IoT-Based Smart Class System

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ABSTRACT

The rapid development of Internet of Things (IoT) technology has significantly transformed various sectors, including education. This study proposes an IoT-Based Smart Class System designed to enhance the effectiveness, efficiency, and interactivity of the learning environment. The proposed system integrates IoT devices such as sensors, microcontrollers, and networked actuators to monitor and control classroom conditions, including lighting, temperature, occupancy, and learning equipment usage in real time. Data collected from these devices are transmitted to a centralized platform for processing, visualization, and decision support. The system enables automated classroom management, improves energy efficiency, and supports data-driven decision-making for educators and administrators. Experimental results and system evaluation indicate that the implementation of the IoT-based smart classroom improves learning comfort, optimizes resource utilization, and provides a scalable solution for modern educational environments. The findings demonstrate that IoT technology has strong potential to support smart education initiatives and the development of intelligent learning spaces.

Keyword : Internet of Things (IoT); Smart Classroom; Smart Education; Classroom Automation; Educational Technology

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1. INTRODUCTION

The rapid advancement of digital technology has significantly reshaped the educational landscape, particularly with the emergence of smart learning environments. Traditional classroom settings often rely on manual management of facilities and learning resources, which can lead to inefficiencies in energy consumption, limited adaptability to student needs, and a lack of real-time data to support instructional and administrative decision-making. As educational institutions increasingly adopt digital transformation strategies, the integration of intelligent systems has become a critical requirement to enhance learning quality and operational efficiency.

The Internet of Things (IoT) has emerged as a key enabling technology for the development of smart environments by allowing physical devices to be interconnected, monitored, and controlled through the internet. In the context of education, IoT technology enables the deployment of sensors, actuators, and embedded systems to collect real-time data related to classroom conditions, such as temperature, lighting, occupancy, and equipment usage. This data-driven approach provides valuable insights that can support automated classroom management, improve learning comfort, and optimize the utilization of educational resources.

Despite the growing interest in smart classrooms, many existing implementations focus primarily on individual components, such as smart attendance systems or energy monitoring, without providing an integrated and scalable solution. Moreover, the lack of centralized control and real-time analytics limits the potential benefits of IoT adoption in educational environments. These challenges highlight the need for a comprehensive IoT-based smart class system that seamlessly integrates monitoring, control, and data analysis functionalities within a unified platform.

This study proposes an IoT-Based Smart Class System designed to address these challenges by integrating IoT devices, communication networks, and a centralized management platform. The system aims to automate classroom operations, enhance energy efficiency, and support data-driven decision-making for educators and administrators. By leveraging real-time data and intelligent control mechanisms, the proposed system contributes to the development of adaptive and sustainable learning environments.

2. RESEARCH METHOD/MATERIAL AND METHOD/LETERATURE REVIEW

The concept of smart classrooms has gained increasing attention as part of the broader development of smart education and intelligent learning environments. Smart classrooms aim to enhance teaching and learning processes by integrating digital technologies, automation, and data-driven decision support systems. Previous studies have shown that smart learning environments can improve student engagement, learning comfort, and operational efficiency through the use of advanced technologies such as cloud computing, artificial intelligence, and the Internet of Things (IoT).

Several studies have explored the application of IoT technology in educational settings. IoT-based systems have been widely used for attendance monitoring, environmental control, energy management, and classroom security. Sensors such as temperature, humidity, light intensity, and motion detectors are commonly deployed to monitor classroom conditions in real time. The collected data are transmitted through wireless communication protocols to centralized platforms, enabling remote monitoring and automated control. These approaches have demonstrated potential in improving energy efficiency and maintaining optimal learning conditions.

Other research has focused on smart classroom management systems that integrate IoT with cloud-based platforms and data analytics. Such systems allow educators and administrators to access real-time information about classroom usage, environmental conditions, and equipment status. However, many existing solutions are limited in scope, addressing only specific functionalities without offering a comprehensive and scalable architecture. Additionally, some implementations lack real-time automation capabilities, relying instead on manual intervention or post-processing analysis.

Furthermore, challenges related to system interoperability, scalability, and data integration remain significant issues in IoT-based smart classroom development. Differences in hardware platforms, communication protocols, and data formats often hinder seamless system integration. These limitations indicate the need for an integrated IoT-based smart class system that combines environmental monitoring, automated control, and centralized data management within a unified framework.

Based on the reviewed literature, it can be concluded that while IoT technology has strong potential to support smart classrooms, there is still a research gap in developing a holistic, efficient, and scalable smart class system. This study addresses this gap by proposing an integrated IoT-based smart classroom architecture designed to improve learning comfort, optimize resource utilization, and support data-driven decision-making.

A. System Architecture

The proposed smart class system is composed of three main layers: the sensing layer, the network layer, and the application layer. The sensing layer consists of IoT devices, including environmental sensors (temperature, humidity, light intensity), motion sensors, and microcontroller units responsible for data acquisition and local processing. These devices continuously collect real-time data related to classroom conditions and usage.

The network layer facilitates data transmission between IoT devices and the central platform using wireless communication technologies such as Wi-Fi or MQTT-based protocols. This layer ensures reliable and real-time data exchange, enabling remote monitoring and control of classroom facilities.

B. Materials and Tools

The hardware components used in this study include microcontroller boards, environmental sensors, actuators, and wireless communication modules. The software components consist of embedded firmware for data acquisition, a cloud-based database for data storage, and a web-based interface for system monitoring and control. Data processing and visualization are performed using appropriate programming frameworks and data analytics tools.

C. Data Collection and Processing
Data are collected continuously from the deployed sensors during classroom activities. The acquired data include environmental parameters and occupancy information, which are transmitted to the central platform in real time. Data preprocessing is conducted to remove noise and handle missing values before further analysis. The processed data are then used to trigger automated control actions and to generate reports for system evaluation.

D. System Evaluation
The performance of the proposed IoT-based smart class system is evaluated based on several criteria, including system reliability, response time, energy efficiency, and user satisfaction. Experimental testing is conducted in a classroom environment to assess the system's ability to maintain optimal learning conditions and to reduce energy consumption. The evaluation results are analyzed to determine the effectiveness and practicality of the proposed system.

3. RESULTS AND DISCUSSION

A. Hardware Design Results
The results of the hardware design in this study can be seen in the components used, namely the ESP8266, flame sensor, MQ-135 smoke sensor, PIR Module sensor, buzzer, LED, ESP32-Cam Camera Sensor and WiFi module. The overall testing of the designed tools can be seen in Figure 1 below:

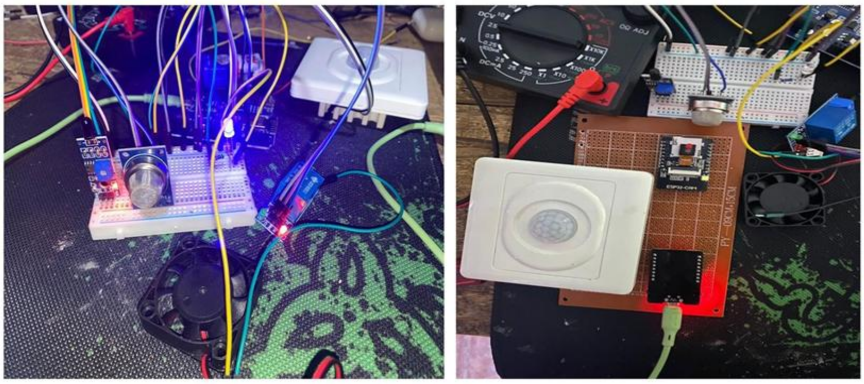


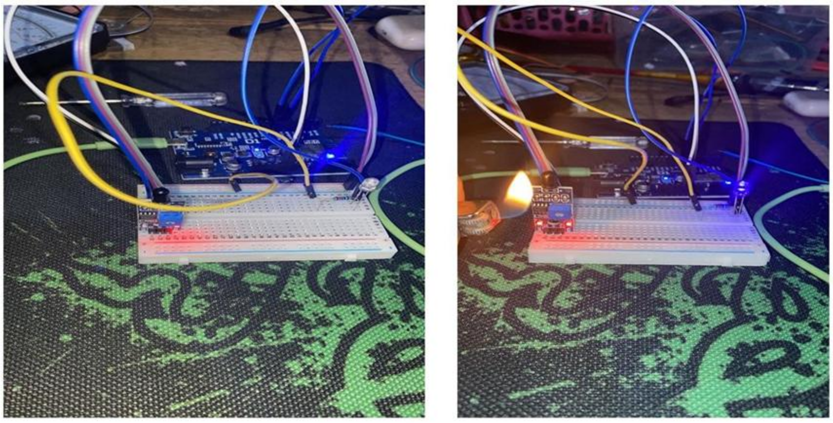
Fig 1. Overall Tool Testing

In Figure 1 above, the hardware design consists of several main components that are interconnected and integrated with one another. The ESP8266 functions as a microcontroller that can connect to a WiFi network. This microcontroller processes data from the installed sensors and controls the output, which can be read via a serial monitor.

In the sensor integration used in this test, the flame sensor is connected to digital pin D1 of the ESP8266 and functions to detect the presence of fire in the classroom. When this sensor detects a fire, this information is processed by the ESP8266. The MQ-2 smoke sensor, connected to analog pin A0 of the ESP8266, is used to measure the concentration of smoke in the air. This sensor is essential for detecting smoke from fires or cigarette smoke, which can disrupt the teaching and learning process. A buzzer and LED connected to digital pin D3 of the ESP8266 serve as alarm indicators. If the flame or smoke sensor detects a danger, the buzzer will sound and the red LED will illuminate as an early warning signal.

Next, the PIR (Passive Infrared) sensor is connected to the ESP8266's D2 digital pin and functions to detect motion in the room. This motion detection is then integrated with the ESP32-Cam Camera Sensor which will capture images of students as part of the automatic attendance system. When the PIR sensor detects motion, the camera will automatically take a photo and send the image to the Telegram BotFather application managed by the lecturer. The WiFi module integrated in the ESP8266 is used to send data to the Blynk.cloud platform for real-time monitoring and sending notifications via students' mobile phones.

B. API Sensor Output Testing (Flame Sensor)
Testing the output of the API (Flame Sensor) sensor aims to determine the condition of the sensor's output and its ability to detect the presence of fire. Figure 2 below shows the implemented test configuration.



a) Pengujian Flame Sensor Tanpa API b) Pengujian Flame Sensor Dengan API

Fig 2. API (Flame Sensor) Testing

Based on Figure 2. above, the API sensor was tested in two scenarios: testing without API and testing with API. In the testing without API, the flame sensor was positioned in a room where there was no fire. The purpose of this test was to ensure that the sensor did not provide a signal or output when no fire was detected.

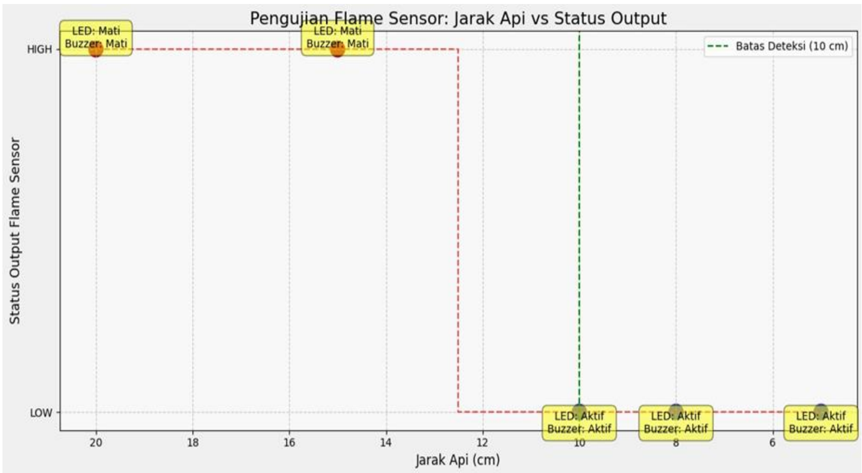
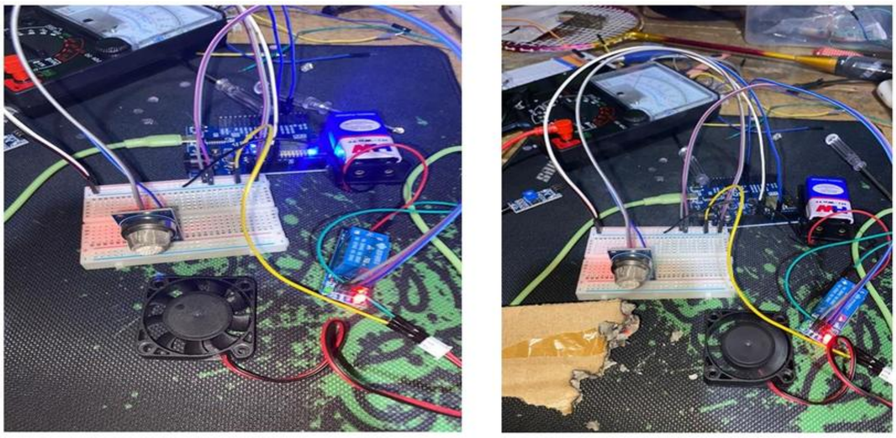


Fig 3. API Sensor Testing

In tests with the flame 20 cm from the sensor, the sensor output was recorded as HIGH, indicating no fire was detected. In tests with a distance of 5 to 10 cm, the sensor output status changed to LOW, indicating fire detection. These results indicate that the flame sensor is capable of detecting fire at a maximum distance of 10 cm.

C. MQ-2 Smoke Sensor Output Testing
The output testing of the MQ-2 smoke sensor aims to determine the sensor's ability to detect smoke concentrations in the air. The MQ-2 smoke sensor is connected to the analog pin (A0) on the ESP8266, which outputs an analog voltage value based on the detected smoke concentration. The results of the MQ-2 smoke sensor test can be seen in Figure 4 below:



a) Pengujian Flame Sensor Tanpa Asap b) Pengujian Flame Sensor Dengan Asap

Fig 4. MQ-2 Smoke Sensor Output Testing

Based on Figure 4.3 above, it can be seen that the smoke sensor output test was carried out in 2 incidents, where incident 1. Testing was carried out without smoke and incident 2. Testing was carried out by providing smoke. In smoke-free testing, the MQ-2 sensor is positioned in a smoke-free room. The purpose of this test is to ensure that the sensor does not produce a signal or output when no smoke is detected.

4. CONCLUSION

Berdasarkan uraian dari hasil dan pembahasan yang sudah dibahas di atas, dapat disimpulkan bahwa perancangan dan implementasi Sistem Smart Class berbasis Internet of Things (IoT) telah berhasil dilakukan dengan baik. Sistem ini dirancang untuk mengatasi permasalahan absensi manual dan meningkatkan keamanan serta kenyamanan lingkungan belajar di kelas. Menggunakan teknologi pengenalan wajah dan deteksi gerakan, sistem absensi otomatis terbukti efektif dalam meningkatkan efisiensi dan akurasi proses absensi mahasiswa. Sensor-sensor yang diintegrasikan dalam sistem, seperti sensor asap MQ-2, Flame sensor, ESP32-Cam, dan sensor PIR, bekerja sesuai dengan fungsi masing-masing dalam mendeteksi keberadaan api, asap, dan gerakan, serta mengirimkan data secara real-time melalui aplikasi Blynk.cloud dan Telegram BotFather.

Tests show that the system is able to detect the presence of smoke with a PPM value above the threshold and activate the fan to reduce the smoke concentration, as well as provide early warnings via LEDs and buzzers when a fire is detected. The integration of IoT technology in the Smart Class concept not only increases the efficiency of the attendance process but also makes a significant contribution in monitoring and controlling the condition of the learning environment automatically. Thus, this study successfully proves that the implementation of an IoT-based Smart Class system can provide an effective solution to improve the quality and safety of the teaching and learning process in the classroom.
Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

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