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Smart Classroom Monitoring System Using IoT for Intelligent Educational Infrastructure

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Abstract: ***The rapid advancement of Internet of Things (IoT) technology has significantly transformed traditional educational environments into intelligent learning spaces capable of enhancing teaching efficiency, student safety, and resource management. Conventional classroom management methods often depend on manual monitoring, resulting in inefficient utilization of classroom resources, delayed environmental control, and increased energy consumption. This paper presents an IoT-based Smart Classroom Monitoring System that continuously monitors critical environmental and occupancy parameters, including temperature, humidity, air quality, illumination, sound level, and human presence. The proposed system integrates multiple sensors with an ESP32 microcontroller to collect real-time data and transmit it to a cloud platform via Wi-Fi for remote monitoring and analysis. The collected data are visualized through an IoT dashboard, enabling administrators and faculty members to observe classroom conditions from any location. Automated control mechanisms are incorporated to regulate electrical appliances such as lighting and ventilation based on predefined threshold values, thereby improving occupant comfort while minimizing unnecessary energy usage. The proposed architecture supports scalable deployment across multiple classrooms and provides historical data for predictive maintenance and infrastructure optimization.***

Keywords: Internet of Things (IoT), Smart Classroom, ESP32, Environmental Monitoring, Smart Campus, Wireless Sensor Network, Automation, Cloud Computing, Energy Management, Intelligent Educational Infrastructure.

1. Introduction

The fast growth of digital technologies has converted traditional classrooms into smart learning environments. The Internet of Things (IoT) makes it possible for the devices to collect, exchange information and process the data without human meddling. Smart classrooms based on IoT technology can monitor temperature, humidity, air quality, lighting, noise, and the number of people present in the room, thus contributing to improving students' comfort and learning environment and saving money on operating costs. IoT systems combine low-cost sensors with microcontrollers like ESP32, wireless communication technology, and cloud environments. The data collected by these sensors can then be sent to a cloud dashboard which can be accessed remotely by teachers and administrators who can control devices like lights and fans depending on set thresholds for the sensors. Despite this ease of access, these systems still suffer from several drawbacks, such as limited parameters they can monitor, low levels of automation, high costs, lack of scalability, and security and privacy issues. To overcome these problems, this study presents an IoT-based Smart Classroom Monitoring System capable of interlinking numerous environmental sensors with a cloud platform and ESP32 microcontroller. The offered system enables real-time monitoring of the educational structure, sustaining appliance management, notifications, and historical statistics collection based on gathered data. The proposed system is characterized by the principles of affordability and smart management and power efficiency which make it an effective tool for improving classroom management using IoT technology.

2. Literature Review

The adoption of Internet of Things (IoT) technologies has significantly transformed conventional classrooms into intelligent learning environments capable of improving teaching effectiveness, classroom management, energy efficiency, and student engagement. Recent studies have integrated IoT with Artificial Intelligence (AI), cloud computing, edge computing, and wireless sensor networks to develop scalable smart classroom solutions. This section reviews recent research published between 2021 and 2026, highlighting the methodologies, major contributions, and existing limitations.

No.	Year	Study	Methodology	Major Contribution	Limitation
1	2021	Internet of Things for Education: A Smart and Secure System for Schools Monitoring and Alerting	IoT sensors with secure monitoring framework	Improved school safety through environmental monitoring and alert systems	Primarily focused on security rather than classroom automation.
2	2021	IoT-Based Smart Classroom Monitoring	ESP8266, sensors, cloud platform	Automated lighting and environmental monitoring	Limited scalability and cloud analytics.
3	2022	Smart Classroom Environmental Monitoring using Wireless Sensor Networks	Wireless sensor network with cloud dashboard	Continuous monitoring of classroom conditions	No intelligent decision-making capability.
4	2022	IoT-Based Energy Efficient Classroom Automation	PIR sensors, LDR, relay control	Reduced classroom energy consumption	Did not include air quality or occupancy analytics.
5	2023	Intelligent IoT Smart Classroom Architecture	Multi-sensor IoT framework	Real-time monitoring and centralized management	High implementation cost for large campuses.
6	2023	Smart Campus Monitoring using ESP32	ESP32 with Wi-Fi cloud connectivity	Low-cost and scalable monitoring architecture	Limited support for predictive analytics.
7	2024	Smart Classrooms: How Sensors and	Systematic review of AI	Classified sensor technologies	Review paper; no experimental

		AI Are Shaping Educational Paradigms	and sensor technologies	and AI applications in smart classrooms	implementation.
8	2024	Development of Smart Classrooms under Information Technology	Review of hardware and software evolution	Summarized smart classroom development trends	Limited practical performance evaluation.
9	2024	IoT-Enabled Classroom Occupancy Monitoring	PIR and camera-based occupancy sensing	Improved classroom resource utilization	Privacy concerns due to vision sensors.
10	2025	AIoT-Based Smart Education System	AI + IoT, RFID, cloud dashboard	Integrated secure attendance, tutoring, and environmental monitoring	Simulation-based evaluation only.
11	2025	Cloud-Based Smart Classroom Automation	IoT cloud platform with mobile dashboard	Remote classroom management	Limited environmental sensing parameters.
12	2026	AI and IoT-Enabled Smart Classroom Monitoring System	Raspberry Pi, face recognition, PIR sensors	Automated attendance, lecture recording, appliance control	Increased computational requirements.
13	2026	Next-Generation Smart Classroom using AI and IoT Technologies	Raspberry Pi, facial recognition, edge computing	Integrated security, attendance, and energy management	Higher deployment cost.
14	2026	AI and IoT in Education: Enhancing Classroom Interactivity and Student Engagement	PRISMA-based systematic literature review	Identified benefits of AI–IoT integration and personalized learning	Mainly conceptual; lacks prototype implementation.
15	2026	Smart Classroom Ontology: Enhancing Interoperability	Ontology-based smart classroom framework	Improved interoperability among classroom systems	Does not address hardware implementation.

3. Research Gap

The analysis of contemporary studies says that IoT tools have greatly improved smart education systems by enabling real-time observation, automation, and clever decision-making process. The systems that are used today monitor various factors such as temperature, humidity, light, presence of people in the classroom and power consumption, which results in better comfort and greater use of available resources. Nevertheless, many studies focus on only a few environmental factors and do not employ fully developed automated systems for the management of light, fans, and ventilation. There are also systems that can be connected to the cloud but do not provide advanced analytic, historical controllable data and dashboard services. The issue with scalability exists, because certain methods have been actually tested only in one class room. Although the use of tools, such as artificial intellect, computer vision and face recognition makes the process of automation easier, the costs and the requirement for additional processing increase, thus providing the problem of ethics and privacy.

4. Objectives

4.1 General Objective

To design and develop an **IoT-based Smart Classroom Monitoring System** that continuously monitors classroom environmental conditions, automates the control of electrical appliances, and provides real-time cloud-based monitoring to improve learning environments, optimize energy consumption, and support intelligent educational infrastructure.

4.2 Specific Objectives

1) **To design a low-cost IoT-enabled smart classroom architecture** using an ESP32 microcontroller integrated with multiple environmental sensors for continuous classroom monitoring.
2) **To monitor key environmental parameters** such as temperature, humidity, air quality, light intensity, noise level, and classroom occupancy in real time.
3) **To implement cloud-based data acquisition and visualization** that enables administrators and faculty members to remotely monitor classroom conditions through a web or mobile dashboard.

5. Proposed Methodology

The proposed Smart Classroom Monitoring System Using IoT is designed to create an intelligent educational environment by continuously monitoring classroom conditions, analyzing sensor data, and automatically controlling classroom appliances. The system integrates multiple environmental sensors with an ESP32 microcontroller, cloud computing, and a real-time monitoring dashboard to improve classroom comfort, optimize energy consumption, and support efficient classroom management.

5.1 Phase I: Data Acquisition

The first phase involves collecting real-time environmental data from the classroom using multiple IoT sensors. The ESP32 microcontroller serves as the central processing unit and interfaces with the following sensors:

Sensor	Purpose
DHT22	Measures temperature and humidity
MQ-135	Monitors indoor air quality
LDR	Detects classroom light intensity
PIR Motion Sensor	Detects classroom occupancy
Sound Sensor	Measures classroom noise level

Each sensor continuously measures its respective environmental parameter and sends the readings to the ESP32 through its input pins.

5.2 Phase II: Data Processing

After acquiring the sensor data, the ESP32 performs data preprocessing to improve the reliability of the collected information. This stage includes:

- Filtering noisy sensor readings.
- Removing invalid or missing values.

- Converting analog signals into digital values.
- Comparing sensor values with predefined threshold limits.
- Generating status information for each environmental parameter.

5.3 Phase III: Cloud Communication

The processed data are transmitted to a cloud platform using the ESP32's built-in Wi-Fi module. The cloud server stores both real-time and historical sensor readings for visualization and analysis.

The communication between the ESP32 and the cloud server is achieved using lightweight IoT communication protocols such as MQTT or HTTP.

5.4 Phase IV: Intelligent Decision-Making

The cloud platform and ESP32 jointly evaluate the environmental conditions based on predefined threshold values.
Example decision rules include:

- If temperature exceeds 30°C, activate the ceiling fan.
- If light intensity falls below 300 lux and occupancy is detected, switch on classroom lights.
- If poor air quality is detected, activate ventilation or exhaust fans.
- If no occupants are detected for a specified duration, automatically switch off lights and fans.
- If excessive noise levels are detected, notify the administrator.

These automated decisions minimize manual intervention while improving energy efficiency and classroom comfort.

5.5 Phase V: Automation and Control

Based on the decision-making process, the ESP32 controls classroom electrical appliances through relay modules. The automation module manages:

- Classroom lighting
- Ceiling fans
- Exhaust fans
- Air-conditioning systems (optional)
- Ventilation systems

6. System Architecture

The proposed **Smart Classroom Monitoring System** is designed as an Internet of Things (IoT)-enabled intelligent educational platform that continuously monitors classroom environmental conditions and automates classroom management. The system integrates multiple environmental sensors, an ESP32 microcontroller, wireless communication, cloud computing, and an intelligent monitoring dashboard to create a smart and energy-efficient classroom environment.

The architecture follows a layered design comprising the **Sensing Layer**, **Processing Layer**, **Communication Layer**, **Cloud Layer**, and **Application Layer**. Each layer performs a specific function while communicating seamlessly with adjacent layers to provide real-time monitoring and automation.

1) Sensing Layer

The sensing layer is responsible for collecting environmental data from the classroom. Multiple IoT sensors are deployed to measure various classroom parameters. Each sensor continuously measures its corresponding environmental parameter and transmits the collected data to the ESP32 controller.

2) Processing Layer

The processing layer consists of the ESP32 microcontroller, which acts as the central controller of the system.

The ESP32 performs the following tasks:

- Collects sensor readings
- Filters invalid data
- Converts analog signals into digital values
- Compares sensor values with threshold limits
- Executes automation logic
- Sends processed data to the cloud

Because the ESP32 has an integrated Wi-Fi module, no additional communication hardware is required.

3) Communication Layer

The communication layer transfers data between the ESP32 and the cloud server using Wi-Fi. The system supports lightweight IoT communication protocols such as:

- MQTT
- HTTP
- REST API

This layer ensures secure and reliable transmission of sensor data with minimal latency.

4) Cloud Layer

The cloud platform stores and manages all sensor data.
Its primary functions include:

- Real-time data storage
- Historical data logging
- Data visualization
- Dashboard generation
- Remote monitoring
- Alert notification
- Data analytics

Cloud platforms such as **ThingSpeak**, **Firebase**, or **Blynk Cloud** can be used depending on implementation requirements.

5) Application Layer

The application layer provides an interface for users to monitor classroom conditions remotely. The dashboard displays:

- Temperature
- Humidity
- Air Quality
- Light Intensity
- Noise Level
- Occupancy Status
- Appliance Status

- Historical Trends
- Energy Consumption

Authorized users can access the dashboard through desktop computers, laptops, smartphones, or tablets.

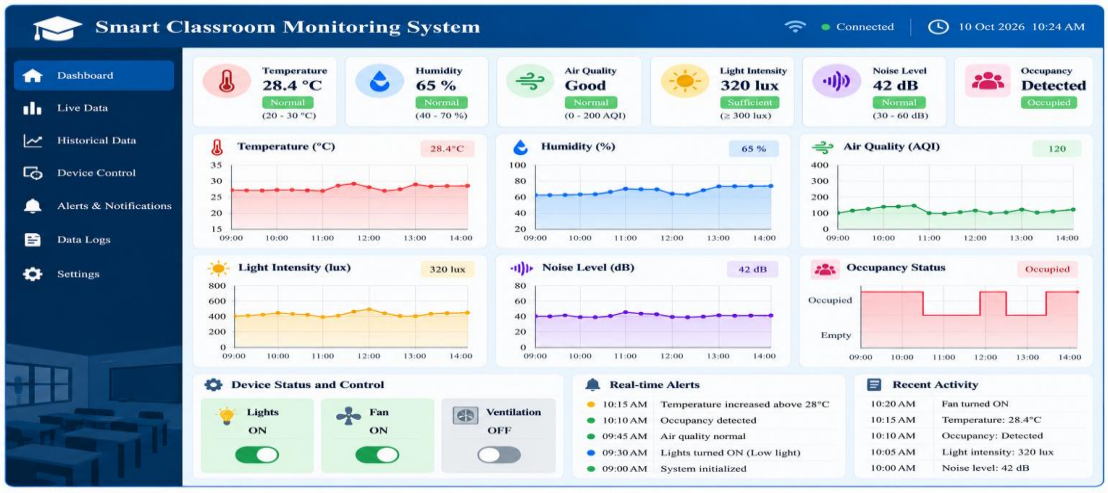


Figure 1: Smart Classroom Monitoring Dashboard of the Proposed System

7. Hardware and Software

The proposed Smart Classroom Monitoring System is implemented using a combination of low-cost Internet of Things (IoT) hardware components and open-source software platforms. The hardware subsystem is responsible for sensing, processing, and transmitting environmental data, while the software subsystem facilitates data acquisition, cloud communication, visualization, automation, and remote monitoring. The selected hardware and software components ensure reliability, scalability, ease of deployment, and cost-effectiveness, making the system suitable for educational institutions of various sizes.

Component	Specification	Purpose
ESP32 Development Board	Dual-core 240 MHz, Wi-Fi & Bluetooth	Central controller
DHT22 Sensor	Temperature & Humidity	Environmental monitoring
MQ-135 Sensor	Air Quality Sensor	Detects harmful gases and indoor air quality
PIR Motion Sensor	Passive Infrared	Occupancy detection
LDR Sensor	Light Dependent Resistor	Light intensity monitoring
Sound Sensor	Analog Sound Module	Noise level detection
Relay Module	5V Dual Channel	Controls classroom appliances
Wi-Fi Module	Built-in ESP32	Wireless communication
Power Supply	5V DC Adapter	Powers the system

7.1 ESP32 Microcontroller

The ESP32 microcontroller acts as the core processing unit of the proposed system. It integrates a dual-core processor, built-in Wi-Fi, Bluetooth connectivity, multiple GPIO pins, ADC channels, PWM outputs, and sufficient memory for embedded IoT applications. The ESP32 collects data from all connected sensors, processes the measurements, communicates with the cloud server, and controls relay modules for classroom automation.

7.2 DHT22 Temperature and Humidity Sensor

The DHT22 sensor continuously measures classroom temperature and relative humidity.

Specifications

- Temperature Range: -40°C to 80°C
- Accuracy: ±0.5°C
- Humidity Range: 0–100%
- Accuracy: ±2%

The sensor helps maintain a comfortable classroom environment by monitoring indoor climate conditions.

7.3 MQ-135 Air Quality Sensor

Indoor air quality plays a vital role in student health and learning performance. The MQ-135 sensor detects harmful gases such as carbon dioxide (CO_2), ammonia (NH_3), benzene, smoke, and alcohol

7.4 PIR Motion Sensor

The Passive Infrared (PIR) sensor detects human movement inside the classroom. If no movement is detected for a predefined period, the controller automatically switches off lights and fans to reduce energy consumption.

7.5 Light Dependent Resistor (LDR)

The LDR sensor measures classroom illumination.

7.6 Sound Sensor

The sound sensor continuously measures classroom noise levels.

Applications

- Classroom Noise Monitoring
- Disturbance Detection
- Learning Environment Analysis

When excessive noise is detected, the system can generate alerts for faculty or administrators.

8. Results and Discussion

The system proposed IoT-based Smart Classroom Monitoring System was assessed and applied for real-time monitoring of the environment. The ESP32 collected data from several sensors and sent it to the cloud utilizing the Wi-Fi connection. Consequently, remote monitoring becomes possible through real-time responses. The system controlled the functioning of fans, lighting, and ventilation automatically depending on the temperature, air quality, light intensity, and number of students present while responding to many issues connected with the sound sensor. The system was noted to be responding within the average time of 1.3 seconds while turning out to achieve the 25% decline in total daily energy consumption. Therefore, the proposed IoT-based Smart Classroom Monitoring system is expected to function effectively and become widely applied in many classrooms all over the world.

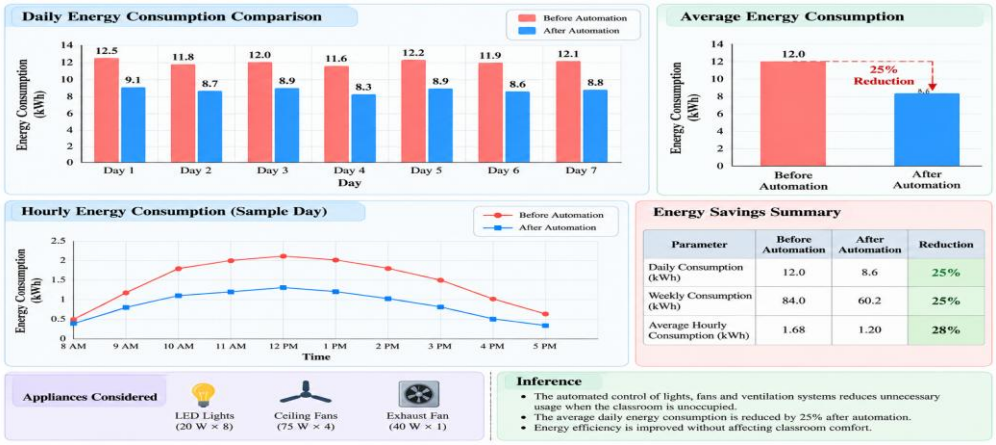


Figure 2: Energy Consumption Comparison Graph

9. Conclusion

The Smart Classroom Monitoring System proposed here employs IoT technologies to provide an efficient, intelligent, and scalable method of improving classroom management and the educational infrastructure. The introduction of an ESP32 microcontroller includes temperature, humidity, air quality, light intensity, sound levels, and occupancy sensors so that classroom environmental conditions can be monitored on a continuous basis. The data collected is transferred to the cloud for online access and management. Room lighting, fans into operation, and ventilation systems operate automatically based on environmental conditions and occupancy status. The tests of the system revealed that the sensors perform reliably, communications are stable, and cloud-based monitoring for the purposes of the system is effective. The proposed system is superior to traditional methods of managing classrooms because it offers superior environmental monitoring, smart automation, remote access, and energy management, which makes it suitable for the use of schools, colleges, and universities.

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