Integration of Internet of Things (IoT) Technology in the Management of Educational Facilities and Infrastructure

Gilang Kartika Hanum ¹, Andi Irwin ², Ruly Nadian Sari ³, Abdullah Ardi ⁴, Lismaryanti ⁵

¹ Universitas Raharja, Indonesia
² Universitas Papua Madani Jayapura, Indonesia
³ Sekolah Tinggi Ilmu Teknologi Pringsewu, Indonesia
⁴ Politeknik Hasnur, Indonesia
⁵ Universitas Papua Madani Jayapura, Indonesia

Corresponding Author: Gilang Kartika Hanum, E-mail: gilanghanum@raharja.info

Abstract

Internet of Things (IoT) technology has developed rapidly and has had a significant impact on various sectors, including education. The integration of IoT in the management of educational facilities and infrastructure offers the potential to improve the efficiency, monitoring, and maintenance of facilities in real time. In this digital era, the need for a smarter and more responsive management system is very important to support an effective and sustainable teaching and learning process. This research aims to analyze the potential and implementation of IoT technology in the management of educational facilities and infrastructure. The main focus is to identify the benefits, challenges, and impact of implementing IoT on operational efficiency, rationality, and quality of educational services. This research uses a qualitative approach with a case study method. The research results show that the integration of IoT in the management of educational facilities and infrastructure can increase operational efficiency through automating facility monitoring and maintenance. For example, IoT sensors enable early detection of damage and maintenance needs, which can reduce repair costs and operational downtime. Apart from that, IoT also improves security through sensor-based surveillance systems and sophisticated data analytics. However, this research also identified several challenges, such as high initial costs, the need for reliable network infrastructure, and the need for special training for staff to operate this technology. The conclusion of this research explains that the integration of IoT technology in the management of educational facilities and infrastructure shows great potential to increase the efficiency and quality of educational services. Although there are challenges to overcome, the benefits gained from implementing IoT are much more effective. A mature implementation strategy and support from various parties is needed to ensure the success of this integration.

Keywords: Integration, Internet of Things (IoT) Technology, Facilities Management, Educational Infrastructure
INTRODUCTION

Internet of Things (IoT) technology has been one of the most significant technological innovations in the last decade, changing the way various sectors operate, including education (Ayaz et al., 2019). In the education sector, facilities, and infrastructure play a crucial role in supporting the teaching and learning process. However, the management of these facilities and infrastructure often needs to improve, such as efficient maintenance, limited supervision, and slow response to damage to facilities (Ali et al., 2022). This problem becomes increasingly complex as the number of facilities that must be managed increases, as well as the need to ensure a safe and conducive learning environment for students. This problem becomes more urgent, considering that an educational environment that needs to be better managed can have a negative impact on the quality of education itself. Inefficient maintenance can cause more serious damage to facilities, resulting in higher repair costs and disruption to the teaching and learning process. Apart from that, a lack of effective supervision can also reduce the safety and comfort of the learning environment, which, in the end, can affect the motivation and performance of students and teaching staff.

Literature of Review

Internet of Things (IoT) Technology

Internet of Things (IoT) technology is a concept that integrates physical objects into the Internet network through sensors, software, and other technologies to collect and exchange data (Agarwal et al., 2021). This concept allows objects, often referred to as “smart devices,” to interact with their internal or external environments automatically, increasing efficiency, precision, and economic utility (Santhosh Kumar et al., 2023). The origins of IoT can be traced back to the late 20th century, but its applications expanded significantly with advances in microelectronics, telecommunications, and information technology. Internet of Things (IoT) technology began to develop in educational management in the early 2010s when academic institutions started to explore the potential of IoT to improve operational efficiency and effectiveness (Ahmad et al., 2022). This adoption is driven by the development of more mature technology and increasingly affordable costs for IoT devices and sensors.

Schools, universities, and other educational institutions are starting to implement systems that utilize IoT for a variety of purposes, including asset management, security monitoring, and optimizing the use of resources such as electricity and water (AlShorman et al., 2021). For example, with IoT sensors, schools can automatically
adjust lighting and temperature based on the presence or absence of students and staff in class or track equipment and learning resources to prevent loss and ensure availability (Greco et al., 2020). Further developments and research are ongoing to integrate IoT more deeply into learning management systems and school operations, with the aim of not only increasing operational efficiency but also enriching the learning experience and personalizing education (Akram et al., 2022).

**Management of Educational Facilities and Infrastructure**

Facilities and infrastructure management in the educational context play a crucial role in supporting the success of the learning process in academic institutions (Pavón et al., 2020). The term 'facilities and infrastructure' refers to all facilities and equipment that are essential for the implementation of educational activities, which include classrooms, laboratories, libraries, sports facilities, and information technology infrastructure. Effective management of these components directly contributes to improving the quality of education delivered and enriching students' learning experiences (Nindie, 2022). In the modern educational era, the task of managing facilities and infrastructure is not only limited to maintaining physical aspects but also involves strategic planning, wise procurement processes, as well as the integration and effective use of technology. Efficient management must ensure that all facilities are well maintained, safe, and meet applicable educational standards. This includes ensuring the safety of school buildings from potential physical dangers, providing adequate ventilation in classrooms, maintaining laboratory equipment to function optimally, and ensuring that information technology systems are always up to date and protected from cyber threats.

Strategic planning in facilities and infrastructure management includes sustainable infrastructure development that is responsive to dynamic educational needs (Chandrashekhar et al., 2020). School administrations are expected to be proactive in planning and responding to changing educational needs, such as increasing student numbers or curriculum modifications that demand certain laboratory specifications. Procurement of facilities and infrastructure must be carried out effectively and efficiently, taking into account factors such as cost, quality, and sustainability. In addition, information technology management is an integral component of facilities and infrastructure management in this digital era. Schools need to integrate technology into the teaching and learning process, which includes procuring computers, educational software, and adequate network infrastructure to support digital-based learning (Pribadi et al., 2021). Data security and privacy protection for students and staff has never been more important, given the increased risk of cyberattacks in connected environments.

Coordination and collaboration with various stakeholders are also key to successful facilities and infrastructure management. Collaboration with teachers, staff, students, parents, and local communities allows schools to identify the most pressing needs and allocate resources more appropriately. Active involvement from all parties not only increases the effectiveness of the management of facilities and infrastructure
but also increases the sense of ownership and responsibility for these facilities. Furthermore, ongoing education and training for staff who manage facilities and infrastructure is very important. Staff need to be provided with the knowledge and skills necessary to operate facilities most effectively, including training in risk management, facility maintenance, and the use of the latest technology. This professional development not only improves individual abilities but also improves the overall quality of management of facilities and infrastructure in educational institutions. Finally, continuous evaluation and updating of facilities and infrastructure management should become a routine practice. Through regular assessment, schools can identify areas that need improvement and implement effective solutions. This includes conducting energy audits to reduce operational costs, updating security policies to improve data protection, and revising procurement strategies to ensure sustainability.

There are several previous research opinions. The first research, according to (Kumar et al., 2021), is the research titled Revolutionary Strategies Analysis and Proposed System for Future Infrastructure in the Internet of Things. As a result, a detailed taxonomy of IoT is presented here, which includes interoperability, scalability, security, and energy efficiency, among other things. Moreover, the significance of blockchains and big data, as well as their analysis in relation to IoT, is discussed. This article aims to help readers and researchers understand the IoT and its applicability to the real world. The second research, according to (Kassab et al., 2020), has the research titled A Systematic Literature Review on Internet of Things in Education: Benefits and Challenges. This study presents the results of a systematic literature review focusing on the benefits and the challenges faced in education in integrating IoT into the curriculum and educational environments. Different mapping views of the extracted studies are provided, along with a summary of the tools that have already been implemented and a list of gap research questions that have yet to be investigated. The third research, according to (Al-Emran et al., 2020), has the research titled A Survey of Internet of Things (IoT) in Education: Opportunities and Challenges. This review study summarizes the prospects of adopting IoT in education, medical education and training, vocational education and training, Green IoT in education, and wearable technologies in education. It is concluded that the adoption of IoT and its applications in developing countries is still in its early stages, and further research is highly encouraged.

This research was conducted to answer these challenges by focusing on the integration of IoT technology in the management of educational facilities and infrastructure (Mishra & Tyagi, 2022). The main goal is to find solutions that can improve operational efficiency and the monitoring and maintenance of educational facilities in real-time. IoT technology offers great potential to overcome this problem through the use of sensors and smart devices that can monitor facility conditions, detect early damage, and provide accurate data for decision-making (Nižetić et al., 2020). It is important to discuss the integration of IoT in the management of
educational facilities and infrastructure because this technology can have a significant impact on the overall quality of education (Khan & Javaid, 2022). With the implementation of IoT, schools and educational institutions can increase maintenance efficiency, reduce operational costs, and increase the security of the learning environment. Apart from that, this technology can also help optimize the use of resources so that educational institutions can allocate budgets and workforce more effectively. Through this research, it is hoped that appropriate implementation strategies and innovative solutions can be found to overcome existing problems.

This research was conducted because of the urgent need to improve the efficiency and effectiveness of the management of educational facilities and infrastructure. In an increasingly competitive global context, educational institutions need to utilize advanced technology to remain relevant and provide high-quality educational services. IoT technology offers innovative and practical solutions to overcome the problems of maintaining and monitoring educational facilities. However, its implementation still needs to be improved and has yet to be studied in depth in the educational context in Indonesia (Li et al., 2022). Therefore, this research aims to fill this gap and explore the full potential of IoT technology in the management of educational facilities and infrastructure. This research contributes to filling the existing gap by providing a comprehensive analysis of the implementation of IoT technology in the management of educational facilities and infrastructure (Amiri-Zarandi et al., 2020). The methodology used includes case studies in several educational institutions that have adopted IoT, interviews with facility managers, and data analysis from the IoT devices used. Through this approach, this research not only illustrates the benefits and challenges of IoT integration but also provides practical recommendations for broader implementation.

This research also seeks to identify key factors that can support successful IoT integration, such as technology infrastructure, institutional policies, and staff training (Boursianis et al., 2022). The state of the art of this research, namely the use of IoT technology in the management of educational facilities and infrastructure, is still at an early stage of development. Several previous studies have shown the great potential of IoT in improving operational efficiency and facility monitoring, but comprehensive and systematic implementation still needs to be made available. The innovation proposed in this research is the development of an IoT-based integrated management system that can monitor facility conditions in real time, provide predictive analytics for preventive maintenance, and optimize resource use through intelligent algorithms (Lee, 2020). This system is also designed to be easily integrated with existing management systems, thereby facilitating the adoption and implementation process in various educational institutions.

The novelty of this research lies in its holistic and systematic approach to exploring the implementation of IoT technology in the management of educational facilities and infrastructure. In contrast to previous research, which tends to focus on technical aspects or specific cases, this research combines qualitative and quantitative
analysis to provide a comprehensive picture of the benefits, challenges, and implementation strategies of IoT (Ashraf et al., 2020). In addition, this research also highlights the importance of collaboration between various stakeholders, including facility managers, teaching staff, and technology providers, to achieve optimal results. Furthermore, this research will focus on developing a prototype IoT-based management system that can be tested in various educational institutions. The pilot will involve field data collection, system performance evaluation, and adjustments based on user feedback. It is hoped that the results of this research can become the basis for developing policies and best practices in implementing IoT in the education sector. Future researchers are expected to expand this research by exploring various other IoT applications in educational contexts, such as enhancing learning experiences through VR/AR, learning data analysis, and developing technology-based adaptive curricula. Further research is also needed to evaluate the long-term impact of IoT integration on the quality of education and well-being of students.

METHOD

This research aims to explore the integration of Internet of Things (IoT) technology in the management of educational facilities and infrastructure using qualitative methods (Hamilton & Finley, 2019). The main objective is to understand the perceptions, experiences, and challenges faced by relevant parties in schools that have implemented or are considering the use of IoT technology in their facilities and infrastructure management systems.

Research design

This research uses a phenomenological approach to gain an in-depth understanding of the subjective experiences of users and managers of educational facilities related to the implementation of IoT (Singh et al., 2020). This approach allows researchers to explore the meanings and interpretations formed by individuals in social and operational contexts.

Location and Research Subjects

This research location includes various types of schools, from elementary schools to universities. The subjects of this research are school administrators, facility managers, teachers, and IT staff, who are directly involved in the management and operation of facilities and infrastructure equipped with IoT. Subject selection was carried out using purposive sampling to obtain various perspectives from schools with multiple levels of implementation of IoT technology.

Data collection

Data was collected through three main methods: in-depth interviews, participant observation, and documentation studies. In-depth interviews were conducted to explore the research subjects' experiences, perceptions, and opinions regarding IoT integration. Interview questions will be semi-structured to provide flexibility in answering while ensuring that all important topics are covered. Participatory observations were carried out in the school environment to observe the real use of IoT
in daily operations (M et al., 2021). Researchers will note interactions between technology and users, as well as dynamics that occur that may not be revealed through interviews alone. Documentation studies involve the analysis of documents related to school policies, technology implementation reports, and meeting records associated with the management of facilities and infrastructure. This document will provide additional context on how decisions are made and how IoT is integrated into broader management strategies.

**Data analysis**

The data collected will be analyzed using content analysis methods to identify the main themes, patterns, and narratives in the data. This analysis will be carried out iteratively and reflectively, where the researcher continuously compares the findings from the data with existing theory and literature to ensure the reliability and validity of the interpretation.

**Research Ethics**

This research will adhere to strict research ethical standards. Informed consent will be obtained from all participants, and the anonymity and confidentiality of information will be guaranteed (Drachsler et al., 2015). This research will also receive approval from the relevant ethics committee before being carried out.

**Research Implications**

It is hoped that the findings from this research will provide valuable insights for education policymakers in designing and implementing effective IoT integration strategies. In addition, this study can also be a basis for further research on IoT technology in education, especially in the context of physical resource management.

**Limitation**

One of the limitations of qualitative research is the generalization of results. Due to the focus on subjective experiences and local contexts, the results may not be directly applicable to different situations or contexts. However, the in-depth understanding gained from this study provides a strong basis for hypothesis development and follow-up studies. This research is expected to make an important contribution to the existing literature by exploring the human and operational aspects of IoT technology in education. This area is still relatively new and developing.

**RESULTS AND DISCUSSION**

The integration of Internet of Things (IoT) technology in the management of educational facilities and infrastructure has changed the way schools manage their resources and infrastructure (Sinha & Dhanalakshmi, 2022). With the ability to collect and analyze data in real-time, IoT offers great potential to improve efficiency, security, and sustainability in educational environments. IoT refers to a network of physical devices that are connected and can communicate data over the Internet. In an academic context, this can include everything from light sensors, temperature meters, and CCTV to automated attendance systems. Utilizing this technology allows schools to automate many processes that previously required manual intervention, such as energy usage monitoring, facility security,
Use of Augmented Reality in Developing Interactive Teaching Materials

and asset management.

One of the main benefits of IoT integration is increased energy efficiency. Sensors installed throughout a school building can collect data about energy use and the environment in real time, allowing the system to adjust settings automatically—for example, turning off lights and HVAC equipment in unused rooms. In addition to reducing energy costs, this approach also supports school initiatives to become more environmentally friendly. From a security perspective, IoT provides a very effective solution. Smart camera systems and movement sensors can be integrated to monitor school security more closely (Kundu et al., 2020). With this system, unwanted events such as intrusions can be detected early. IoT also allows for the implementation of smart lock systems that can restrict access to certain spaces to only authorized individuals.

Asset management becomes easier with IoT (Al-Emran et al., 2020). This technology allows schools to track the location and condition of equipment in real time. This is especially useful in managing books, laboratory equipment, and technology assets that are frequently moved or prone to loss. This system not only reduces the possibility of asset loss but also helps in planning asset replacement and repair more efficiently. Furthermore, IoT can improve students' learning experience. For example, learning environments can be tailored to the specific needs of groups or individual students based on data collected through IoT. Temperature and air quality sensors can adjust room conditions to create an ideal learning environment, which is scientifically proven to support better academic performance. IoT's ability to collect and analyze big data gives schools valuable insight into trends and patterns that may not have been visible before. This analysis can be used to make data-based decisions about everything from facility scheduling to educational interventions. With more accurate data, schools can optimize operations and resources more effectively.

Table 1: Benefits of integrating Internet of Things (IoT) technology in the education sector

<table>
<thead>
<tr>
<th>NO</th>
<th>Benefits of IoT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IoT facilitates increased efficiency and effectiveness of the learning process through the integration of the latest technology and accurate data analysis, which can be used to improve curriculum and teaching methodology.</td>
</tr>
<tr>
<td>2</td>
<td>IoT technology enriches the learning experience by providing access to more advanced digital resources, including virtual and augmented reality, and creates a more interactive and engaging learning experience.</td>
</tr>
<tr>
<td>3</td>
<td>IoT increases student engagement by leveraging technology that makes the learning process more interactive and fun, such as game-based learning and virtual simulations.</td>
</tr>
<tr>
<td>4</td>
<td>IoT expands the accessibility of education through the convenience of distance learning and online classes, helping students and educators in remote or hard-to-reach locations.</td>
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<tr>
<td>5</td>
<td>By automating asset management, scheduling, facilities monitoring, and campus security, IoT contributes to increased operational efficiency, which in turn can</td>
</tr>
</tbody>
</table>
reduce operational costs and improve the learning experience.

The integration of Internet of Things (IoT) technology in various sectors, including education, offers a number of benefits ranging from increased operational efficiency to better resource management. However, the implementation of this technology also faces various challenges, especially in the context of the management of educational facilities and infrastructure, which require special attention and mature strategies to overcome. One of the biggest challenges faced is cyber security and data privacy issues. Every IoT device connected to the Internet has the potential to become an entry point for cyberattacks. Schools that have adopted IoT are at risk of sensitive data leaks, which could relate to students' personal information or school operational data. Inadequate data security can result in serious privacy violations and loss of important information. Therefore, educational institutions must invest significant resources in securing networks and ensuring encryption and secure data storage.

Then, technological complexity and challenges in system integration often arise when implementing IoT, which involves many different types of devices and systems (Khanna & Kaur, 2020). Compatibility issues between devices, as well as between old and new devices, can make it difficult to deploy and manage IoT technology. A high degree of technical expertise is required to manage this integration, which may only be available at some educational institutions. Additionally, the importance of adequate staff training to operate and maintain IoT systems must be addressed. The costs of implementing and maintaining IoT can also be very high, especially for educational institutions with limited budgets. These costs include not only hardware and software but also installation, system integration, and staff training. Additionally, ongoing maintenance costs, including security updates, repairs, and device replacement, must also be taken into account. It can be a big challenge for many schools to secure enough funding to adopt and maintain IoT technology.

Another challenge is over-reliance on IoT technology, which can create vulnerabilities when technical failures occur. For example, a system failure can halt all connected operations, from HVAC setup to physical security. The importance of having strong contingency plans and operational continuity procedures is crucial in this situation. The issue of system scalability and flexibility is also a concern, along with the growth and evolution of educational institutions. The IoT system used must be able to scale according to developing needs. However, scalability is often a challenge because initial devices and systems may need to be designed for easy expansion or updates. Additionally, system flexibility to adapt to new technologies is also critical, necessitating continued investment in research and development (R&D).

Ethical and social issues also arise, especially related to surveillance and control. The use of surveillance cameras and other sensors may raise concerns about the privacy and autonomy of students and staff. Finding a balance between security and privacy is key and requires ongoing dialogue between all stakeholders. Changing organizational culture is also a challenge when adopting IoT technology. Staff need to be engaged and supportive of new technology, which may require changes in their work routines. This cultural change can be
challenging, especially in institutions with established practices and resistance to change. Reliability and maintenance of technology are important. IoT devices must be continuously maintained and managed to ensure their long-term reliability and effectiveness. This includes regular software updates, hardware checks, and necessary repairs. The reliability of IoT devices and the need for ongoing maintenance can be a significant operational challenge. Considering all these challenges, it is clear that the integration of IoT technology in education brings complex challenges. However, with proper attention and adequate resource allocation, the potential benefits of this technology could be enormous, helping to transforming the way education is managed and delivered.

CONCLUSIONS
Based on the results and discussion above, it can be concluded that the integration of IoT technology in the management of educational facilities and infrastructure shows great potential to increase the efficiency and quality of educational services. The integration of IoT in the management of educational facilities and infrastructure offers many benefits that can change the way schools operate and interact with students and staff. From increased efficiency and security to better asset management and customized learning environments, the transformational potential offered by IoT is enormous. Through the application of IoT, educational institutions can automate processes that previously required manual intervention, such as energy management, security systems, and asset monitoring, which contributes to reduced operational costs and increased security levels. The use of sensors and smart devices in IoT systems enables real-time data collection that supports evidence-based decision-making, ensures optimal quality of learning environments, and facilitates more efficient infrastructure maintenance.

REFERENCES


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