The Application of the Internet of Things (IoT) in Educational Governance System

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Abstract

The integration of the Internet of Things (IoT) into educational governance represents a transformative trend, promising to enhance efficiency, data-driven decision-making, and resource optimization. However, within the unique and archipelagic context of Indonesia, characterized by disparities in infrastructure, resource distribution, and cultural diversity, the application of IoT faces distinct challenges and opportunities. This study, from the perspective of educational management, aims to explore viable models and pathways for IoT implementation in Indonesian educational governance. The research employs a mixed-methods approach, combining literature review, policy analysis, and case studies of pioneering IoT applications in Indonesian schools and government initiatives. It seeks to analyze the current state of IoT readiness in Indonesia's education sector, identify key challenges (e.g., digital divide, data security, technical expertise), and elucidate the potential impacts of IoT on core governance functions such as asset management, student safety, energy conservation, and personalized learning support. The expected outcomes include: (1) A proposed framework for IoT-integrated educational governance tailored to Indonesia's geographi-cal and socio-economic context, emphasizing a phased and equitable implementation strategy. (2) Specific policy recommendations for the government, educational institutions, and other stakeholders to foster infrastructure development, teacher training, and data privacy standards. The study argues that a strategically implemented IoT ecosystem can significantly bridge educational management gaps across the Indonesian archipelago, promoting more responsive, efficient, and equitable educational governance, thereby contributing to the realization of *Indonesia's Merdeka Belajar* (Freedom to Learn) vision.

Keywords: Internet of things; Educational governance framework construction; Indonesian education system

Introduction

The rapid advancement of digital technologies has accelerated the global transformation toward smart education, where educational governance increasingly relies on intelligent systems, real-time data, and interconnected digital infrastructures (Langat, 2024; Rizvi et al., 2025). As one of the core technologies of the

Fourth Industrial Revolution (Industry 4.0), the Internet of Things (IoT) has emerged as a key enabler of this transformation by connecting physical devices, communication networks, and data analytics to support evidence-based decision-making and efficient educational management (Badr & Ahmed, 2025; Çela et al., 2024). The integration of IoT into educational systems offers significant opportunities to improve governance through automated monitoring, resource optimization, learning environment management, and data-driven policy formulation.

Despite these global developments, the implementation of IoT-based educational governance remains particularly challenging in developing countries, including Indonesia. As the world's largest archipelagic nation, Indonesia consists of thousands of islands with schools distributed across urban centers, rural communities, and geographically isolated regionsn (Cendana et al., 2025; Junus & Putra, 2025). This geographical diversity creates substantial disparities in educational infrastructure, internet connectivity, and access to digital technologies, making unified educational governance and equitable service delivery difficult to achieve (Shamsudinova et al., 2025; Soanes-White, 2022; Topal & Geçer, 2024). Furthermore, the uneven distribution of educational resources, limited technological infrastructure in remote areas, and challenges in collecting real-time educational data continue to hinder effective policy implementation and monitoring.

Recognizing these challenges, the Indonesian government has introduced several strategic initiatives to accelerate digital transformation across various sectors, including education. National policies such as the Making Indonesia 4.0 roadmap, the Digital Indonesia vision, and the Ministry of Education's *Merdeka Belajar* (Freedom to Learn) program emphasize the adoption of digital technologies to improve educational quality, accessibility, and governance. These policy frameworks provide strategic direction and institutional support for integrating emerging technologies, including IoT, into educational management systems. Nevertheless, while internet penetration and mobile network coverage have improved considerably in recent years, significant digital inequalities persist between urban and rural areas, highlighting the need for context-sensitive technological implementation strategies (Alli et al., 2025; Çela et al., 2024; Machkour & Abriane, 2024).

From a theoretical perspective, educational governance has evolved from traditional bureaucratic administration toward more collaborative, participatory, and data-driven governance models. Modern educational governance emphasizes transparency, accountability, stakeholder collaboration, and evidence-based decision-making. Within this paradigm, IoT technology offers considerable potential by enabling continuous data collection through sensing devices, networked communication, and intelligent data processing (Kumar et al., 2025; Machkour & Abriane, 2024). In educational settings, IoT applications extend beyond instructional activities to encompass smart campus management, including energy efficiency, security monitoring, and asset management; smart classrooms that facilitate environmental monitoring and interactive learning; and integrated student management systems that support attendance tracking, health monitoring, and learning behavior analysis (Palarimath et al., 2025; Ţălu, 2025).

Previous studies have extensively examined IoT applications in educational environments, particularly in developed countries and several Southeast Asian contexts. Existing research has primarily focused on technological implementation, smart classroom development, learning analytics, and digital campus management (Badr & Ahmed, 2025; Hijazi et al., 2025). However, relatively limited attention has been devoted to developing comprehensive governance frameworks that address the unique institutional, geographical, and infrastructural conditions of developing countries such as Indonesia. Consequently, there remains a significant research gap regarding how IoT can be systematically integrated into educational governance to support national educational policy implementation while addressing local contextual challenges.

Therefore, this study aims to develop a feasible framework for implementing IoT-based educational governance in Indonesia by considering the country's distinctive geographical, institutional, and technological characteristics. Specifically, this study seeks to answer three research questions: (1) How can a feasible framework for IoT application in educational governance be constructed based on Indonesia's national context? (2) What are the major barriers and challenges to implementing IoT in educational governance? and (3) What implementation pathway can effectively facilitate the adoption of IoT technologies to improve educational governance across Indonesia? By addressing these questions, this study contributes both theoretically and practically to the growing body of literature on smart education and educational governance, while providing strategic recommendations for policymakers, educational administrators, and other stakeholders seeking to accelerate Indonesia's digital education transformation.

Methodology

This study employed a mixed-methods research design to comprehensively examine the potential implementation of the Internet of Things (IoT) in educational governance in Indonesia. The study combines the positivist paradigm, which focuses on objective measurement and quantitative analysis, with the interpretivist paradigm, which emphasizes understanding stakeholders' perspectives and contextual experiences. This approach was selected to provide both empirical evidence and in-depth insights into the opportunities, challenges, and implementation strategies of IoT within Indonesia's educational governance system.

The qualitative component consisted of document analysis, semi-structured interviews, and case studies. National education policies, digital transformation strategies, and government regulations including the Making Indonesia 4.0 roadmap, the Digital Indonesia vision, and the Merdeka Belajar policy were systematically analyzed to identify policy directions supporting IoT adoption in education. Semi-structured interviews were conducted with officials from the Ministry of Education, school principals, and school IT administrators to explore current practices, implementation challenges, and institutional needs. In addition, case studies were undertaken in selected smart schools in Bandung to examine how IoT technologies have been applied in school management, classroom operations, and administrative decision-making.

The quantitative component involved a questionnaire survey distributed to school administrators across several provinces in Indonesia to assess the availability of digital infrastructure, organizational readiness, willingness to adopt IoT technologies, and perceived implementation barriers. The collected quantitative data were analyzed using descriptive statistical techniques, while qualitative data from documents, interviews, and case studies were analyzed using thematic analysis. Finally, the findings from both approaches were integrated through data triangulation to strengthen the validity of the results and to develop a comprehensive framework for IoT-based educational governance that is appropriate to Indonesia's national context.

Results and Discussion

Application Scenarios and Benefits of IoT in Indonesian Educational Governance

The findings indicate that the Internet of Things (IoT) has significant potential to improve educational governance in Indonesia through several interconnected application scenarios. First, IoT can enhance infrastructure and resource management by utilizing smart sensors to monitor school building conditions, optimize electricity and water consumption, and manage educational assets such as laboratory equipment, computers, and library collections. Such applications are particularly relevant for Indonesia, where schools are geographically dispersed across urban, rural, and remote island regions, making conventional monitoring and maintenance both costly and inefficient.

Second, IoT supports the teaching and learning process through smart classroom technologies capable of automatically regulating lighting, temperature, and classroom environments while simultaneously collecting anonymized learning analytics to assist teachers in evaluating classroom engagement and improving instructional strategies. Third, IoT contributes to student safety and attendance management through RFID-based identification cards or wearable devices that enable automatic attendance recording, facilitate emergency response, and strengthen campus security systems. Furthermore, the continuous collection of educational data generated by IoT devices provides valuable evidence for data-driven decision-making, allowing policymakers to monitor school performance, optimize resource allocation, and evaluate educational policies more accurately at local, provincial, and national levels.

Challenges and Constraints of IoT Implementation

Despite these opportunities, the study identifies several critical challenges that may hinder the implementation of IoT-based educational governance in Indonesia. The most significant challenge concerns digital infrastructure and regional disparities, as many schools particularly in eastern Indonesia and remote areas continue to experience unstable internet connectivity, inadequate electricity supply, and limited access to digital infrastructure.

Financial sustainability also represents a major concern because IoT implementation requires substantial initial investment for hardware procurement, system integration, maintenance, and periodic technological

upgrades. In addition, the successful adoption of IoT depends heavily on the digital competencies of teachers, school leaders, and administrative personnel, many of whom still require professional development in operating IoT systems, interpreting educational data, and integrating digital technologies into school management (Arokiasamy et al., 2025; He, 2025). The research further highlights concerns regarding data privacy and cybersecurity, especially considering the increasing collection of student data and the necessity of complying with Indonesia's Personal Data Protection regulations . Finally, organizational and cultural resistance remains a challenge, as some educational institutions continue to rely on traditional administrative practices and demonstrate limited readiness to adopt technology-driven governance models.

IoT Governance Framework and Policy Recommendations

Based on these findings, this study proposes a comprehensive IoT-based Educational Governance Framewor tailored to Indonesia's national context. The framework consists of five interrelated components. The vision layer aligns IoT implementation with the objectives of Merdeka Belajar and the promotion of equitable educational access. The governance layer emphasizes collaborative responsibilities among government agencies, schools, technology providers, universities, and local communities. The technology layer recommends adopting affordable, scalable, and easy-to-maintain IoT solutions suitable for diverse educational environments.

The application layer distinguishes between core applications, including asset management, attendance systems, environmental monitoring, and campus security, and advanced applications such as personalized learning support and learning analytics (Ţălu, 2025; Xie et al., 2025; Yadav et al., 2025). Finally, the safeguard layer focuses on establishing technical standards, cybersecurity mechanisms, data governance policies, and continuous human resource development. To facilitate implementation, the study recommends a three-stage adoption pathway consisting of a short-term pilot phase in selected smart schools, a medium-term expansion phase through provincial standardization and wider adoption, and a long-term nationwide implementation strategy aimed at reducing educational inequalities across regions. In addition, the study recommends that the government integrate educational IoT into the national digital transformation agenda, provide financial incentives and regulatory support, encourage schools to incorporate IoT into institutional development plans, and strengthen collaboration with higher education institutions to develop interdisciplinary expertise capable of sustaining future smart education initiatives.

Conclusion

This study examined the potential application of the Internet of Things (IoT) in educational governance within the Indonesian context. The findings demonstrate that IoT has considerable potential to improve the efficiency, transparency, and effectiveness of educational governance by enabling data-driven decision-making,

optimizing resource management, enhancing school infrastructure monitoring, and supporting student-centered educational services. Given Indonesia's geographical characteristics as an archipelagic country with significant disparities in educational resources and digital infrastructure, IoT offers an innovative approach to addressing long-standing governance challenges while supporting the national vision of *Merdeka Belajar* and smart education. To facilitate this transformation, the study proposes a comprehensive IoT-based educational governance framework consisting of five interconnected components: the vision, governance, technology, application, and safeguard layers. Together, these components provide a practical and scalable roadmap for implementing IoT across schools with different levels of technological readiness.

Despite its promising potential, the successful implementation of IoT requires addressing several interconnected challenges beyond technological issues alone. The study identifies infrastructure limitations, unequal internet access, financial sustainability, limited digital competencies among educational personnel, data privacy and cybersecurity concerns, and organizational resistance to technological change as the primary barriers to adoption. These findings suggest that effective IoT implementation depends not only on technological investment but also on supportive public policies, sustainable funding mechanisms, capacity building for educators and administrators, and strong governance frameworks that ensure ethical and secure data management. Consequently, a phased implementation strategy beginning with pilot schools, followed by gradual expansion based on evaluated best practices, is considered the most feasible approach for Indonesia.

This study has several limitations. The case studies and survey respondents primarily represent schools with relatively better digital infrastructure, which may limit the generalizability of the findings to schools in remote and underserved regions. Furthermore, because IoT adoption in Indonesian education is still at an early stage, several projected benefits require validation through long-term empirical evidence. Future research should therefore conduct longitudinal studies to evaluate the long-term impacts of IoT on educational governance, investigate low-cost and sustainable IoT solutions for resource-constrained areas, explore the integration of IoT with emerging technologies such as artificial intelligence, and examine effective approaches to educational data privacy and cybersecurity. Overall, this study contributes a practical framework that can guide policymakers, educational institutions, and other stakeholders in advancing digital transformation and building a more equitable, efficient, and sustainable educational governance system in Indonesia.

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