Journal of Computer Science and Technology Studies
ISSN: 2709-104X
DOI: 10.32996/jcsts
Journal Homepage: www.al-kindipublisher.com/index.php/jcsts

JCSTS
AL-KINDI CENTER FOR RESEARCH AND DEVELOPMENT

| RESEARCH ARTICLE

Assessing The Development of an Automated Fan Control System

Julie Ann Lopez
Cebu technological University, Philippines
Corresponding Author: Julie Ann Lopez, **E-mail**: Jjulielopez08@gmail.com

| ABSTRACT

In today's world, automation is necessary for efficient and responsive systems. Automated systems provide significant benefits such as increased productivity and reduced human error, making them increasingly important across various industries. The development of an automated fan control system addressed the limitations of the existing manual fan. Manual fan control often leads to energy waste, insufficient comfort, and higher operating costs. This study aimed to address this gap by developing and implementing an automated fan control system that correctly maintained and optimized temperature, convenience, and reduced energy usage. The automated system was designed for real-time monitoring, utilizing advanced algorithms to control fan operations based on detected human movement and real-time conditions. The results showed that respondents assessed the acceptability of the automated fan control system (AFCS) using the Technology Acceptance Model (TAM). The results from the study provided strong suggestions to adopt and implement automated fan control systems to enhance environmental sustainability and user satisfaction.

| KEYWORDS

Automated Fan Control System, Smart Classroom, Environmental Control, Thermal Comfort, Technology Acceptance Model (TAM)

| ARTICLE INFORMATION

ACCEPTED: 01 January 2026 **PUBLISHED:** 30 January 2026 **DOI:** 10.32996/jcsts.2026.8.2.4

Introduction

Maintaining thermal comfort in educational institutions is essential for promoting effective teaching and learning outcomes. In tropical regions like the Philippines, classrooms and laboratories often suffer from excessive heat and humidity, impairing concentration and productivity (Marzuki et al., 2021). While air conditioning is effective, it is costly and unsustainable in many public institutions. Fan systems provide a more affordable alternative, but manual operation can be inefficient and inconsistent. The rise of smart systems and automation provides new opportunities for optimizing energy usage and maintaining comfort levels. Automation in ventilation not only enhances convenience but also supports sustainability goals, as smart controls can reduce unnecessary energy use while responding dynamically to environmental conditions (Wang et al., 2020). The development of an automated fan control system involves sensor integration, microcontroller programming, and feedback mechanisms that adjust to real-time temperature and humidity changes. Sensors such as DHT22 or SHT31 can collect environmental data, while microcontrollers like Arduino or ESP32 process this data to automate fan operation (Chandran et al., 2022). The system's performance must ensure responsiveness, while features like remote control, temperature thresholds, and manual override improve usability. Reliability and durability are essential to reduce maintenance in high-use environments like classrooms and laboratories. Moreover, system design must consider ease of deployment and minimal disruption to existing infrastructure, aligning with the increasing call for modular, adaptable smart systems in educational institutions (Islam et al., 2023).

An effective system design goes beyond functionality it should also consider human interaction, ergonomics, and the spatial constraints of learning environments. Ergonomically designed systems are intuitive, reduce user fatigue, and offer a better user experience (Yoo et al., 2020). In the case of automated fan systems, components like interface panels, physical placement of sensors, and access to control features must be designed to accommodate both students and faculty. Incorporating user

feedback in the design phase ensures better usability and promotes long-term acceptance. Given that many faculty members are not tech-savvy, simplicity and clarity in both hardware and software interfaces play an essential role in determining adoption in schools and universities (Park et al., 2021).

The Technology Acceptance Model (TAM) remains widely used to evaluate user adoption of emerging technologies, including smart classroom innovations. TAM posits that perceived usefulness, ease of use, and actual system use are critical predictors of acceptance (Venkatesh et al., 2021). In educational contexts, users are more likely to adopt technology if they believe it enhances productivity and is easy to interact with. For automated fan systems, perceived usefulness might relate to improved classroom comfort and energy efficiency, while ease of use pertains to intuitive controls and system responsiveness. Studies have also highlighted the importance of user trust and familiarity in driving continued use of smart environmental systems in academic settings (Nguyen et al., 2022).

Although numerous studies have addressed smart systems in educational settings, most focus on complex technologies such as virtual learning environments or smart lighting. Minimal research has been conducted on automated ventilation solutions tailored for low-cost implementation in classrooms, particularly within developing countries. Furthermore, many engineering-focused projects do not evaluate user acceptability, overlooking essential insights from educators and students. There is also a lack of localized studies within the Philippine context, where budget limitations and tropical climate make fan-based automation particularly relevant. This gap indicates the need for integrative research combining technical development with behavioral assessment frameworks such as TAM.

This study aims to design, develop, and evaluate an automated fan control system for selected classrooms and laboratories at Cebu Technological University Main Campus, where energy efficiency and learning comfort are essential concerns. The system will be assessed based on its technical requirements performance, features, reliability, durability, design, and ergonomics ensuring both functionality and usability. In parallel, the research will explore the extent of system acceptability using the Technology Acceptance Model, with data gathered from faculty and students. As CTU moves toward integrating more sustainable and technology-driven learning environments, this project aligns with institutional goals and national directives on smart education infrastructure and green campus initiatives.

Literature Review

The integration of automated environmental control systems in educational settings has gained momentum due to rising concerns over energy efficiency and occupant comfort. Studies have shown that automated systems using IoT technologies can significantly improve indoor air quality and thermal comfort in classrooms (Wang et al., 2020; Chandran et al., 2022). These systems typically employ sensors, microcontrollers, and feedback algorithms to regulate fan speed or activation based on real-time environmental data (Islam et al., 2023; Kim et al., 2021). For instance, low-cost systems based on Arduino and DHT11 sensors have been successfully implemented in schools to manage heat and humidity without the high energy costs associated with air conditioning (Kamarudin et al., 2021). Furthermore, modular and scalable designs allow easy deployment in existing classroom infrastructure (Chung et al., 2022), making automated fan systems a practical solution for developing countries. Emphasis is also placed on system reliability, durability, and ease of maintenance to ensure continuous operation with minimal oversight (Alshamrani & Khan, 2023).

The user acceptance of such automated systems is frequently evaluated through the Technology Acceptance Model (TAM), which identifies perceived usefulness and perceived ease of use as key predictors of technology adoption (Venkatesh et al., 2021). In classroom settings, users particularly faculty and students are more likely to adopt environmental control systems if they perceive them as beneficial and easy to operate (Nguyen et al., 2022). Several studies have applied TAM to smart classroom technologies, emphasizing the importance of user trust, simplicity, and system reliability in influencing actual use (Hussain et al., 2023; Park et al., 2021). Additionally, ergonomic design and user interface quality are recognized as critical components in driving sustained engagement with smart systems (Yoo et al., 2020). In the context of developing nations, affordability and localized relevance are added factors that influence TAM variables and must be considered in design and evaluation (Ramos et al., 2023; Ali & Ismail, 2020). These findings highlight the need for context-specific solutions that are both technically sound and user-accepted.

Methodology

This study employed a comparative quantitative research design to assess the acceptability and effectiveness of the developed automated fan control system among two respondent groups professors/experts and students at Cebu Technological University Main Campus. A comparative approach was used to determine whether there is a significant difference in perceptions between the two groups, as supported by Iranifard and Latifnejad Roudsari (2022), who emphasized the relevance of such designs in

analyzing group-based differences. The participants consisted of ten (10) professors and forty (40) undergraduate students enrolled in the Bachelor of Science in Mechatronics Engineering (BSMx) program. The study utilized a standardized and researcher-made survey questionnaire as the primary data collection tool. The questionnaire had three parts: (1) demographic information, (2) evaluation of the system's technical requirements based on Garvin's (1987) quality dimensions performance, features, reliability, durability, design, and ergonomics and (3) user acceptability following Davis' (1989) Technology Acceptance Model (TAM), which includes perceived usefulness, perceived ease of use, and actual system use. Data collection was conducted onsite, with responses scored using a 4-point Likert scale, where 4.00 to 3.26 indicated "Highly Acceptable," and 1.00 to 1.19 indicated "Not Acceptable." The collected data were statistically analyzed to determine mean scores, overall acceptability levels, and any significant differences in perceptions between the two groups. This methodological structure allowed the researcher to assess not only the technical merit of the system but also its practical acceptability in an educational setting.

Results

The data presented in Table 1 indicates that both professors and students rated the performance of the Automated Fan Control System (AFCS) as highly acceptable across all evaluated criteria. The highest average weighted mean (AWM) of 3.90 was observed for the criterion "Meets intended functionality" by both respondent groups, indicating strong agreement that the system performs its core functions effectively.

Table 1. Performance in AFCS

Performance	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
Response time to temperature changes.	3.70	0.48	HA	3.88	0.33	HA	3.79	Highly Acceptable
Efficient fan speed adjustment.	3.70	0.48	HA	3.78	0.42	HA	3.74	Highly Acceptable
Maintain consistent temperature within a set range.	3.80	0.42	HA	3.70	0.46	HA	3.75	Highly Acceptable
Meets intended functionality.	3.90	0.32	HA	3.90	0.30	HA	3.90	Highly Acceptable
Average	3.78	0.079	HA	3.82	0.075	HA	3.80	Highly Acceptable

In terms of responsiveness, professors rated the system's reaction to temperature changes at 3.70, while students gave a slightly higher rating of 3.88, both falling within the "Highly Acceptable" range. Similarly, efficient fan speed adjustment received AWMs of 3.70 and 3.78 from professors and students respectively, again showing consistent satisfaction. Although there were minor variations in standard deviations, they remained relatively low, suggesting a general consensus among respondents. The overall average performance rating was 3.80, interpreted as "Highly Acceptable." This reflects the system's success in delivering reliable, responsive, and effective fan control within classroom and laboratory environments, satisfying both technical expectations and user comfort needs.

Table 2. Features in AFCS

Features	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
Provide feedback on its performance and status	3.90	0.32	HA	3.93	0.27	HA	3.92	Highly Acceptable
Offers advanced features that enhance user convenience	3.70	0.48	HA	3.85	0.36	HA	3.78	Highly Acceptable
Automatic shut- off when no presence is detected	3.70	0.67	HA	3.93	0.27	HA	3.82	Highly Acceptable

User-friendly interface	3.80	0.42	HA	3.8	0.41	HA	3.80	Highly Acceptable
Average	3.78	0.151	HA	3.88	0.070	HA	3.83	Highly Acceptable

Table 2 shows that the features of the Automated Fan Control System (AFCS) were evaluated as Highly Acceptable by both professors and students. The highest mean rating was obtained for "Provides feedback on its performance and status" with a mean of 3.92, indicating that respondents strongly appreciated the system's ability to inform users of its operational condition. The feature "Automatic shut-off when no presence is detected" also received a high mean of 3.82, reflecting positive perceptions of the system's energy-saving and safety function. The provision of advanced features that enhance user convenience yielded a mean of 3.78, while the user-friendly interface obtained a mean of 3.80, both interpreted as highly acceptable, showing that the system is easy to use and offers practical functions.

Table 3. Reality s in AFCS

Reliability	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
rarely requires minimal maintenance or repairs.	3.50	0.53	HA	3.38	0.67	HA	3.44	Highly Acceptable
Provide efficient and consistent results.	3.60	0.52	HA	3.60	0.50	HA	3.60	Highly Acceptable
Uses high- quality durable and long-lasting materials.	3.70	0.48	HA	3.53	0.51	HA	3.62	Highly Acceptable
Consistent performance over an extended period of operation.	3.80	0.42	HA	3.70	0.46	HA	3.75	Highly Acceptable
Average	3.65	0.047	HA	3.55	0.091	HA	3.60	Highly Acceptable

Table 3 highlights the reliability of the Automated Fan Control System (AFCS) as perceived by professors and students, with all criteria rated as Highly Acceptable. The highest-rated item was "Consistent performance over an extended period of operation," which received a mean score of 3.75, indicating that users found the system dependable over time. The criterion "Uses high-quality, durable, and long-lasting materials" also received strong ratings, with a combined mean of 3.62, suggesting confidence in the system's build quality. Both groups agreed that the system "Provides efficient and consistent results," with identical AWM scores of 3.60, reinforcing its perceived reliability. Although the lowest mean (3.44) was recorded for "Rarely requires minimal maintenance or repairs," it still falls within the "Highly Acceptable" range, suggesting that while maintenance is occasionally needed, it is not a significant concern.

Table 4. Durability s in AFCS

Durability	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
The AFCS is designed for long-term use.	3.80	0.42	HA	3.45	0.55	HA	3.63	Highly Acceptable
Easy to repair or replace components if necessary.	3.60	0.70	HA	3.23	0.70	HA	3.42	Highly Acceptable
Average	3.70	0.196	HA	3.34	0.103	HA	3.52	Highly Acceptable

Table 4 presents the assessment of the durability of the Automated Fan Control System (AFCS), with all indicators rated as Highl

environments. Although students rated "Easy to repair or replace components if necessary" slightly lower (3.23) compared to professors (3.60), the combined mean of 3.42 still indicates a positive perception of the system's maintainability. The overall average mean score of 3.52 for durability confirms that both groups believe the system is built with long-lasting components, is repairable when needed, and can perform effectively over time. Despite slight variations in perception, the data suggest that the system is structurally dependable and meets user expectations for long-term usage in classroom and laboratory settings.

Table 5. Design s in AFCS

Design	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
Pleasing appearance and design.	4.0	0.00	HA	3.88	0.33	HA	3.94	Highly Acceptable
The wiring and installation setup are neatly arranged.	3.90	0.32	HA	3.90	0.30	HA	3.90	Highly Acceptable
The AFCS display is clear and readable.	3.90	032	HA	3.98	0.16	HA	3.94	Highly Acceptable
Average	3.93	0.183	HA	3.92	0.094	HA	3.93	Highly Acceptable

Table 5 shows the evaluation of the design aspects of the Automated Fan Control System (AFCS), with results indicating a Highly Acceptable rating from both professors and students across all design-related criteria. The criterion "Pleasing appearance and design" received a combined mean of 3.94, the highest among the items, reflecting strong agreement that the system is visually appealing and well-crafted. Similarly, both groups gave an identical mean of 3.90 for "The wiring and installation setup are neatly arranged," demonstrating that the physical setup of the system was seen as clean, organized, and professionally done. For "The AFCS display is clear and readable," students gave the highest score of 3.98, slightly higher than professors' 3.90, with a combined mean of 3.94, indicating ease in reading system outputs. The overall average mean of 3.93 confirms that the system design is functional, visually acceptable, and easy to navigate. These high ratings reflect successful integration of aesthetic and practical considerations in the system's development.

Table 6 presents the evaluation of the ergonomics of the Automated Fan Control System (AFCS), with all indicators receiving a Highly Acceptable rating from both professors and students. The highest-rated criterion was "The AFCS is designed for user comfort," with a combined mean of 3.89, reflecting strong agreement that the system prioritizes user-friendly interaction and minimizes physical or cognitive strain. "The AFCS is accessible to all users" followed closely with a mean of 3.85, indicating that the system can be easily operated by a wide range of users, regardless of technical background.

Table 6. Ergonomics s in AFCS

Ergonomics	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
The AFCS is accessible to all users.	3.90	0.32	HA	3.80	0.41	HA	3.85	Highly Acceptable
The AFCS is designed for user comfort.	3.90	0.32	HA	3.88	0.33	HA	3.89	Highly Acceptable
The AFCS operates quietly without causing disturbance.	3.80	0.42	HA	3.75	0.44	HA	3.78	Highly Acceptable
Average	3.87	0.061	HA	3.81	0.053	HA	3.84	Highly Acceptable

The lowest mean, though still within the highly acceptable range, was 3.78 for "The AFCS operates quietly without causing disturbance," showing that while some variation in perception exists, the system is generally seen as non-disruptive during operation. The overall average mean of 3.84 confirms that the system meets ergonomic standards, offering ease of use, comfort, and silent operation all essential features for maintaining a productive academic environment.

Table 7. Perceived Usefulness in AFCS

Usefulness	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
PU1. Using AFCS improves my comfort level.	3.80	0.63	HA	3.93	0.27	HA	3.87	Highly Acceptable
PU2. Using AFCS saves me time compared to manual control.	3.80	0.42	HA	3.93	0.27	HA	3.87	Highly Acceptable
PU3. Using AFCS can reduce energy waste.	3.70	0.48	HA	3.93	0.27	HA	3.82	Highly Acceptable
PU4. Using AFCS is effective in maintaining a comfortable temperature.	3.80	0.42	HA	3.85	0.43	HA	3.83	Highly Acceptable
PU5. I am satisfied with the performance of the AFCS.	3.80	0.42	HA	3.88	0.33	HA	3.84	Highly Acceptable
Average	3.78	0.086	HA	3.90	0.070	HA	3.84	Highly Acceptable

Table 7 presents the results on the Perceived Usefulness of the Automated Fan Control System (AFCS), based on the Technology Acceptance Model (TAM). Both professors and students consistently rated the system as Highly Acceptable across all usefulness indicators. The highest

mean ratings of 3.87 were given to statements PU1 ("Using AFCS improves my comfort level") and PU2 ("Using AFCS saves me time compared to manual control"), reflecting strong agreement that the system enhances user comfort and operational efficiency. The lowest mean, 3.82, was still highly acceptable and related to energy conservation (PU3), suggesting slightly more variability in users' views on AFCS's impact on energy savings. Students generally gave slightly higher ratings than professors across all items, which may indicate greater appreciation for the system's convenience. Overall, the combined average mean of 3.84 confirms that users perceive the AFCS as a useful and effective tool for improving comfort, saving time, and supporting energy efficiency within the classroom or laboratory environment.

Table 8. Ease of Use in AFCS

Ease of Use	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
PEU1. I would find this AFCS easy to understand.	3.80	0.42	HA	3.83	0.38	HA	3.82	Highly Acceptable
PEU2. This AFCS has a user-friendly interface.	3.90	0.32	HA	3.85	0.36	HA	3.88	Highly Acceptable
PEU3. This AFCS requires minimal effort to use.	3.90	0.32	HA	3.75	0.49	HA	3.83	Highly Acceptable
PEU4. I can easily learn how to use the AFCS.	3.80	0.42	HA	3.83	0.38	HA	3.82	Highly Acceptable
PEU5. I experienced no difficulties using the AFCS	3.80	0.42	HA	3.78	0.42	HA	3.79	Highly Acceptable
Average	3.84	0.058	HA	3.81	0.052	HA	3.82	Highly Acceptable

Table 8 summarizes respondents' perceptions of the Ease of Use of the Automated Fan Control System (AFCS), based on the Technology Acceptance Model (TAM). All five indicators were rated as Highly Acceptable by both professors and students, indicating strong agreement that the system is easy to understand, operate, and learn. The highest overall mean was 3.88 for the statement "This AFCS has a user-friendly interface," highlighting the clarity and accessibility of the system's design. "This AFCS requires minimal effort to use" also scored well (3.83), confirming that interaction with the system does not demand advanced technical skills. The lowest, though still within the Highly Acceptable range, was "I experienced no difficulties using the AFCS" with a mean of 3.79, suggesting that while the system is generally intuitive, minor usability issues may exist for some users. The combined average mean of 3.82 confirms that the AFCS meets user expectations in terms of ease of use, contributing to its positive reception and potential for wider adoption within educational settings.

Table 9. Actual System Use in AFCS

Actual Use	Professors			Students			Mean	Verbal Description
	AWM	SD	VD	AWM	SD	VD		
AU1. The AFCS responds quickly to environmental changes.	3.80	0.42	HA	3.93	0.27	HA	3.87	Highly Acceptable
AU2. The AFCS features are effective.	3.60	0.70	HA	3.98	0.16	HA	3.79	Highly Acceptable
AU3. I would recommend this AFCS to others	3.80	0.42	HA	3.95	0.22	HA	3.88	Highly Acceptable

Average	3.73	0.160	HA	3.95	0.055	HA	3.84	Highly Acceptable

Table 9 presents the evaluation of the Actual System Use of the Automated Fan Control System (AFCS), based on the third construct of the Technology Acceptance Model (TAM). Both professors and students rated all aspects as Highly Acceptable, reflecting strong confidence in the system's practical functionality. The highest rating was for "I would recommend this AFCS to others," with a combined mean of 3.88, showing users' willingness to endorse the system, a strong indicator of satisfaction and trust. "The AFCS responds quickly to environmental changes" followed closely with a mean of 3.87, confirming its real-time responsiveness. Although "The AFCS features are effective" received the lowest mean (3.79), it still falls within the Highly Acceptable range, suggesting minor differences in user experience between groups—particularly with professors rating it lower than students. The overall average mean of 3.84 demonstrates that users not only perceive the system as useful and easy to use but also actively recognize its effectiveness and would advocate for its use in similar environments.

Table 10. The significant difference between the perception of the professor and the student respondents as to the acceptability of the automated fan control system

	Mean (M)	Standard Deviation (SD)	t	Critical Value (CV)	p-value	Decision	Interpretation
Professors	3.784	0.0085	0.121	2.2281	0.9051	Fail to Reject H_0	Not significant
Students	3.776	0.0057					

Table 10 displays the statistical analysis comparing the perceptions of professors and students regarding the acceptability of the Automated Fan Control System (AFCS). The mean score for professors was 3.784 (SD = 0.0085), while students had a mean score of 3.776 (SD = 0.0057). The computed t-value of 0.121 is significantly lower than the critical value of 2.2281, and the p-value of 0.9051 is substantially higher than the significance level (typically $\alpha = 0.05$). Based on these results, the decision is to fail to reject the null hypothesis (H_0), indicating that there is no statistically significant difference between the perceptions of the two groups. This means that both professors and students have similar levels of acceptability toward the AFCS. Their evaluations, though slightly varied in mean, are not statistically distinct, supporting the system's broad acceptability across user types.

Discussion

Based on the comprehensive evaluation of the Automated Fan Control System (AFCS), the findings reveal that both professors and students consistently rated the system as Highly Acceptable across all technical and user-acceptance dimensions. In terms of performance, the system was seen as reliable in responding to temperature changes, adjusting fan speeds efficiently, and maintaining a consistent environment—all essential features for classroom and laboratory comfort. Features such as real-time feedback, automatic shut-off, and a user-friendly interface were also appreciated by both groups, indicating that the system not only functions well but also align with user expectations. Moreover, high ratings in reliability, durability, and design show that the system is perceived as well-built, long-lasting, and neatly integrated into its environment. From an ergonomic standpoint, users found it comfortable, accessible, and non-disruptive, affirming its suitability for continuous use in educational settings. On the other hand, the system also performed strongly when evaluated under the Technology Acceptance Model (TAM) framework. Respondents perceived the AFCS as useful, especially in terms of enhancing comfort, saving time, and reducing energy waste. The ease of use was also highly rated, with participants noting the system's intuitive interface and minimal learning curve. Actual use indicators further confirmed that users found the system functional and worth recommending. Importantly, the statistical analysis revealed no significant difference between professors' and students' perceptions regarding system acceptability (p-value = 0.9051), reinforcing the consistency of positive feedback across user groups. These results suggest that the AFCS is not only technically sound but also widely acceptable to its intended users, making it a viable solution for broader implementation in academic institutions like Cebu Technological University.

Conclusion

The results of this study affirm that the Automated Fan Control System (AFCS) developed for the classrooms and laboratories is both technically effective and widely accepted by its intended users. Across all assessed criteria performance, features, reliability, durability, design, and ergonomics the system received consistent "Highly Acceptable" ratings from both professors and students. These results indicate that the AFCS effectively delivers its intended functionalities, such as responsive temperature

regulation, user-friendly interface, and energy efficiency, while also meeting expectations for long-term use and ease of maintenance. Furthermore, the system's evaluation under the Technology Acceptance Model (TAM) demonstrated strong perceived usefulness, ease of use, and actual system use. The absence of a statistically significant difference between the perceptions of professors and students confirms a shared confidence in the system's design and functionality. Overall, the findings suggest that the AFCS is a reliable, sustainable, and user-centered solution for improving thermal comfort and energy management in academic environments. With this, the system shows strong potential for institutional adoption and serves as a model for integrating low-cost, automated solutions into educational infrastructure.

References

[1]. Ali, A. A., & Ismail, K. (2020). Smart environmental control in developing countries: Current trends and challenges. *Renewable and Sustainable Energy Reviews, 132*, 110043. https://doi.org/10.1016/j.rser.2020.110043

[2]. Alshamrani, A., & Khan, A. I. (2023). A review of IoT-based smart building systems: Architectures and future trends. *Journal of Ambient Intelligence and Humanized Computing, 14*(1), 305–321. https://doi.org/10.1007/s12652-022-03735-5

[3]. Chandran, K., Joseph, M., & Alex, T. (2022). IoT-based smart ventilation system using temperature and humidity sensors. *Journal of Intelligent Systems, 31*(1), 45–54. https://doi.org/10.1515/jisys-2021-0022

[4]. Chung, H., Lee, K., & Kim, J. (2022). Design and implementation of a modular smart classroom system for effective learning environments. *Sensors, 22*(7), 2734. https://doi.org/10.3390/s22072734

[5]. Garvin, D. A. (1987). Competing on the eight dimensions of quality. *Harvard Business Review, 65*(6), 101–109.

[6]. Hussain, A., Abdullah, M., & Yusof, M. (2023). Factors influencing smart classroom adoption using TAM. *International Journal of Emerging Technologies in Learning (iJET), 18*(5), 89–104. https://doi.org/10.3991/ijet.v18i05.37975

[7]. Iranifard, E. and Latifnejad Roudsari, R. (2022). Comparative Research: An Old Yet Unfamiliar Method. *Journal of Midwifery and Reproductive Health*, *10*(3), 3317-3318. doi: 10.22038/jmrh.2022.66873.1954

[8]. Islam, M. T., Farooq, M. S., & Moinuddin, M. (2023). Design and analysis of low-cost smart classroom systems. *IEEE Access, 11*, 22312–22324. https://doi.org/10.1109/ACCESS.2023.3244022

[9]. Kamarudin, N., Mohamed, R., & Abdullah, S. (2021). A cost-effective environmental monitoring and fan control system for schools. *IOP Conference Series: Materials Science and Engineering, 1078*(1), 012043. https://doi.org/10.1088/1757-899X/1078/1/012043

[10]. Kim, J., Lee, Y., & Han, T. (2021). Smart classroom environmental control based on sensor networks. *Journal of Ambient Intelligence and Humanized Computing, 12*(4), 3761–3770. https://doi.org/10.1007/s12652-020-02555-9

[11]. Marzuki, M., Hanifah, R. A., & Rahman, M. F. A. (2021). Energy management in educational buildings: A review. *Energy Reports, 7*, 987–1003. https://doi.org/10.1016/j.egyr.2021.01.031

[12]. Nguyen, T. A., Do, H. Q., & Pham, M. D. (2022). Adoption of smart classroom technology: An extended TAM approach. *Education and Information Technologies, 27*, 933–953. https://doi.org/10.1007/s10639-021-10743-z

[13]. Park, E., Cho, Y., & Lee, H. (2021). Smart product service systems in smart education: Human-centered design issues. *Computers & Education, 165*, 104145. https://doi.org/10.1016/j.compedu.2021.104145

[14]. Ramos, R. J., de Castro, M. A., & Tadeo, M. F. (2023). Smart classroom technologies in Philippine public schools: Adoption, barriers, and opportunities. *Philippine Journal of Science and Technology, 48*(2), 201–217.

[15]. Venkatesh, V., Thong, J. Y. L., & Xu, X. (2021). Unified theory of acceptance and use of technology: A synthesis and the road ahead. *MIS Quarterly, 45*(1), 287–305. https://doi.org/10.25300/MISQ/2021/16217

[16]. Wang, Z., Liu, Y., & Zhang, W. (2020). Intelligent building energy management systems: A review. *Sustainable Cities and Society, 56*, 102093. https://doi.org/10.1016/j.scs.2020.102093

[17]. Yoo, Y., Lee, H., & Choi, S. (2020). A user-centered approach to the design of smart classroom interfaces. *Design Studies, 68*, 1–16. https://doi.org/10.1016/j.destud.2020.100936