamic elementary education. The results are organized according to the three research questions guiding this review.

RQ1: How Do Regional Data Centers Support Digital Literacy Development and Innovative Science Learning in Islamic Elementary Education?

The reviewed studies indicate that regional data centers serve as a critical technological foundation for the storage, management, and distribution of educational resources. By providing reliable access to digital content, cloud-based applications, learning management systems, and educational databases, regional data infrastructures

facilitate students' engagement with digital learning environments. Several studies reported that improved access to digital platforms enhances students' digital literacy skills, including information retrieval, digital communication, critical evaluation of online resources, and technology-assisted problem-solving.

Furthermore, regional data centers support innovative science learning by enabling the integration of interactive simulations, virtual laboratories, multimedia learning resources, and data-driven instructional tools. These technologies promote inquiry-based, project-based, and collaborative learning approaches that strengthen scientific reasoning, creativity, and critical thinking among elementary school students. Within Islamic elementary education, such innovations contribute to more engaging and contextualized science learning experiences while maintaining alignment with Islamic educational values.

RQ2: How Do Regional Data Infrastructures Contribute to Educational Accessibility, Learning Effectiveness, and Pedagogical Sustainability?

The analysis reveals that regional data infrastructures significantly improve educational accessibility by reducing disparities in access to digital learning resources between urban and rural educational institutions. Cloud-based services and decentralized data management systems allow schools with limited local technological capacity to access educational materials and digital learning platforms more efficiently.

In terms of learning effectiveness, the reviewed literature consistently demonstrates that technology-supported pedagogy improves student engagement, learning achievement, and instructional efficiency. Regional data centers contribute to these outcomes by ensuring stable access to educational content, facilitating real-time communication, and supporting data-informed instructional decision-making. Additionally, the literature highlights the role of digital infrastructures in promoting pedagogical sustainability through scalable, cost-efficient, and environmentally sustainable educational systems. Long-term sustainability is achieved through continuous access to digital resources, institutional data management, and support for professional development initiatives that enhance teachers' digital competencies.

RQ3: What Challenges and Opportunities Are Associated with the Implementation of Regional Data Center-Supported Digital Learning Ecosystems in Islamic Elementary Schools?

Despite their potential benefits, several challenges remain. The most frequently reported barriers include inadequate technological infrastructure, unequal internet connectivity, limited teacher digital competence, financial constraints, and resistance to technological change. These challenges are particularly evident in rural and geographically isolated regions where access to digital resources remains uneven.

At the same time, the literature identifies substantial opportunities for strengthening digital learning ecosystems in Islamic elementary schools. Emerging technologies such as artificial intelligence, learning analytics, cloud computing, and adaptive learning systems offer new possibilities for personalized learning, efficient educational management, and enhanced instructional quality. Furthermore, integrating Islamic values into digital literacy initiatives creates opportunities to develop ethically grounded digital learning environments that support both technological advancement and character development. The findings suggest that strategic investments in regional data infrastructure, teacher training, and policy support are essential for maximizing the educational benefits of sustainable digital transformation.

The findings demonstrate that regional data centers function not merely as technological facilities but as strategic enablers of sustainable digital pedagogy and educational transformation. Consistent with previous studies on digital learning ecosystems, the availability of robust digital infrastructure supports educational accessibility, strengthens digital literacy, and facilitates innovative science learning practices. The review also

highlights the importance of teacher readiness and institutional capacity in translating technological resources into meaningful educational outcomes.

Moreover, the findings underscore the relevance of integrating digital innovation with Islamic educational principles. Rather than replacing traditional values, digital technologies can serve as complementary tools to enhance the quality of learning, foster critical thinking, and prepare students for participation in a digitally connected society. Therefore, sustainable digital transformation in Islamic elementary education requires a holistic approach that combines infrastructure development, pedagogical innovation, digital literacy enhancement, and value-based educational practices.

Distribution of Reviewed Studies

To strengthen the credibility and reproducibility of the review, the study documented the search strategy, eligibility criteria, article selection process, and data extraction procedure. Duplicate records were removed before full-text screening. Each selected article was evaluated based on relevance, methodological clarity, and contribution to the research questions. The article selection process should be presented in Figure 1 as a formal flowchart, while the complete data extraction matrix should be provided in the supplementary material. The analysis of the 52 selected studies revealed a diverse yet concentrated distribution of research themes related to digital transformation in education. As illustrated in Figure 1, the literature is predominantly focused on Digital Pedagogy and Learning Innovation (28.8%), followed by Artificial

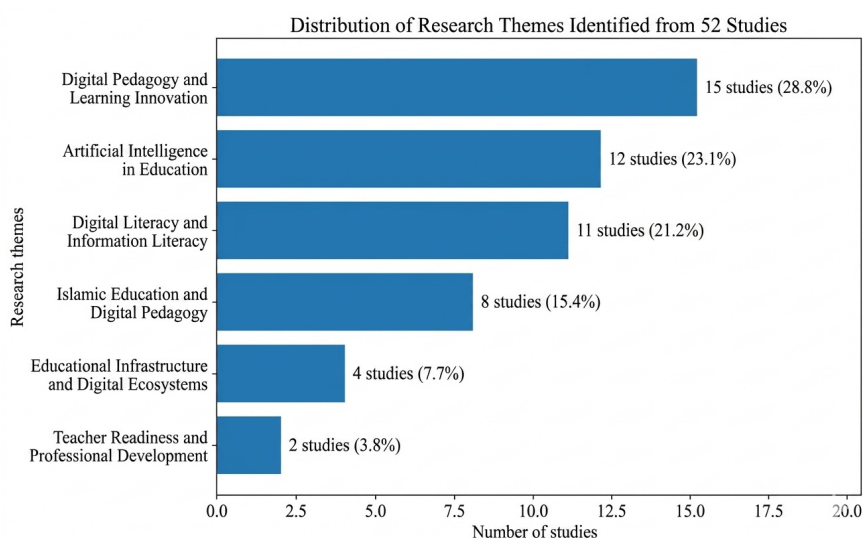


Figure 1. Distribution of Research Themes Identified from 52 Studies

Intelligence in Education (23.1%), Digital Literacy and Information Literacy (21.2%), Islamic Education and Islamic Digital Pedagogy (15.4%), Educational Infrastructure and Digital Ecosystems (7.7%), and Teacher Readiness and Professional Development (3.8%).

The distribution indicates that contemporary scholarship is primarily concerned with pedagogical innovation and the integration of emerging technologies into teaching and learning processes. In contrast, studies explicitly examining educational infrastructure, regional data ecosystems, and Islamic elementary education remain comparatively limited. This imbalance suggests that while the pedagogical dimensions of digital transformation have received substantial attention, the infrastructural foundations supporting sustainable digital learning ecosystems warrant further investigation.

Furthermore, the reviewed publications demonstrate increasing scholarly interest in digital pedagogy and educational technology over recent years, particularly following the rapid expansion of technology-supported learning environments. The concentration of publications in 2025–2026 reflects growing academic attention to the challenges and opportunities associated with sustainable digital transformation in education.

A total of 8 studies (15.4%) focused on Islamic Education and Digital Pedagogy. This theme demonstrates growing scholarly attention to integrating technological innovation with Islamic educational values and principles. Meanwhile, Educational Infrastructure and Digital Ecosystems appeared in 4 studies (7.7%). Teacher Readiness and Professional Development was the smallest category, with only 2 studies (3.8%). Overall, the thematic distribution shows that existing research primarily concentrates on pedagogical innovation, artificial intelligence, and digital literacy, while fewer studies examine infrastructure readiness and teacher capacity development. This imbalance indicates a research gap that should be addressed in future studies on sustainable digital transformation in education.

Distribution of Reviewed Studies according to the Main Research Themes Identified during the Analysis

Table 2 presents the distribution of the 52 selected studies across the primary thematic categories identified through coding and thematic synthesis. The table provides an overview of the dominant research areas represented in the reviewed literature and

Table 2. Distribution of reviewed studies based on research themes

No.	Research Theme	Number of Studies
1	Digital Pedagogy in Islamic Education	15
2	Regional Data Centers and Cloud Infrastructure	10
3	Digital Literacy Development	9
4	Innovative Science Learning Models	11
5	Educational Sustainability and Accessibility	8
Total		52

serves as the basis for subsequent thematic analysis.

The data in Table 2 indicate that digital pedagogy in Islamic education became the most frequently discussed topic among the reviewed studies. However, research specifically examining the relationship between regional data centers and sustainable digital pedagogy remained limited. This finding confirms a research gap regarding the integration of technological infrastructure in Islamic elementary education systems.

The growing emphasis on digital pedagogy reflects a broader transformation in educational practices toward technology-enhanced learning environments. The reviewed studies consistently indicate that the successful implementation of digital pedagogy depends not only on instructional innovation but also on the availability of reliable technological infrastructure, teacher digital competence, and institutional readiness (Ma & Ismail, 2025; Georgopoulou & Troussas, 2025; Ncube & Tawanda, 2025). Furthermore, several studies highlight that sustainable digital learning environments require continuous access to digital resources, cloud-based platforms, and educational technology systems that can support long-term teaching and learning activities (Malik et al., 2025; Russo, 2025; Webb & Galamba, 2026). In this context, regional data centers can be conceptually understood as a supporting infrastructure that may facilitate the continuity, accessibility, and scalability of digital learning ecosystems, thereby contributing to institutional preparedness for ongoing digital transformation.

The Role of Regional Data Centers in Digital Pedagogy

The analysis suggests that regional data centers may support educational accessibility, data management efficiency, and the sustainability of digital learning ecosystems by

improving the availability and reliability of digital services. Several reviewed studies reported that decentralized digital infrastructures can reduce network latency, improve system responsiveness, and facilitate more stable access to cloud-based educational platforms, particularly in geographically dispersed or underserved areas (Ma & Ismail, 2025; Russo, 2025).

These findings can be interpreted through the Technology–Organization–Environment (TOE) Framework, which emphasizes that the successful adoption and utilization of digital technologies are influenced not only by technological capabilities but also by organizational readiness and environmental conditions. From this perspective, regional data centers function as an enabling technological infrastructure that may reduce environmental barriers to digital learning by improving connectivity, system reliability, and access to educational resources. Consequently, schools in rural and remote regions may have greater opportunities to participate in digitally supported learning environments when equipped with adequate infrastructure.

Furthermore, the reviewed literature indicates that the educational benefits associated with regional data infrastructures extend beyond technical performance. Improved infrastructure can facilitate access to learning management systems, digital repositories, virtual laboratories, and online communication platforms, thereby creating conditions that support broader educational participation and continuity. However, the literature also emphasizes that the effectiveness of such infrastructures depends on complementary factors, including teacher digital competence, institutional support, and the availability of relevant digital learning resources.

Table 3 illustrates that regional data centers contribute to digital learning ecosystems through three interconnected dimensions: accessibility, efficiency, and equity. Accessibility refers to improved availability of digital learning services and resources; efficiency relates to enhanced system performance and educational data management; while equity reflects the potential reduction of digital divides between urban and rural schools. Together, these dimensions create enabling conditions for more sustainable and inclusive digital education environments.

The findings demonstrate that regional data centers serve not only as storage facilities but also as strategic educational infrastructure supporting sustainable digital ecosystems. Decentralizing educational data systems

Table 3. Research themes and number of studies

No.	Research Theme	Number of Studies	Percentage
1	Digital Pedagogy and Learning Innovation	15	28.8%
2	Artificial Intelligence in Education	12	23.1%
3	Digital Literacy and Information Literacy	11	21.2%
4	Islamic Education and Digital Pedagogy	8	15.4%
5	Educational Infrastructure and Digital Ecosystems	4	7.7%
6	Teacher Readiness and Professional Development	2	3.8%
Total		52	100%

improves service reliability and reduces operational barriers in underserved regions (Turvey & Pachler, 2026). The present study supports this argument by demonstrating that regional data centers enhance institutional flexibility and strengthen the implementation of digital pedagogy in Islamic schools.

Furthermore, the reviewed studies indicated that schools with better technological infrastructure were better able to implement adaptive and student-centered learning approaches. Reliable cloud services enabled teachers to utilize multimedia resources, virtual laboratories, digital assessment systems, and collaborative online learning platforms more effectively. This finding aligns with previous research emphasizing that educational technology infrastructure significantly influences the quality of digital learning experiences (Ma & Ismail, 2025).

Innovative Science Learning Models in Islamic Elementary Education

Another major finding of this review concerns the relationship between digital infrastructure and the implementation of innovative science learning models. Rather than functioning as isolated technological resources, digital infrastructures were consistently identified as enabling conditions that support the adoption of technology-enhanced pedagogical approaches. The synthesis of the 52 reviewed studies indicates that different components of digital infrastructure contribute to specific learning models in distinct ways.

Reliable cloud-based systems, learning management systems (LMS), and digital content repositories were frequently associated with implementing blended learning by facilitating continuous access to learning materials, online assessments, and asynchronous learning activities. Inquiry-based

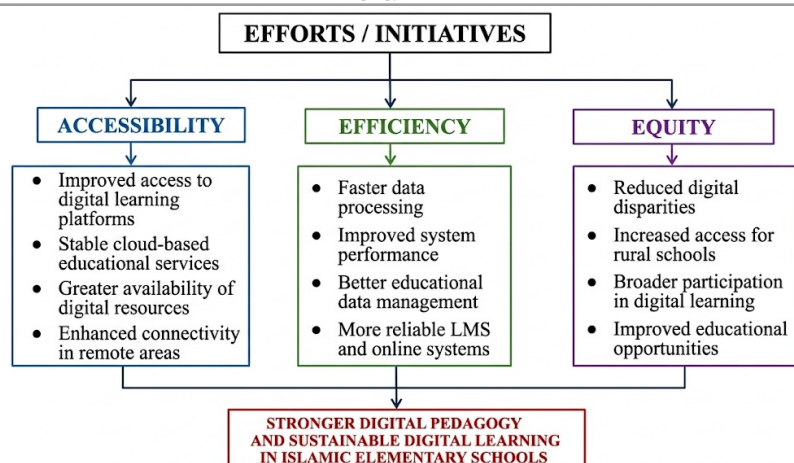


Figure 2. Concept Map of Digital Infrastructure Components Supporting Innovative Science Learning Models.

learning was commonly supported by digital libraries, online databases, virtual laboratories, and simulation platforms, enabling students to investigate scientific phenomena and engage in evidence-based learning. Meanwhile, artificial intelligence (AI)-assisted learning was linked to advanced digital infrastructures, including educational data systems, learning analytics platforms, adaptive learning environments, and AI-powered educational applications that support personalized instruction and data-informed decision-making.

To illustrate these relationships, Figure 2 presents a concept map showing how specific digital infrastructure components support various innovative science learning models identified in the reviewed literature. The concept map demonstrates that the educational value of digital infrastructure does not emerge from technological availability alone. Instead, its contribution is mediated by specific pedagogical models that use digital resources in learning activities. The reviewed studies suggest that cloud infrastructure primarily supports blended learning environments, digital repositories and virtual laboratories facilitate inquiry-based science learning, and AI-enabled systems provide opportunities for personalized and adaptive learning experiences. Collectively, these interactions contribute to the development of digital literacy, scientific competencies, and sustainable digital pedagogy within technology-enhanced educational environments.

The analysis of the 52 selected studies showed that blended learning was among the most frequently reported pedagogical approaches identified in the reviewed literature. Specifically, 18 of the 52 studies (34.6%) discussed implementing blended learning to integrate face-to-face instruction with digital

learning environments. The reviewed studies highlighted that blended learning provides flexibility in accessing educational resources, supports continuity of learning, and enables students to engage with learning materials beyond traditional classroom settings. In addition, inquiry-based learning (12 studies; 23.1%) and project-based learning (10 studies; 19.2%) were frequently reported as effective approaches for promoting scientific understanding, problem-solving skills, and active student participation. These findings suggest that technology-supported pedagogical models are commonly associated with efforts to enhance learner engagement and educational effectiveness in digitally mediated learning environments.

The findings further suggest that AI-assisted learning technologies have started to influence Islamic elementary education by providing personalized learning recommendations and adaptive assessment systems. This transformation reflects the growing integration of artificial intelligence within educational environments. AI-supported learning systems can improve students' cognitive engagement and learning efficiency through adaptive feedback mechanisms (Nasir, 2021).

The successful implementation of these innovative learning models strongly depended on the readiness of the digital infrastructure. Schools supported by stable cloud systems and regional data centers demonstrated greater capability to manage digital learning resources and maintain educational continuity. This indicates that pedagogical innovation and technological infrastructure are interconnected components within sustainable digital education systems.

Table 3. presents the innovative science learning models identified in the reviewed studies and their primary educational impacts.

No.	Innovative Learning Approach	Educational Contributions and Outcomes
1	Blended Learning	Facilitates greater learning flexibility by combining face-to-face and online instruction, leading to higher student participation and learning continuity.
2	Inquiry-Oriented Learning	Encourages learners to investigate, analyze, and construct knowledge independently, thereby strengthening critical thinking and scientific inquiry skills.
3	Project-Oriented Learning	Promotes teamwork, creativity, and real-world problem-solving through collaborative project activities and experiential learning experiences.
4	Gamified Learning Strategies	Creates a more engaging learning environment by incorporating game elements that enhance motivation, participation, and learner enthusiasm.
5	AI-Supported Learning	Enables personalized learning pathways through adaptive technologies that provide tailored instruction, feedback, and learning support.

Digital Literacy Enhancement through Sustainable Infrastructure

The review suggests that regional data centers may indirectly contribute to the development of digital literacy among teachers and students by improving access to digital learning environments, rather than directly enhancing digital competencies (Lee & Huh, 2024). Several studies indicate that reliable digital infrastructure facilitates more consistent access to learning management systems, online educational resources, cloud-based applications, virtual learning environments, and technology-supported instructional tools (Khan et al., 2022). Increased access to these digital platforms creates opportunities for teachers and students to engage more frequently with digital technologies, develop information-searching skills, participate in online collaboration, and practice the effective use of digital resources in learning activities (Neumann, 2017).

Therefore, the relationship between regional data centers and digital literacy should be understood as a mediated process (Reddy, 2023). The reviewed literature suggests that digital infrastructure serves as an enabling condition for the availability, accessibility, and continuity of digital learning services. In contrast, the actual development of digital literacy depends on how these technologies are

integrated into pedagogical practices, teacher professional development, and student learning experiences. Consequently, improvements in digital literacy are more appropriately attributed to increased engagement with digitally supported learning environments that are facilitated by reliable technological infrastructure.

The reviewed literature indicates that teachers in digitally supported educational environments demonstrated improved competence in utilizing educational technologies, conducting online assessments, integrating multimedia resources, and implementing technology-enhanced pedagogical practices. This pattern was identified in 11 of the 52 reviewed studies (Fitrah et al., 2025; Ma & Ismail, 2025; Robandi et al., 2025; Irish et al., 2025; Wang & Chen, 2025; Malik et al., 2025; Ncube & Tawanda, 2025; Georgopoulou & Troussas, 2025; Lo, 2025; Webb & Galamba, 2026).

Similarly, enhanced student digital literacy, information literacy, communication skills, and collaborative competencies were reported in 15 of the 52 reviewed studies (Fitrianto & Farisi, 2025; López, 2025; Chiu et al., 2025; Sunday et al., 2025; Chun et al., 2025; Liu & Ma, 2025; Avila-Garzon & Bacca-Acosta, 2025; Robandi et al., 2025; (Guess,

2020); Ma & Ismail, 2025; Malik et al., 2025; Georgopoulou & Troussas, 2025; Ncube & Tawanda, 2025; Lo, 2025). These findings suggest that digital infrastructure indirectly supports competency development by expanding opportunities to participate in technology-enhanced learning environments.

These findings support the perspective which states that digital literacy development requires not only technological devices but also sustainable digital ecosystems capable of facilitating continuous learning interactions. In Islamic education contexts, digital literacy enhancement is particularly important because it enables students to access broader scientific knowledge while maintaining Islamic educational values (Malik et al., 2025).

The findings further indicate that sustainable infrastructure reduces technological anxiety among teachers and students. Educational institutions with stable digital systems were more likely to adopt innovative pedagogical practices than those facing frequent connectivity disruptions and limited server capacity. Consequently, regional data centers become strategic instruments for strengthening institutional resilience and educational sustainability.

Educational Sustainability and Reduction of the Digital Divide

One of the most important findings of this study is the role of regional data centers in reducing educational inequality between urban and rural Islamic schools (Liu & Ma, 2025). The reviewed studies consistently highlighted that inadequate digital infrastructure remains a major barrier to equal educational opportunities in developing regions.

The integration of regional data centers was found to improve internet accessibility, optimize the distribution of educational services, and support cloud-based learning in geographically isolated areas (Wang & Chen, 2025). Schools located in rural regions benefited from improved access to digital educational resources, online teacher training, and collaborative learning networks.

This finding confirms that digital sustainability cannot be separated from infrastructure development policies. Sustainable digital pedagogy requires long-term institutional investment, technological support systems, and collaborative partnerships between governments, educational institutions, and technology providers. Educational transformation requires systematic infrastructure support to ensure equitable learning opportunities (Russo, 2025).

The implications of this study suggest

that regional data centers should be considered part of national educational development strategies, particularly within Islamic education systems. Beyond technological benefits, regional data centers contribute to educational resilience, institutional adaptability, and sustainable digital transformation (Farmer & Farmer, 2023). The findings also reinforce the theoretical understanding that educational innovation is influenced not only by pedagogical practices but also by the availability of reliable technological ecosystems.

Overall, the results demonstrate that regional data centers act as catalysts for sustainable digital pedagogy by strengthening digital literacy, improving the quality of science learning, and reducing digital disparities in Islamic elementary education. The integration of innovative learning models with sustainable digital infrastructure creates opportunities for more inclusive, adaptive, and future-oriented educational systems.

The findings of this study demonstrate that regional data centers have become increasingly important in supporting sustainable digital pedagogy within Islamic elementary education. The integration of digital infrastructure with innovative learning models creates a more adaptive educational environment capable of responding to the demands of twenty-first-century learning (Jermstad, 2025). This study confirms that educational transformation in the digital era cannot rely solely on pedagogical innovation without adequate technological infrastructure. Instead, sustainable digital education requires a strong relationship between educational technology systems, institutional readiness, teacher competence, and equitable digital accessibility.

One important finding is the increasing scholarly attention toward digital pedagogy and educational technology infrastructure between 2025 and 2026. This trend reflects the acceleration of global educational digitalization after the COVID-19 pandemic, which forced educational institutions to rapidly adopt online and hybrid learning systems. Similar findings were reported by Gurion et al. (2025), who argued that the pandemic significantly accelerated digital transformation in education while exposing inequalities in access to technology and institutional preparedness. The present study expands this perspective by highlighting that Islamic elementary education also experiences similar transformation challenges, particularly regarding infrastructure sustainability and equitable digital access (Irish et al., 2025).

The study further reveals that regional data centers serve as strategic infrastructure that can strengthen educational sustainability. Traditionally, discussions regarding educational innovation focused primarily on teaching methods and instructional media (Hanifansyah et al., 2025). However, this study demonstrates that digital infrastructure itself has become an essential pedagogical component. Reliable regional data centers improve cloud-based educational services, enhance digital accessibility, and support learning continuity through efficient data management systems. This finding aligns with the technological determinism perspective, which emphasizes that technological networks significantly influence social and institutional transformation processes (Chiu et al., 2025). Viewed through the constructivist perspective established in the methodology, these findings suggest that digital technologies can function as mediating tools.

The contribution of regional data centers to educational equity is another critical finding in this study. The reviewed literature consistently shows that digital inequality remains a major barrier to educational quality in rural and underdeveloped Islamic schools (Elihami et al., 2024). In many developing regions, unstable internet connectivity, limited server capacity, and insufficient digital resources constrain students' and teachers' opportunities to fully participate in digital learning environments. The integration of regional data centers helps address these barriers by decentralizing digital services and improving accessibility for geographically isolated schools (Ncube & Tawanda, 2025). This supports previous research, which emphasized that equitable digital infrastructure is fundamental to achieving inclusive, high-quality education.

Furthermore, the findings indicate that the sustainability of digital pedagogy is closely associated with the reliability of educational technology infrastructure (Li et al., 2026). Across the reviewed studies, schools supported by stable digital ecosystems demonstrated greater capacity to implement student-centered, collaborative, and technology-enhanced learning approaches (Abas et al., 2023). Reliable digital infrastructures enabled teachers to integrate multimedia resources, virtual laboratories, online assessment systems, and collaborative learning platforms more effectively, thereby creating richer and more interactive learning environments (Mavuso & Olaitan, 2024).

The implementation of innovative science learning models also emerged as a significant

aspect of sustainable digital pedagogy in Islamic elementary schools. Blended learning was identified as the most frequently applied instructional model due to its flexibility in combining face-to-face interaction with digital learning activities. This result is consistent with Islomjon (2025), who explained that blended learning creates more flexible learning opportunities while improving student engagement and learning continuity. Within Islamic educational contexts, blended learning also allows schools to maintain religious and moral instructional traditions while integrating modern technological practices.

Inquiry-based learning and project-based learning were also found to significantly improve students' scientific reasoning, collaboration, and problem-solving abilities. These learning models encourage active student participation and contextual exploration of scientific concepts. The findings confirm previous studies (Langan et al., 2025), which highlighted that technology-supported inquiry learning enhances students' critical thinking and conceptual understanding. In Islamic elementary schools, such approaches may contribute not only to cognitive development but also to cultivating ethical and collaborative values aligned with Islamic educational principles.

Another important finding concerns the growing integration of artificial intelligence within elementary science learning. AI-assisted learning systems provide adaptive instruction, personalized feedback, and flexible learning pathways that accommodate students' diverse learning needs (Sunday et al., 2025). This reflects broader educational trends toward intelligent learning environments and adaptive educational technologies. However, the study also suggests that successful AI integration depends heavily on digital infrastructure readiness, teacher digital competence, and institutional technological support. Without sustainable infrastructure, AI-based educational innovations may widen existing educational inequalities rather than reduce them (Karwadi et al., 2025).

The findings also emphasize the relationship between regional data centers and the enhancement of digital literacy. Digital literacy is no longer limited to operating technical devices but also includes information evaluation, digital communication, collaboration, and ethical use of technology (Robandi et al., 2025). Teachers and students in digitally supported schools demonstrated stronger digital competencies due to more consistent integration of technology into learning activities (Fitrah et al., 2025). This

finding supports the framework proposed by Webb & Galamba (2026), which conceptualizes digital literacy as a multidimensional competence combining technical, cognitive, and socio-emotional skills.

In the context of Islamic education, enhancing digital literacy is especially significant because students must navigate digital information while upholding Islamic ethical values. The integration of sustainable digital pedagogy enables Islamic schools to balance technological modernization with the preservation of religious identity. Consequently, regional data centers indirectly contribute not only to educational accessibility but also to the development of digitally literate Muslim learners who can participate responsibly in the global digital society.

The findings of this study also reveal several broader implications for educational policy and institutional development. First, digital transformation policies should prioritize infrastructure sustainability alongside pedagogical innovation. Governments and educational institutions need to recognize regional data centers as strategic educational investments rather than merely technical facilities. Second, teacher professional development programs should integrate digital pedagogy training with technology literacy enhancement to ensure the effective use of digital infrastructure. Third, collaborative partnerships among governments, educational institutions, and technology providers are necessary to strengthen the long-term sustainability of the digital ecosystem.

From a theoretical perspective, this study contributes to the growing discourse on sustainable digital pedagogy by integrating educational technology infrastructure into discussions of instructional innovation. Previous studies often examined digital learning models independently from infrastructure development. In contrast, this study demonstrates that sustainable educational transformation requires an integrated ecosystem consisting of pedagogical innovation, technological infrastructure, digital literacy, and institutional support systems.

Despite its contributions, this study also has several limitations. The research relied exclusively on secondary data obtained from selected publications, which may limit contextual specificity regarding local educational implementation. In addition, most of the reviewed studies focused on general digital pedagogy rather than on specifically examining Islamic elementary education. Future research is therefore recommended to conduct empirical investigations involving

teachers, students, and policymakers to explore the practical implementation of regional data centers in Islamic educational institutions.

General, the discussion confirms that regional data centers serve as catalysts for sustainable digital pedagogy by supporting educational accessibility, digital literacy, innovative science learning, and institutional resilience. The integration of technological infrastructure and innovative pedagogical approaches creates opportunities for more inclusive, adaptive, and sustainable Islamic education systems that can address future educational challenges in the digital era.

■ CONCLUSION

This study suggests that regional data centers have the potential to serve as an important enabling component within sustainable digital learning ecosystems, including those applicable to Islamic elementary education. Based on the synthesis of the reviewed literature, the availability of reliable digital infrastructure may facilitate greater access to digital learning resources, support the implementation of innovative pedagogical approaches, and strengthen opportunities for digital literacy development. However, these conclusions should be interpreted as conceptual implications derived from broader research on digital pedagogy, educational technology infrastructure, and digital learning environments rather than as direct empirical evidence from Islamic elementary schools.

The review further indicates that sustainable digital pedagogy is shaped by the interplay among technological infrastructure, teachers' digital competence, institutional readiness, and pedagogical innovation. Approaches such as blended learning, inquiry-based learning, project-based learning, and AI-supported instruction appear promising for enhancing learning experiences when supported by adequate digital ecosystems. Nevertheless, the extent to which regional data centers directly affect learning outcomes and educational sustainability in Islamic elementary education remains underexplored and requires further empirical investigation.

Therefore, this study contributes a conceptual framework that highlights the possible relationship between regional digital infrastructures and sustainable digital pedagogy in Islamic elementary education. Future research should employ case studies, surveys, experimental designs, or longitudinal investigations in Islamic elementary school settings to validate and extend the propositions identified through this systematic literature

review.

The findings demonstrate that regional data centers function as catalysts for reducing the digital divide between urban and rural Islamic schools by improving cloud-based educational services, learning management efficiency, and equitable access to digital learning resources. In addition, sustainable digital infrastructure supports the development of students' scientific understanding, critical thinking, collaboration skills, and digital competencies while enabling teachers to implement more adaptive and student-centered learning practices. This study also contributes to the theoretical development of sustainable digital pedagogy by emphasizing that educational innovation should be viewed as an integrated system involving pedagogical models, digital infrastructure, institutional readiness, and digital literacy enhancement.

The novelty of this study lies in its integration of regional data center infrastructure into the discourse of Islamic educational sustainability and innovative science learning at the elementary level. This perspective expands on previous educational technology studies that primarily focused on instructional methods and did not adequately address infrastructure sustainability as a critical educational component.

Based on these findings, it is recommended that governments, educational institutions, and technology stakeholders strengthen collaborative efforts to develop sustainable regional digital infrastructures that support inclusive Islamic education. Teacher professional development programs should also prioritize digital pedagogy and technological literacy to optimize the utilization of educational technologies. Future studies are encouraged to conduct empirical, field-based investigations to examine the practical implementation and effectiveness of regional data centers across diverse Islamic educational contexts.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the research of this manuscript, the author(s) used generative artificial intelligence (AI) tools, including ChatGPT (OpenAI), to assist with language modification, grammar correction, text organization, and improvement of readability. The AI tool was utilized solely as a support instrument and did not contribute to the generation of original research findings, data analysis, interpretation of results, or scientific conclusions. The author(s) carefully reviewed, edited, and verified all AI-assisted content and assume full

responsibility for the accuracy, integrity, and originality of the final manuscript. All intellectual contributions, research design, data collection, analysis, interpretation, and conclusions remain the sole responsibility of the author(s). The use of generative AI complied with the ethical guidelines and publication policies of the respective journal and institution

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