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Learnviro: An IoT-Based Innovation for Monitoring the Learning Environment

Ika Maryani [1*], Okimustava [2], Suyatno [1], Enung Hasanah [3]
[1] Doctoral Program in Education, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2] Physics Education, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[3] Master Program in Educational Management, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
*Corresponding Author: ika.maryani@pgsd.uad.ac.id

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ABSTRACT

Background: Aisyiyah Bantul's Leading Elementary School faces challenges in maintaining an optimal learning environment, particularly regarding temperature, humidity, and lighting. This community service program introduces Learnviro, an IoT-based solution for real-time environmental monitoring, enabling schools to make data-driven decisions to enhance learning conditions.
Contribution: Learnviro empowers teachers by providing real-time data, allowing them to make informed adjustments that support differentiated instruction. The system also improves school management by optimizing classroom conditions and infrastructure maintenance.
Method: The program consists of four stages: (1) collaboration with partner schools to assess needs, (2) installation of IoT devices in classrooms, (3) teacher training on interpreting and applying environmental data, and (4) continuous technical support. Data collection involved observations, interviews, and questionnaires, analyzed descriptively to evaluate the program's effectiveness.
Results: Learnviro effectively provided real-time environmental data, improving teachers' proficiency in utilizing IoT-based insights for classroom management. Students reported increased comfort and focus, while schools experienced better infrastructure maintenance through data-driven decision-making.
Conclusion: Learnviro has proven to be an effective tool for optimizing classroom conditions and empowering the school community. By integrating IoT technology into education, this initiative demonstrates the practical application of intelligent environmental monitoring in addressing real-world.

1. Introduction

Exemplary Elementary School Aisyiyah Bantul is a distinguished elementary school in Bantul Regency, Yogyakarta Special Region (DIY), renowned for its commitment to high-quality education and the integration of Islamic values. As the student population continues to grow, the school faces increasing challenges in maintaining optimal learning conditions. To address these challenges, Aisyiyah Bantul's Leading Elementary School requires innovative solutions to cultivate a conducive learning environment and enhance student academic achievement.

As an educational institution, the school is dedicated to fostering an optimal and inclusive learning environment for all students. However, a key challenge lies in the absence of adequate tools for precise and continuous monitoring of classroom environmental conditions. This limitation impedes the school's ability to ensure that learning spaces consistently meet the required standards for student comfort and academic performance.

In an effective learning environment, factors such as room temperature, humidity, air quality, and lighting play a critical role in shaping students' comfort and learning efficiency, ultimately influencing their academic performance and overall well-being [1], [2]. The physical learning environment, particularly temperature, humidity, and light intensity, has a significant impact on students' comfort and concentration levels [3]–[5]. Without proper regulation, these factors can lead to discomfort, thereby reducing learning effectiveness [6]. Given Indonesia's tropical climate, characterized by high temperatures and humidity, especially during midday, classroom conditions can become less conducive to learning, particularly during the dry and rainy seasons when humidity levels reach extreme levels.

To date, classroom condition monitoring in schools remains a manual and non-integrated process, resulting in a time-consuming and error-prone approach [7]. This undermines the effectiveness of environmental data collection for the learning environment, leading to a lack of up-to-date information that could guide decision-making aimed at improving the quality of the learning space. Accurate, real-time data is essential for facilitating evidence-based decision-making, particularly in efforts to enhance classroom comfort and efficiency [8], [9]. The absence of such data also impedes the establishment of differentiated learning, where students with diverse needs can learn in conducive environments. Inadequate monitoring of the learning environment can create disparities in students' learning experiences, especially for those who require specific accommodations [10]. The adoption of IoT-based monitoring technology offers a solution by providing more detailed data, such as temperature, humidity, and air quality, all of which play a pivotal role in supporting differentiated learning [11]. Unlike conventional monitoring methods, IoT allows automated, real-time data collection, reducing human error and enabling immediate responses to environmental changes [12], [13]. This system ensures that teachers and administrators can access reliable information to optimize classroom conditions efficiently. Furthermore, IoT integration in education

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represents an emerging technological advancement, offering a scalable solution that can be adapted to various school settings. An overview of the school's building conditions is presented in Figure 1.

Figure 1. The Building of Aisyiyah Bantul Exemplary Elementary School

As shown in Figure 1, the current structure of the developing building, which consists of two floors with an open space at the center, holds the potential to create a conducive learning environment. However, the school must address the possible fluctuations in conditions that could significantly affect the classroom environment. Initial observations and discussions with school officials have highlighted several key challenges that impact the learning environment at Aisyiyah Bantul Exemplary Elementary School. A primary concern is the instability of classroom temperatures, particularly during the day when air temperatures rise significantly. Such temperature fluctuations can cause discomfort among students, thereby hindering their ability to concentrate [14], [15]. Additionally, temperature fluctuations are often challenging to monitor effectively due to the absence of an automated system capable of providing real-time data on temperature conditions in each classroom. The second challenge pertains to the impact of humidity, which varies significantly being high during the rainy season and low during the dry season, on students' physical comfort during learning. Excessively high humidity levels can create a suffocating environment, leading to increased fatigue among students, while low humidity levels can result in dry air and deteriorate indoor air quality [16]. This issue is significant, as improper humidity levels can adversely affect students' respiratory health and ultimately diminish the quality of their learning experience [17]. The third challenge pertains to the intensity of light within the classroom, whether sourced from natural or artificial illumination. Such lighting is often non-uniform and does not meet the established standards for an optimal learning environment. Inadequate illumination, whether excessively bright or overly dim, may compromise students' ocular health and disrupt their concentration during academic activities [18]. Irregular natural lighting warrants particular attention, particularly in classrooms with limited access to daylight or during overcast conditions, which may result in suboptimal indoor environments.

Given the various challenges related to temperature, humidity, and light intensity, a monitoring system capable of providing real-time data for each classroom is essential. An Internet of Things (IoT)-based monitoring system offers an effective solution to these issues. By employing IoT sensors, data pertaining to temperature, humidity, and light intensity can be continuously monitored in real time for each classroom. Such a system not only aids educational institutions in identifying classrooms with inadequate environmental conditions but also supplies valuable information for informed decision-making [19], such as determining when to enhance ventilation or adjust lighting.

In the context of differentiated learning, data on classroom conditions plays a crucial role in adapting instructional approaches to optimize student comfort and engagement [20]. For instance, teachers can modify lesson plans when environmental conditions are found to be suboptimal, thereby fostering a learning environment that better accommodates students' individual needs. The integration of this technology represents a collaborative effort to establish a conducive, healthy, and comfortable setting for both teaching and learning.

Following extensive discussions, both the proposal team and the school principal identified these challenges as urgent priorities requiring immediate intervention. This program is not merely a technological intervention but also a collaborative effort between researchers and the school community. The active involvement of teachers, administrators, and students in data collection, analysis, and decision-making fosters a sense of ownership and sustainability. By equipping educators with training and resources, the initiative ensures that schools can independently manage and utilize IoT data for long-term improvements. By utilizing Internet of Things (IoT)-based technology, schools can gain access to accurate, real-time data for monitoring classroom environmental conditions. This data enables the dynamic adjustment of instructional activities to align with the prevailing physical environment, thereby enhancing the overall quality of education. Additionally, the data collected through the IoT system serves as a valuable resource for schools in formulating long-term strategies to improve learning environments. Such insights can inform evidence-based decision-making regarding classroom facility maintenance and infrastructure improvements, including the installation of air conditioning, additional ventilation, or enhanced lighting.

The urgency of community service Seeing the various challenges Aisyiyah Bantul's Leading Elementary School faces in creating an optimal learning environment, ranging from temperature fluctuations and extreme humidity to uneven lighting, an integrated, accurate, and sustainable solution is needed. The unavailability of real-time classroom environmental data not only hinders evidence-based decision-making but also directly impacts student comfort and learning achievement. In this context, research and development of an Internet of Things (IoT)-based monitoring system is urgent. This system acts as a technical aid and a foundation for learning management responsive to student needs. In other words, without proper technological intervention, the quality of learning is at risk of declining because environmental factors are not managed optimally. Therefore, this research must be carried out

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immediately to address data gaps, improve the quality of the learning environment, and support the implementation of student-centered learning.

Based on the issues outlined above, this program's Research and Community Service Contributes addresses two significant challenges: an integrated classroom environmental monitoring system and insufficient data to implement blended learning effectively. In addition to monitoring, Learnviro enables practical applications such as adjusting ventilation, optimizing lighting schedules, and informing classroom activities based on environmental data. This approach ensures that technology is implemented and actively improves classroom management, making the learning environment more adaptive and student-centered. Therefore, this initiative aims to support school teachers by equipping them with Learnviro, an IoT-based system that facilitates real-time classroom monitoring and improves learning conditions.

2. Method

The primary solution proposed to address the challenges of the learning environment at Aisyiyah Bantul Exemplary Elementary School is the implementation of Learnviro, a system for real-time classroom condition monitoring. This system is designed to track temperature, humidity, and light intensity, with each classroom equipped with IoT sensors capable of automatically measuring these parameters. The collected data will be transmitted to a monitoring platform accessible to teachers, school staff, and facility managers.

The implementation of this system will enable the school to obtain accurate and up-to-date information on classroom environmental conditions, allowing for prompt and informed decision-making to maintain an optimal learning environment. Necessary adjustments may include modifying ventilation, enhancing air conditioning, or improving lighting. The device was initially developed in the previous year and is now ready for reproduction and deployment as part of this community engagement initiative. Figure 2 presents the IoT-based learning environment monitoring device to be utilized in this program.

The implementation of this program followed four key stages: collaboration with partner schools, installation of IoT devices, teacher training, and continuous technical support. Learnviro utilized an IoT-based monitoring system consisting of DHT22 sensors for temperature and humidity, BH1750 for light intensity, and an ESP8266 microcontroller that transmitted data via MQTT to a cloud-based Firebase database. This setup enabled real-time access and visualization through a web dashboard. The teacher training was designed as an Educational Technology intervention, covering the operation of Learnviro, data interpretation for optimizing classroom conditions, and strategies for integrating environmental data into teaching practices.

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Figure 2. Learnviro

Several designated classroom areas will be equipped with IoT sensors capable of automatically measuring these parameters. The collected data will be transmitted to the monitoring platform (**https://sim.learnviro.id/**), which can be accessed by teachers, school staff, and facility managers. Through this system, the school will obtain accurate and up-to-date data on the environmental conditions of each classroom. This information enables the school to take immediate action to maintain an optimal learning environment, such as adjusting ventilation, enhancing air conditioning, or improving lighting. The methodology employed in this program is presented in Figure 3.

Figure 3 presents the program implementation process, which begins with team coordination with partner institutions, followed by the dissemination of the program to all teachers at the partner school. This is followed by the installation of devices in classrooms and verification of their internet connectivity. Subsequently, accounts are created for administrators, teachers, and students. The program also includes a two-day teacher training session, followed by a one-week classroom mentoring phase in selected classrooms. The final stage involves monitoring and evaluating the program's effectiveness in facilitating the learning process. Data collection is conducted using both qualitative and quantitative methods, incorporating interviews and semantic differential scale questionnaires.

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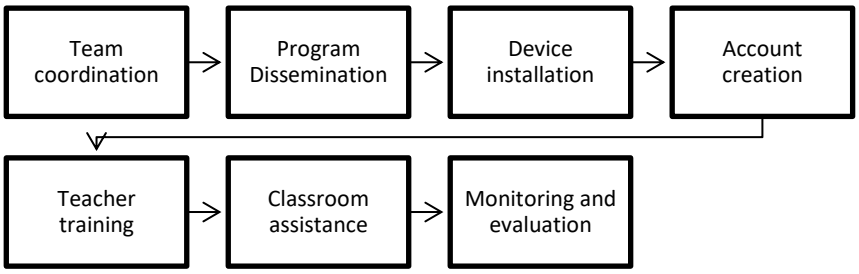

Figure 3. Program Implementation Method

3. Results and Discussion

This community service program successfully implemented an Internet of Things (IoT)-based monitoring system at the school to improve the comfort and quality of the learning environment. The outcomes of this implementation encompass several key aspects, as outlined below:

3.1. Installation of Learnviro in Classrooms

Learnviro has been installed in multiple classrooms to monitor three essential parameters: temperature, humidity, and light intensity. The data collected in real-time is integrated into a monitoring platform, accessible by both teachers and school administrators. The sensors are strategically positioned in each classroom to ensure that the collected data accurately reflects the overall environmental conditions. To ensure precision, the sensors were rigorously tested prior to installation, with careful consideration given to factors such as placement to prevent interference from student activities. Beyond classroom monitoring, the program significantly improved teachers' technological literacy. Prior to the training, only 35% of teachers reported familiarity with IoT-based monitoring tools. After the training, 85% expressed confidence in using the Learnviro platform for classroom management. This increase in digital competency enables teachers to sustain the system independently, reducing reliance on external technical support. Furthermore, teachers demonstrated an ability to integrate IoT data into lesson planning, reinforcing the role of technology in differentiated instruction. The installation process of Learnviro is depicted in Figure 4.

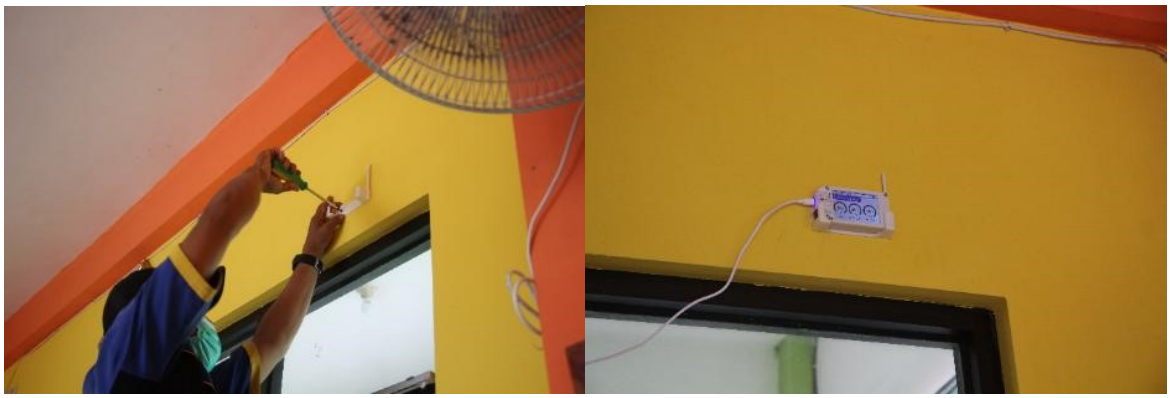

Figure 4. Learnviro Installation Process

The data collected by the sensors is automatically transmitted to a web-based platform (https://sim.learnviro.id/), which is accessible to both teachers and school administrators. This platform is designed with an intuitive user interface, enabling users to efficiently interpret real-time data.

3.2. Teacher Training on IoT Technology Understanding

Teachers and school staff have participated in training sessions to deepen their understanding of the IoT platform. As a result, they are now adept at interpreting the data presented in graphical form and analyzing the learning environment conditions based on the measured parameters. T Survey results showed that 90% of teachers agreed that real-time environmental monitoring helped them optimize classroom conditions, and 80% of students reported increased comfort during lessons. Testimonials from teachers highlighted how access to real-time data allowed them to adjust ventilation strategies and modify classroom layouts proactively. One teacher stated, 'I never realized how much temperature fluctuations affected students' focus until we had access to real-time data. This system has changed how we manage classroom conditions he collected data reveal variations in temperature, humidity, and lighting conditions within the classroom. For instance, daytime temperatures frequently exceed 30°C, particularly during the dry season. During the rainy season, humidity levels may surpass 80%, creating a muggy and uncomfortable environment for students. Furthermore, uneven natural lighting negatively impacts student visibility, especially in classrooms with limited ventilation.

Figure 5. Training on the Application of IoT for Monitoring Room Conditions

This program also underscores the importance of training teachers and school staff to maximize the potential of IoT technology. The training includes guidance on utilizing the IoT platform, with teachers being trained to access data presented in graphical form, which illustrates variations in temperature, humidity, and lighting, as shown in Figure 5. This data is subsequently employed to assess classroom conditions. The second phase of the training focuses on understanding the impact of environmental parameters, emphasizing their significance on student comfort. For instance, elevated temperatures can impair concentration, while inadequate lighting can lead to eye strain. Additionally, the training incorporates the integration

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of data into the learning process. Teachers are instructed on how to adapt teaching strategies based on environmental conditions. For example, temperature data can be used to determine when to schedule additional breaks if the classroom temperature becomes too high. At this stage, a total of 70 teachers actively participated in the training, as shown in Figure 6.

The semantic scale employed ranged from 1 to 7, with higher values indicating greater competence. The results of the training indicate that teachers' ability to integrate IoT into the planning, implementation, and evaluation of learning activities falls within the competence range of 3 to 6. Furthermore, teachers have begun to recognize the significance of the learning environment in influencing student academic performance. The analysis of teachers' competencies is presented in Figure 7.

Figure 6. A total of 70 elementary school teachers participated in the training

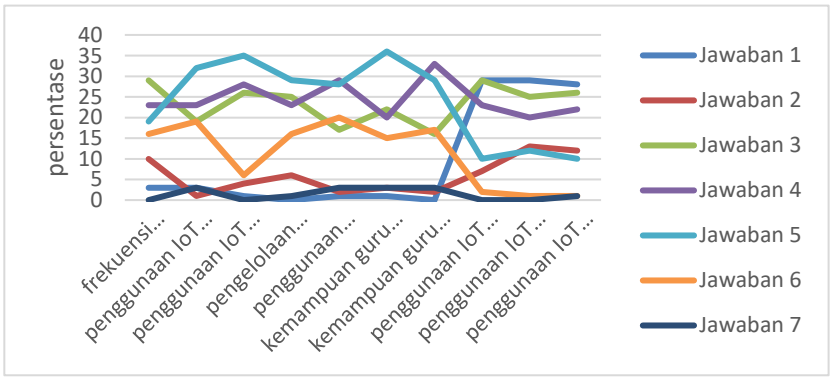

Figure 7. Results of the Analysis of Teachers' Ability to Implement IoT

3.3. Analysis of Learning Environment Data

The collected data reveal variations in temperature, humidity, and lighting conditions within the classroom. For instance, daytime temperatures frequently exceed 30°C, particularly during the dry season. During the rainy season, humidity levels may surpass 80%, creating a muggy and uncomfortable environment for students. Furthermore, uneven natural lighting

negatively impacts student visibility, especially in classrooms with limited ventilation. An example of the readings obtained from the Learnviro platform is presented in Figure 8.

Following system implementation, the collected data revealed noteworthy patterns in the learning environment at the observed school. During the daytime, particularly in the dry season, classroom temperatures frequently exceed 30°C, causing discomfort among students and potentially impairing their concentration. In the rainy season, humidity levels exceed 80%; while high humidity produces a muggy atmosphere, low humidity during the dry season results in a dry and uncomfortable environment. Furthermore, uneven natural lighting is a significant issue in several classrooms, with those having limited access to natural light often exhibiting substandard lighting intensity, especially under overcast conditions. These findings provide valuable insights into the challenges the school faces in establishing an optimal learning environment.

Figure 8. Example of Learnviro Readings Accessible on the Platform

3.4. Corrective Actions Based on IoT Data

Based on the IoT data, the school implemented several corrective measures. These measures included installing fans or ventilation systems to mitigate high classroom temperatures, adjusting student desk positions to optimize natural lighting, and rescheduling learning activities to better align with environmental conditions. These recommendations were developed from monitoring results and subsequent follow-up during mentoring sessions, as illustrated in Figure 9. To ensure the long-term sustainability of Learnviro, the school has initiated a partnership with local education authorities to secure funding for sensor maintenance and periodic upgrades. Additionally, an in-house technical support team

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comprising trained teachers has been established to troubleshoot minor issues. Plans are also in place to expand Learnviro's implementation to neighboring schools, leveraging its cost-effectiveness and scalability. Future development may include a mobile application for easier monitoring and integration with existing school management systems.

Based on the collected data, the school has implemented several measures to enhance the learning environment. To address elevated classroom temperatures, additional fans were installed and ventilation was improved in several classrooms, thereby facilitating better air circulation. Teachers also repositioned student desks to optimize natural lighting, relocating them from darker areas to positions closer to windows. Furthermore, when classroom temperatures were excessively high, activities requiring intense concentration were rescheduled to the morning, while more relaxed activities were allocated to the afternoon.

Figure 9. Training in Response to Classroom Condition Monitoring Results

The IoT system has proven effective in providing accurate, real-time data regarding the learning environment. This data enables the school to make evidence-based decisions, such as upgrading facilities or adjusting the learning schedule. Moreover, the system assists teachers in responding more effectively to environmental factors that affect student comfort. The implementation of IoT technology further supports differentiated instruction; with the available data, teachers can tailor their instructional strategies to meet the diverse needs of students. For instance, students who are more sensitive to high temperatures can be relocated to cooler classrooms (environmental differentiation) [20]. Such differentiated instruction fosters a more inclusive and adaptive learning experience [21].

The sustainability of this program depends on the school's capacity to maintain the IoT system. Consequently, technical training for teachers has been prioritized to ensure the optimal operation and utilization of IoT devices. This training has proven effective in enhancing teachers' abilities to integrate technology into their instructional practices [22]. Additionally, the school must budget for routine maintenance, including the replacement of malfunctioning

sensors, as the IoT system requires ongoing financial commitment [23]. The success of Learnviro presents an opportunity for broader adoption in schools with similar environmental challenges. Given its affordability and effectiveness, the system has potential for commercialization as a low-cost IoT solution for educational institutions. Collaboration with educational technology startups could further refine and distribute the product on a larger scale. This initiative not only enhances school infrastructure but also contributes to the digital transformation of education in Indonesia, aligning with national priorities for smart classrooms and sustainable learning environments.

Despite its successes, the implementation of this program has encountered several challenges, including budget constraints, technological limitations, and variable student responses to environmental changes. The installation and maintenance costs associated with the IoT system are relatively high, necessitating additional financial support from governmental agencies or industrial partners [24]. Some teachers initially had difficulty understanding IoT data, especially in real-time data analysis, indicating the need for further support in the form of technical guidance [25]. Initially, some teachers experienced difficulties in interpreting IoT data, particularly in the analysis of real-time data, indicating the need for further technical guidance [26].

Although classroom conditions have improved, students require time to adapt to the changes, such as repositioned desks or the use of additional fans, which may temporarily affect their learning comfort [27]. Support from the school, including clear explanations and gradual adaptation strategies, is essential for overcoming these challenges. The program has had a significant positive impact on the quality of education at Aisyiyah Bantul Exemplary Elementary School. Students have reported increased comfort during the learning process, and teachers have found the program beneficial in planning their instructional strategies. Furthermore, the data collected have provided a basis for evaluating and developing future school infrastructure.

4. Conclusion

Based on the implementation of Learnviro at Aisyiyah Bantul Exemplary Elementary School it can be concluded that this IoT-based system effectively facilitates real-time monitoring of the learning environment. The data produced enable the school to make evidence-based decisions to enhance the comfort and quality of classroom spaces. Moreover, the teacher training provided has improved their ability to integrate technology into differentiated instruction. Overall, this implementation has yielded positive outcomes for both student comfort and the effectiveness of the learning process. However, the sustainability of the program depends on ongoing financial support for system maintenance and continuous training. With proper management, Learnviro can serve as a sustainable model for innovation in enhancing the quality of education in Indonesia.

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However, several limitations should be acknowledged. The study was conducted within a single institutional context, which may limit the generalizability of the findings to other educational settings with different infrastructure, resources, or climate conditions. Furthermore, while improvements in teacher competence and classroom management were reported, the long-term impact of Learnviro on student learning outcomes and academic achievement has not yet been systematically evaluated. Future research should consider conducting longitudinal studies across diverse school environments to examine the sustained impact of IoT-based monitoring on educational outcomes. Additionally, integrating other environmental parameters, such as CO_2 levels or ambient noise, could offer a more holistic view of the learning environment. Exploring adaptive learning strategies that dynamically respond to real-time environmental data may also enhance instructional effectiveness. These future directions will be instrumental in strengthening the role of smart technology in promoting equitable, student-centered, and sustainable learning environments.

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