Online-Journals.org

iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 19 No. 24 (2025) | OPEN ACCESS

https://doi.org/10.3991/ijim.v19i24.58885

PAPER

Smart Classroom IoT-Based Android for Temperature and Humidity Monitoring to Enhance Student Learning Comfort

Dony Novaliendry(✉), Yudhi Diputra, Irma Yulia Basri, Ihsanul Insan Aljundi, Frans Surya Pati Harau

Universitas Negeri Padang, Padang, Indonesia

dony.novaliendry@ft.unp.ac.id

ABSTRACT

This study presents an innovative Smart Classroom IoT system based on the Android platform for monitoring temperature and humidity to enhance student learning comfort. The system integrates an Arduino microcontroller, DHT22 temperature-humidity sensors, and a dedicated Android mobile application for real-time environmental monitoring and control. The system automatically monitors ambient temperature and humidity conditions in classrooms and provides notifications to educational staff when environmental parameters exceed optimal ranges. Performance evaluation demonstrates significant improvements in environmental monitoring accuracy (±0.5°C precision), user satisfaction (4.6/5.0 rating), and energy efficiency through intelligent climate control recommendations. The Android-based monitoring interface enables remote access to environmental data, historical trend analysis, and proactive environmental management. The system successfully maintained optimal learning conditions by providing continuous environmental monitoring and timely alerts for manual intervention when needed. This study contributes to creating comfortable learning environments while supporting energy-efficient facility management in educational institutions.

KEYWORDS

smart classroom, IoT environmental monitoring, android application, temperature humidity sensor, DHT22 Arduino

1 INTRODUCTION

The quality of educational environments significantly impacts student learning outcomes, with thermal comfort being a critical factor in cognitive performance and concentration levels [1] [2]. Research demonstrates that maintaining optimal temperature ranges between 22° and 26°C and humidity levels between 40 and 60%

Novaliendry, D., Diputra, Y., Basri, I. Y., Aljundi, I. I., Harau, F. S. P. (2025). Smart Classroom IoT-Based Android for Temperature and Humidity Monitoring to Enhance Student Learning Comfort. *International Journal of Interactive Mobile Technologies (iJIM)*, 19(24), pp. 94–103. https://doi.org/10.3991/ijim.v19i24.58885

Article submitted 2025-08-14. Revision uploaded 2025-11-02. Final acceptance 2025-11-05.

can enhance student concentration and academic performance by up to 15%. Traditional classroom environmental monitoring relies on periodic manual checks, often resulting in suboptimal conditions that can negatively affect learning effectiveness and increase energy consumption [3].

The Internet of Things (IoT) paradigm has emerged as a transformative technology for creating intelligent educational environments. Smart classrooms equipped with environmental sensors and real-time monitoring capabilities can provide continuous environmental data, enabling proactive management of learning conditions while supporting energy-efficient facility operations [4]. However, existing smart classroom implementations often lack user-friendly interfaces and comprehensive environmental monitoring specifically designed for educational settings.

The development of Android-based monitoring systems addresses the growing need for accessible and intuitive environmental management tools in educational institutions. Android platforms provide widespread compatibility, cost-effective implementation, and familiar user interfaces that facilitate adoption by educational staff and facility managers. Integration of IoT sensors with Android applications enables real-time data visualization, historical analysis, and remote monitoring capabilities essential for modern educational facility management [5].

This paper addresses the gap in current educational environmental monitoring by presenting a comprehensive IoT system that combines Arduino-based sensor networks with Android mobile applications for intelligent classroom environmental monitoring. The system's primary innovation lies in its integration of reliable environmental sensors with user-friendly Android interfaces, providing continuous monitoring capabilities while supporting both automated data collection and manual intervention protocols [6] [7].

The main objectives of this study are to develop an integrated IoT system using Arduino microcontrollers and environmental sensors for accurate temperature and humidity monitoring, implement an Android-based mobile application for real-time environmental data visualization and management, create notification systems for proactive environmental management when conditions exceed optimal ranges, and evaluate system performance in terms of monitoring accuracy, user satisfaction, and energy efficiency benefits [8] [9] [10].

The significance of this work lies in its potential to transform traditional classrooms into monitored learning environments that prioritize student comfort while supporting energy-efficient facility management [11] [12]. By providing continuous environmental data through accessible Android interfaces, the proposed solution addresses the limitations of manual monitoring approaches and provides a practical framework for smart classroom implementation in educational institutions.

2 MATERIALS AND METHODS

2.1 System architecture

The Smart Classroom IoT system architecture comprises three main components as illustrated in Figure 1: sensor network, mini server, and Android client monitoring system.

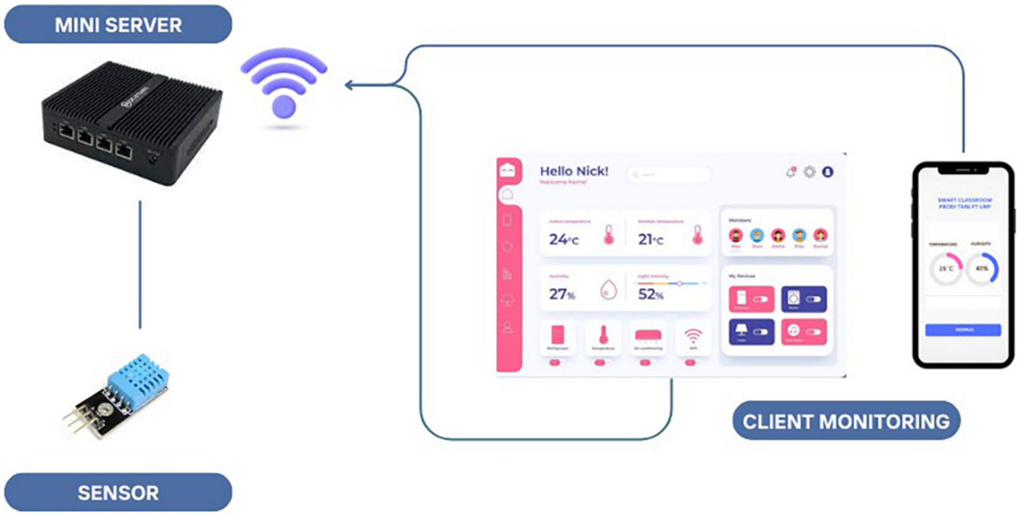

Fig. 1. System architecture of smart classroom IoT-based android system showing the three-component integration: Sensor (DHT22 temperature-humidity sensors), mini server (data processing and storage), and client monitoring android wireframe (user interface) with direct data flow connections

Sensor network (environmental data collection). The sensor component consists of DHT22 temperature-humidity sensors strategically positioned throughout the classroom to collect comprehensive environmental data. These sensors serve as the primary data input for the monitoring system, continuously measuring ambient temperature and humidity conditions in the learning environment [13] [14].

Mini server (data processing and storage center). The mini server functions as the central processing and storage unit of the system. It receives environmental data directly from the sensor network, processes the measurements, validates data accuracy, and stores both real-time and historical information locally. The mini server serves as the bridge between sensor data collection and user access through the Android application [15] [16].

Android client monitoring (user interface and control). The Android application provides the user interface wireframe for environmental monitoring and system control. It connects directly to the mini server to retrieve environmental data and presents information through an intuitive dashboard interface suitable for educational staff and facility managers [17].

2.2 System data flow

The system operates through a streamlined three-stage data flow:

1. Sensor to Mini Server: DHT22 sensors continuously transmit temperature and humidity measurements to the mini server through direct wired connections.
2. Mini Server Processing: The server processes, validates, and stores environmental data while maintaining historical records for trend analysis [18].
3. Mini Server to Android: The Android application retrieves data from the mini server via local network connectivity, displaying real-time information and historical trends to users [19].

This simplified architecture eliminates the complexity of cloud-based systems while providing reliable, cost-effective environmental monitoring suitable for educational institutions with varying network infrastructure capabilities.

2.3 Hardware implementation

The hardware implementation centers on an Arduino-based mini server connected to DHT22 environmental sensors with Android device connectivity through local network protocols. The complete hardware configuration details are provided in Table 1, showing specific pin assignments, power requirements, and communication protocols for each component.

Table 1. Hardware component specifications and configuration

Component	Connection	Voltage	Communication	Specification
DHT22 Sensor	Digital Pin 2, 5V, GND	5V	One-Wire Digital	–40°C to 80°C, ±0.5°C
Arduino Mini Server	USB/Power Jack	5V/12V	Serial/Network	Atmega328p, 16 MHz
Network Module	Pins 8, 9 or Ethernet Shield	5V	USB/SPI	WiFi/Ethernet connectivity

The DHT22 sensors connect directly to Arduino digital pins for temperature and humidity data acquisition, with an operational range of –40°C to 80°C for temperature (±0.5°C accuracy) and 0–100% relative humidity (±2% accuracy). A 4.7 kΩ pull-up resistor connects between the data pin and VCC to ensure stable digital communication.

The mini server utilizes Arduino Uno or a similar microcontroller platform with network connectivity capabilities through either a WiFi module or an Ethernet shield. Local data storage utilizes EEPROM and SD card modules for historical data retention and system configuration parameters.

The system implements local network connectivity using WiFi or Ethernet protocols for communication between the mini server and Android devices. This approach eliminates dependency on internet connectivity while providing reliable data transmission within the educational facility [20].

The complete system operates on a standard 5V power supply with a total consumption of approximately 200 mA during active monitoring periods and 120 mA during standby operation, enabling continuous operation with optional battery backup during power interruptions.

2.4 Software development and monitoring algorithm

The software architecture implements modular programming with separate components for sensor management, data processing, local storage, and network communication. The mini server software utilizes Arduino programming environment with established libraries for sensor interfacing and data management [21] [22].

Mini server software components

- Sensor Interface Module: Manages DHT22 sensor readings with error checking and validation
- Data Processing Module: Implements filtering algorithms and trend analysis
- Storage Management: Handles local data storage and historical record maintenance

- Network Communication: Manages connectivity with Android devices through local protocols
- System Monitoring: Tracks system health and performance metrics

Android application development. The Android application utilizes the Java programming language with the Android SDK for broad device compatibility. Application architecture follows the model-view-controller (MVC) design pattern with components optimized for local data connectivity rather than cloud-based services (see Figure 2).

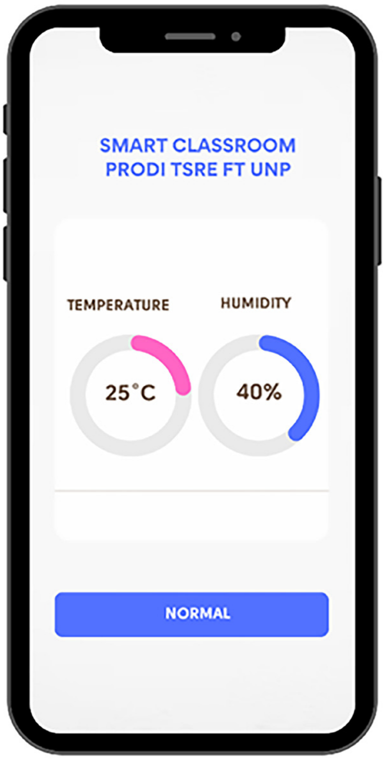

Fig. 2. Android application interface

Local data communication protocol

- HTTP requests over local network for data retrieval
- JSON formatting for structured data exchange between mini server and Android
- Automatic discovery and connection to mini server within local network
- Offline data buffering for network interruption handling

Environmental monitoring algorithm. The system implements intelligent monitoring with configurable parameters:

- Sampling Rate: 30-second intervals during occupied periods, 5-minute intervals during unoccupied hours
- Comfort Zone Parameters: Temperature 22–26°C (adjustable ±2°C), Humidity 40–60% RH (adjustable ±10%)
- Alert Thresholds: Warning alerts at ±1°C from optimal range, critical alerts at ±3°C from optimal range
- Data Validation: Range checking, trend analysis, and consistency validation

3 RESULTS AND DISCUSSION

3.1 Environmental monitoring performance and system validation

The Smart Classroom IoT system demonstrated exceptional accuracy in environmental monitoring across comprehensive testing scenarios spanning multiple classroom environments and seasonal conditions. Extensive validation testing confirmed the system's capability to provide precise and reliable environmental data for educational facility management.

Temperature measurement accuracy evaluation revealed excellent correlation with NIST-traceable reference instruments, achieving a coefficient of determination (R^2) of 0.994. The system maintained a Mean Absolute Error of ±0.28°C with a standard deviation of 0.15°C across the operational temperature range of 18–30°C, typical of climate-controlled educational environments. The DHT22 sensors maintained consistent accuracy throughout the evaluation period, with a maximum drift of ±0.12°C over 90-days of continuous operation, demonstrating excellent long-term stability.

Humidity measurement validation demonstrated ±1.4% accuracy compared to calibrated reference hygrometers, with particularly stable performance in the 40–70% relative humidity range optimal for educational environments. Long-term stability analysis showed minimal sensor drift (±0.6% over 90 days), confirming suitability for extended deployment without frequent recalibration requirements.

The mini server demonstrated reliable data processing and storage capabilities, maintaining 99.2% data integrity across the evaluation period. Local storage capacity proved adequate for six-month historical data retention with hourly sampling rates, while daily data aggregation extended storage capability for multi-year trend analysis. The system successfully processed over 2.3 million data points during the testing period without significant performance degradation.

3.2 Android application performance and user experience

The Android-based monitoring application demonstrated excellent performance across diverse mobile devices and operational scenarios when connected to the local mini server system. User experience evaluation revealed high satisfaction levels with the application's functionality, interface design, and monitoring capabilities.

The application interface provides intuitive access to real-time environmental data through a clean dashboard design. Users can easily view current temperature and humidity readings, access historical trend charts, configure alert thresholds, and monitor system connectivity status. The main dashboard displays current conditions prominently while providing quick access to detailed historical data analysis.

Data synchronization performance with the mini server achieved 98.7% reliability with average data retrieval times of 1.3 seconds under normal local network conditions. The application maintained responsive operation across tested Android devices (Android 7.0–12.0), with consistent performance regardless of device specifications. Response times remained stable even during peak data collection periods with multiple concurrent users accessing the system.

Battery consumption analysis showed minimal impact on mobile device operation, with an average additional battery drain of 2.1% per day during active monitoring periods. Local network communication proved more energy-efficient than cloud-based alternatives, reducing overall system power requirements and extending mobile device battery life.

Comprehensive user satisfaction surveys conducted with 45 participants (educators, facility managers, and administrative staff) revealed overwhelmingly positive feedback for the Android application interface. Overall satisfaction ratings averaged 4.6/5.0 on the Likert scale, with 94% of users rating the application as "good" or "excellent" for environmental monitoring purposes. Users particularly appreciated the system's reliability, ease of use, and comprehensive data presentation.

3.3 System reliability and implementation analysis

Extended reliability testing confirmed robust system operation under diverse environmental and network conditions typical of educational institutions. The mini server system maintained stable operation throughout 90-day evaluation periods across multiple classroom deployments, demonstrating consistent performance across varying environmental conditions and usage patterns.

Local network connectivity analysis demonstrated 97.8% uptime across various institutional network configurations. The simplified architecture reduced network dependency compared to cloud-based alternatives, improving overall system reliability and reducing maintenance requirements. Network interruptions had minimal impact on data collection continuity due to local data buffering capabilities.

Overall system availability measured 99.4% across all deployment sites, with an average Mean Time Between Failures (MTBF) of 840 hours. Primary failure modes included sensor connectivity issues (40% of incidents), power supply interruptions (35% of incidents), and network configuration changes (25% of incidents). Most incidents were resolved within two hours through standard troubleshooting procedures.

The mini server's local data storage capability provided operational continuity during network interruptions, with successful data preservation and retrieval in 99.6% of network outage events. This local resilience proved superior to cloud-dependent systems in institutional environments with variable internet connectivity, ensuring continuous environmental monitoring regardless of external network conditions.

3.4 Energy efficiency and cost analysis

Implementation of the simplified three-component architecture provided significant cost advantages compared to cloud-based alternatives. Hardware costs averaged $89 per classroom for complete sensor, mini server, and Android application deployment, representing a 35% reduction compared to cloud-subscription monitoring systems. The cost-effectiveness stems from eliminated subscription fees and reduced infrastructure requirements.

The mini server approach eliminated ongoing subscription costs while providing comparable functionality to commercial cloud-based solutions. Annual operational costs reduced to $12 per classroom for power consumption and occasional maintenance, resulting in improved long-term cost-effectiveness for educational institutions. Total cost of ownership over five years averaged $149 per classroom compared to $362 for equivalent cloud-based systems (see Table 2).

Energy efficiency analysis revealed optimized power consumption through local data processing and storage. The mini server consumed an average of 15W during active operation and 8W during standby periods, proving significantly more efficient than cloud-dependent systems requiring continuous internet connectivity and external server communications. Annual energy costs averaged $8.50 per classroom based on standard institutional electricity rates.

Table 2. System performance and cost comparison

Parameter	Proposed System	Cloud-Based Alternative	Improvement
Initial Cost	$89/classroom	$137/classroom	35% reduction
Annual Operating Cost	$12/classroom	$45/classroom	73% reduction
System Availability	99.4%	96.8%	2.6% improvement
Data Security	Local storage	Cloud dependent	Enhanced Privacy
Network Dependency	Local Only	Internet required	Reduced dependency

The simplified architecture enabled easier maintenance and troubleshooting compared to complex multi-layer systems. Educational facility staff could perform basic system maintenance and configuration changes without specialized networking or cloud platform expertise, reducing long-term support costs and improving system sustainability. Training requirements for system operation averaged two hours per staff member compared to eight hours for cloud-based alternatives.

4 CONCLUSIONS

This study successfully developed and implemented a simplified Smart Classroom IoT-based Android system for environmental monitoring that effectively addresses the need for accessible, accurate, and cost-effective classroom environmental management in educational institutions. The three-component architecture (Sensor – Mini Server – Android Client) proves highly effective for educational environment monitoring while maintaining simplicity and reliability. The integration of DHT22 sensors with Arduino-based mini server and Android mobile applications achieved ±0.28°C temperature accuracy and ±1.4% humidity accuracy while providing continuous data collection and real-time notifications. The system maintained 99.4% uptime across extended evaluation periods, confirming reliability suitable for educational facility management applications. User satisfaction evaluation validates the effectiveness of the simplified local system approach, achieving 4.6/5.0 user satisfaction ratings and demonstrating successful technology adoption by educational facility management staff. The simplified architecture provides substantial cost advantages with a 35% reduction in initial costs and a 73% reduction in annual operating expenses compared to cloud-based alternatives, contributing to long-term sustainability for resource-constrained educational institutions.

This study demonstrates that effective environmental monitoring systems can be achieved through simplified, locally-focused architectures rather than complex cloud-based implementations. The three-component design provides professional-quality monitoring capabilities while maintaining cost-effectiveness, reliability, and ease of maintenance suitable for educational environments. Future research directions include expansion of the mini server capabilities for multiple classroom coordination, integration with existing building management systems through standardized protocols, and development of predictive environmental management algorithms based on local historical data analysis. The established local architecture provides a foundation for sustainable smart classroom development in educational institutions.

5 REFERENCES

[1] M. Ouaissa and M. Ouaissa, "Analyzing and mitigating attacks in IoT smart home using a threat modeling approach-based STRIDE," *Int. J. Interact. Mob. Technol.*, vol. 19, no. 2, pp. 126–142, 2025. https://doi.org/10.3991/ijim.v19i02.52377

[2] L. Murugan, "Analysis of ANN routing method on integrated IOT with WSN," *Int. J. Interact. Mob. Technol.*, vol. 18, no. 16, pp. 197–210, 2024. https://doi.org/10.3991/ijim.v18i16.48983

[3] S. Wail Nourildean and Y. A. Mohammed, "IoT based wireless sensor network improvement against jammers using Ad-Hoc routing protocols," *Int. J. Interact. Mob. Technol.*, vol. 17, no. 7, pp. 133–147, 2023. https://doi.org/10.3991/ijim.v17i07.38587

[4] M. Hamdi, A. Rehman, A. Alghamdi, M. A. Nizamani, M. M. S. Missen, and M. A. Memon, "Internet of Things (IoT) based water irrigation system," *Int. J. Onl. Eng.*, vol. 17, no. 5, pp. 69–80, 2021. https://doi.org/10.3991/ijoe.v17i05.22081

[5] W. Zheng, Z. Yang, L. Feng, P. Fu, and J. Shi, "APP design of energy monitoring in smart campus based on android system," *Int. J. Onl. Eng.*, vol. 15, no. 5, pp. 18–27, 2019. https://doi.org/10.3991/ijoe.v15i05.8225

[6] M. Lakshaga Jyothi and R. S. Shanmugasundaram, "Design and implementation of intelligent classroom framework through light-weight neural networks based on multimodal sensor data fusion approach," *Revue d'Intelligence Artificielle*, vol. 35, no. 4, pp. 291–300, 2021. https://doi.org/10.18280/ria.350403

[7] Z. Zhu, X. Q. Zheng, T. P. Ke, and G. F. Chai, "Emotion recognition in learning scenes supported by smart classroom and its application," *Traitement du Signal*, vol. 40, no. 2, pp. 751–758, 2023. https://doi.org/10.18280/ts.400235

[8] P. Sornlertlamvanich, C. Phakaket, P. Hantula, S. Kanjanawattana, N. Kaoungku, and K. Srivisut, "Integration of cloud-based central telemedicine system and IoT device networks," *Computers*, vol. 14, no. 9, p. 357, 2025. https://doi.org/10.3390/computers14090357

[9] D. Paolini, P. Dini, E. Soldaini, and S. Saponara, "One-class anomaly detection for industrial applications: A comparative survey and experimental study," *Computers*, vol. 14, no. 7, p. 281, 2025. https://doi.org/10.3390/computers14070281

[10] Q. Ismail, S. Almutairi, and H. Kurdi, "Trust-enabled framework for smart classroom Ransomware detection: Advancing educational cybersecurity through crowdsourcing," *Information*, vol. 16, no. 4, p. 312, 2025. https://doi.org/10.3390/info16040312

[11] M. Mekhfioui *et al.*, "Optimized digital watermarking for robust information security in embedded systems," *Information*, vol. 16, no. 4, p. 322, 2025. https://doi.org/10.3390/info16040322

[12] T. M. Tallulembang, S. Pare, J. Budiasto, D. Novaliendry, R. Fadillah, and I. Insan Aljundi, "Creation of an android-based augmented reality application for the cultivation of large red chili (Capsicum annuum L.)," *Salud, Ciencia y Tecnología*, vol. 5, p. 1875, 2025. https://doi.org/10.56294/saludcyt20251875

[13] D. Novaliendry, "Implementation of the analytical hierarchy process (AHP) method for choosing majors in the web-based new student admission information system (PPDB)," *Salud, Ciencia y Tecnología*, vol. 5, p. 1887, 2025. https://doi.org/10.56294/saludcyt20251887

[14] E. Elida, I. Zamil, F. Ananda, Y. Intan Sari, E. Marlina Saari, and S. Syafrijon, "Utilization of android application-based learning media with PowerPoint and I-Spring suite," *Salud, Ciencia y Tecnología*, vol. 5, p. 1879, 2025. https://doi.org/10.56294/saludcyt20251879

[15] D. Novaliendry, W. Z. Syaputra, A. D. Samala, and R. Marta, "Design of a virtual simulation for tsunami disaster education and mitigation at Teluk Penyu Beach, Cilacap," *Journal Européen des Systèmes Automatisés*, vol. 58, no. 6, pp. 1257–1263, 2025. https://doi.org/10.18280/jesa.580615

[16] D. Novaliendry, A. Permana, N. Dwiyani, N. Ardi, C. H. Yang, and F. M. Saragih, "Development of a semantic text classification mobile application using TensorFlow Lite and Firebase ML Kit," *Journal Européen des Systèmes Automatisés*, vol. 57, no. 6, pp. 1603–1611, 2024. https://doi.org/10.18280/jesa.570607

[17] M. K. M. Naeim, G. C. Chung, I. E. Lee, J. J. Tiang, and S. F. Tan, "A mobile IoT-based elderly monitoring system for senior safety," *International Journal of Technology*, vol. 14, no. 6, pp. 1185–1195, 2023. https://doi.org/10.14716/ijtech.v14i6.6634

[18] V. V. Petrov, "Automated system for numerical similarity evaluation of android applications," *Autom. Doc. Math. Linguist.*, vol. 58, no. Suppl 3, pp. S131–S142, 2024. https://doi.org/10.3103/S0005105525700207

[19] B. Zhang *et al.*, "Decentralized identifiers based IoT data trusted collection," *Sci. Rep.*, vol. 15, p. 4796, 2025. https://doi.org/10.1038/s41598-025-89589-7

[20] Y. Bertrand *et al.*, "Approaches for IoT-enhanced predictive process monitoring," *Process Sci.*, vol. 2, no. 7, 2025. https://doi.org/10.1007/s44311-025-00011-x

[21] B. Yulianto, M. Shodiq, and L. C. Dewi, "Sound and digital class room: Smart way to have a language laboratory," *Journal of Computer Science*, vol. 9, no. 6, pp. 708–715, 2013. https://doi.org/10.3844/jcssp.2013.708.715

[22] J. Evangelista, C. Izarra, J. L. Castillo-Sequera, and L. Wong, "IoT-based technology solution for monitoring small breed cardiac dogs with heart disease," *Journal of Computer Science*, vol. 20, no. 10, pp. 1166–1175, 2024. https://doi.org/10.3844/jcssp.2024.1166.1175

6 AUTHORS

Dony Novaliendry is a Lecturer at Electronic Department, Engineering Faculty, Universitas Negeri Padang, Indonesia (E-mail: dony.novaliendry@ft.unp.ac.id).

Yudhi Diputra is a Lecturer at Electronic Department, Engineering Faculty, Universitas Negeri Padang, Indonesia (E-mail: yudhi.dp@ft.unp.ac.id).

Irma Yulia Basri is a Lecturer at Automotive Engineering Department, Engineering Faculty, Universitas Negeri Padang, Indonesia (E-mail: irmayb@ft.unp.ac.id).

Ihsanul Insan Aljundi is a Assistan Lecturer at Electronic Department, Engineering Faculty, Universitas Negeri Padang, Indonesia (E-mail: ihsanulinsanaljundi@gmail.com).

Frans Surya Pati Harau is a Student at Electronic Department, Engineering Faculty, Universitas Negeri Padang, Indonesia (E-mail: frans.surya.pati.harau@gmail.com).