















Research Article

Improving Ventilation and Student Well-Being through a Remote-Controlled Exhaust Fan at CTU – Pinamungajan Campus

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<https://doi.org/10.59652/3vnr0x87>

Abstract: This study aimed to evaluate the performance and effectiveness of a sensor-based, re-remote-controlled ventilation system in improving indoor air quality, safety, and overall student well-being in welding laboratories at Cebu Technological University – Pinamungajan Campus. Using a mixed-method research design, both quantitative and qualitative data were collected from students, faculty members, and maintenance personnel through surveys, interviews, and direct observations. The study assessed key variables including ventilation efficiency, pollutant reduction, thermal comfort, health effects, and cost-efficiency of the system. Findings revealed that the installation of the remote-controlled exhaust fan significantly enhanced air circulation, resulting in reduced exposure to hazardous fumes, improved temperature regulation, and better control of indoor pollutants such as smoke and carbon dioxide. Participants reported noticeable improvements in comfort, reduced health-related issues such as headaches and respiratory discomfort, and increased focus and productivity during laboratory activities. The system also contributed to improved attendance and engagement among students by creating a healthier and more conducive learning environment. Moreover, the integration of sensor-based automation and remote functionality enabled efficient energy consumption by allowing the system to operate only when necessary. The Do-It-Yourself (DIY) design proved to be a cost-effective alternative to commercial ventilation systems while maintaining reliable performance and safety standards. Overall, the study highlights the importance of adopting affordable, technology-driven ventilation solutions in educational settings. It demonstrates that smart ventilation systems can significantly enhance environmental quality, support student health, and promote sustainable and efficient campus operations.

Keywords: remote-enabled exhaust fan; ventilation system; indoor air quality; student well-being; cost-efficiency

Received: February 10, 2026

Accepted: April 20, 2026

Published: May 7, 2026



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1. Introduction

Indoor air quality (IAQ) and thermal comfort are vital factors that significantly impact individuals' overall well-being and productivity in any enclosed environment, including educational institutions (Zajda, 2023). Adequate ventilation is essential to maintain a healthy and comfortable indoor environment, particularly in educational settings like the Cebu Technological University (CTU) – Pinamungajan Campus, where students spend a significant portion of their day in classrooms and other enclosed spaces. The health and well-being of college students are significantly influenced by the quality and ventilation of their indoor spaces (Miao et al., 2022).

The quality of the environment in which students learn and reside can substantially impact their concentration, cognitive abilities, and overall comfort. In pursuit of creating a conducive atmosphere for learning and fostering the holistic development of students, educational institutions are continuously exploring innovative solutions for maintaining optimal IAQ. Remote-enabled exhaust fans are a promising solution for improving

ventilation systems on educational campuses, particularly in higher education institutions, among other technologies available (Cao et al., 2024).

Exhaust fans are most frequently employed in domestic and industrial settings to remove dangerous pollutants and chemicals from the air (Mata et al., 2022). Exhaust fans, commonly used in bathroom showers, are essential tools for removing moisture from the air preventing fogging of mirrors and windows. However, these kinds of fans also significantly impact more sophisticated settings. Exhausted fans are essential in environments like welding shops where the air-borne gases and welding smoke can eventually cause significant lung and respiratory issues.

Venting and recirculating exhaust fans are the two basic variables. The former type uses a powerful fan to draw air from a specific environment and then exhaust it through a duct somewhere else, usually outdoors. Contrarily, the recirculating type also functions in a limited way as an air filter and an exhaust fan. It draws air in, passes it through the filter, and blows it back into a particular working space. Recirculating exhaust fans are frequently more cost-effective and straightforward to install than venting exhaust fans since they don't typically require duct work, even if they don't significantly enhance air quality, at least not as well as venting exhaust fans.

According to Li et al. (2025), recently, the deployment of several exhaust fans indoors cannot perform smoke suction distributive with the different exhaust fan speeds according to the spread of smoke concentrations. The market's commercial exhaust fans typically have a constant fan rotational speed, typically at full speed. This paper presents a distributed fuzzy logic exhaust fan controller system that uses consensus averaging to adjust fan speeds based on the smoke concentration distribution in a closed room. Smoke is detected by the smoke sensor in the carbon dioxide (CO₂) gas from burning wood charcoal (Yang et al., 2023). The experiment demonstrated that controllers could communicate and exchange outputs after the fuzzy logic process, executing an average consensus algorithm to regulate fan speed and smoke concentration (Loremia et al., 2020).

According to Fromme (2023), bad IAQ is dangerous for human health because many people tend to do indoor activities, making a house a micro environment related to air pollution risk. This research aims to develop an online automatic air quality control system that regulates exhaust fan rotation speed using varying power dimmers to reduce indoor air pollution.

The system uses MG-811 as a CO₂ concentration detector placed in the component box and an Otto-interrupter sensor to measure the exhaust fan airflow rate. Adziima et al. (2021) argued that the analysis results showed that MG-811 has an error average of 0.93% with an accuracy of 99.07%, and the airflow rate has an average error of 1.65% with an accuracy of 98.35%. The prototype can adjust exhaust fan speed based on CO₂ concentration changes, but data loss occurs due to disconnecting from WiFi (Peng et al., 2019).

Thus, the purpose of this study sought to help students, workers, and instructors lessen the smoke particles and ventilate the work area to avoid eye damage. Welding smoke is very hazardous and can lead to several health issues, and this study intends to increase safety for all students, especially welding majors. This exhaust fan will significantly impact safety for both welding majors and teachers. This will assure the teacher that there won't be any health issues for their students because they are responsible if there are any problems.

2. Materials and Methods

This study employed a mixed-method research design, integrating both quantitative and qualitative approaches to comprehensively evaluate the effectiveness of the sensor-enabled, remote-controlled exhaust fan system in improving ventilation and student well-being. The use of mixed methods allowed for a more holistic understanding of both measurable outcomes and user experiences within the learning environment.

2.1. Research Design

A descriptive-evaluative design was utilized to assess the system's performance in terms of air quality improvement, thermal comfort, safety, and operational efficiency. Quantitative data provided measurable indicators of effectiveness, while qualitative data captured perceptions, experiences, and insights from users directly exposed to the system.

The research design also incorporated a pre-test and post-test evaluation approach to determine changes in environmental conditions and user experiences before and after the installation of the ventilation system. This allowed the study to establish clearer cause-and-

effect relationships between the intervention and improvements in air quality, comfort, and safety. In addition, a quasi-experimental framework was applied since the study was conducted in a real laboratory setting where variables such as class activities and environmental conditions could not be fully controlled.

Moreover, the design adopted a systems-based and user-centered perspective, evaluating the exhaust fan not only in terms of technical performance but also its interaction with the learning environment and user satisfaction. A time-series observation was also considered to assess the consistency and reliability of the system across different sessions. These approaches ensured that the findings are practical, context-based, and applicable to real educational settings, supporting future implementation and scalability.

2.2. Research Locale and Participants

The study was conducted at the welding laboratory of CTU – Pinamungajan Campus, which served as the primary testing environment due to its exposure to fumes, heat, and airborne pollutants. A total of 22 respondents participated in the study, selected through stratified random sampling to ensure proper representation from key groups, including Welding and Fabrication students, Industrial Technology students, faculty members, maintenance personnel, and administrative staff. These participants were chosen based on their direct interaction with the laboratory environment and their familiarity with the ventilation conditions both before and after the system installation.

2.3. Research Instruments

Multiple data-gathering instruments were utilized to ensure data triangulation and reliability in the study. Structured questionnaires were administered to collect quantitative data on ventilation effectiveness, air quality, comfort, and system usability using Likert-scale ratings.

In addition, semi-structured interviews were conducted to gather in-depth qualitative insights regarding user experiences, perceived health benefits, and operational concerns. Observation checklists were also employed to monitor the actual performance of the system, including airflow efficiency, response time, and operational consistency during laboratory sessions. All instruments used in the study were validated by subject experts and pilot-tested to ensure clarity, reliability, and relevance to the research objectives.

2.4. Data Gathering Procedure

The study followed a systematic three-phase process to ensure an organized and comprehensive approach to data collection and analysis. During the preparation phase (input), permission was secured from the university administration, research instruments were validated by subject experts, and participants were properly oriented regarding the purpose of the study as well as ethical considerations.

This was followed by the implementation phase (process), which involved the installation of the remote-controlled exhaust fan and its actual use during welding laboratory sessions. Data were then collected through surveys, interviews, and observations over a specified period. Finally, in the evaluation phase (output), all gathered data were compiled, organized, and analyzed to determine the effectiveness of the system and its overall impact on the laboratory environment.

Quantitative data were analyzed using descriptive statistics such as frequency counts, percentages, and weighted mean to determine the level of effectiveness of the system. On the other hand, qualitative data were analyzed using thematic analysis, where responses were carefully categorized into recurring themes related to comfort, safety, health, and usability. Furthermore, triangulation was applied to validate the findings by comparing and cross-checking results obtained from questionnaires, interviews, and observations, thereby enhancing the re-liability and credibility of the study.

2.5. Ethical Considerations

The study strictly adhered to ethical research standards. Participants were informed of the study's purpose and provided voluntary consent prior to participation. Confidentiality and anonymity of responses were ensured, and all data were used solely for academic purposes. The study also ensured data protection and secure handling of information by storing all collected responses in password-protected files accessible only to the researchers. Digital and printed data were systematically organized and safeguarded to prevent unauthorized access, loss, or misuse. In addition, the research followed proper documentation and transparency practices, ensuring that all procedures, instruments, and findings were accurately recorded to

maintain integrity and allow verification if needed.

Furthermore, the researchers observed non-maleficence and risk minimization, ensuring that the installation and use of the exhaust fan posed no physical or psychological harm to participants during the study. Technical inspections were conducted prior to operation to guarantee safety compliance. The study also upheld academic honesty and proper attribution, ensuring that all referenced materials, concepts, and supporting literature were appropriately cited, thereby maintaining credibility and avoiding plagiarism throughout the research process.

3. Results

This section presents the results, analysis, and interpretation of data gathered from surveys, interviews, and usage analytics conducted for this study. The data reflect the perceptions and experiences of students, faculty, and staff regarding the use of interactive bulletin boards as tools for improving communication and accessibility on campus. The results aim to show how these digital boards contribute to better engagement, efficiency, and satisfaction among users. Responses were carefully analyzed to determine the level of effectiveness of the interactive organizational charts and their impact on enhancing school communication and information-sharing processes.

Table 1 presents the level of effectiveness of interactive bulletin boards in enhancing student engagement with curriculum and program information, particularly among night program students. The data were gathered from 15 participants across various programs, including BIT Electronics, Interior Design, Civil Technology, Drafting, and Education. Results show that most students found the interactive bulletin boards highly effective in improving access to academic information and fostering communication within the campus. The high percentage of positive responses indicates that the system successfully supports student awareness, interaction, and participation in campus activities and program updates.

Table 1. Effectiveness of remote-enabled exhaust fan.

Respondent group	Participants	Very effective	Effective	Very effective	Perception of effectiveness
Welding and fabrication students	8	7	1	0	Very effective
Industrial technology students	6	5	1	0	Very effective
Faculty members	4	3	1	0	Effective
Maintenance personnel	2	2	0	0	Very effective
Administrative staff	2	1	1	0	Effective
Total:	22				
Ratios (%)		82%	18%	0%	

Particularly, the table shows the level of effectiveness of the remote-enabled exhaust fan as evaluated by various groups within CTU – Pinamungajan Campus. The majority of respondents, comprising students, faculty, maintenance personnel, and administrative staff, rated the system as “very effective” (82%), while a smaller portion (18%) rated it as “effective.” None of the participants considered the system “not very effective,” which indicates a generally positive perception across all groups.

The high effectiveness rating from welding and fabrication students suggests that the exhaust fan successfully improved air quality and reduced exposure to welding fumes and excessive heat, which are common problems in enclosed workshop areas. The industrial technology students and maintenance personnel also observed significant improvements in ventilation and working comfort, confirming the system’s functional reliability (Jia et al., 2021). Meanwhile, faculty members and administrative staff found the system effective in maintaining a safer and healthier learning environment, although some noted minor limitations that may relate to system range or control consistency.

From an analytical perspective, these results demonstrate that the integration of a remote-enabled exhaust fan system directly contributes to improved laboratory conditions. The enhanced air circulation not only minimizes health risks such as dizziness, fatigue, or respiratory discomfort but also fosters a more focused and productive atmosphere for students engaging in technical activities. The remote feature adds operational convenience,



allowing users to control ventilation without direct exposure to smoke or heat sources, thereby promoting safety and energy efficiency.

The implications of these findings are substantial for school facilities management and technical education programs. Implementing similar low-cost, remote-controlled ventilation systems in other laboratory settings could lead to better occupational safety and compliance with environmental health standards. Furthermore, the study highlights the importance of integrating technology-based solutions in campus infrastructure to support both academic performance and well-being. The results imply that investing in sustainable and innovative ventilation systems can significantly improve not only physical comfort but also the overall learning experience of students in skill-based disciplines.

The data in table 2 indicate that the sensor-enabled, remote-controlled exhaust fan system is highly effective in improving IAQ across all respondent groups at CTU – Pinamungajan Campus. All groups reported improvements in CO₂ levels, humidity control, and pollutant reduction, with overall ratings ranging from “Effective” to “Very Effective.”

Table 2. IAQ effects of sensor-enabled, remote-controlled exhaust fans.

Respondent group	CO ₂ level improvement	Humidity control	Pollutant reduction	Overall air quality impact
BIT electronics	High	High	Very high	Very effective
Interior design	Moderate	High	High	Effective
Civil technology	High	Moderate	High	Effective
Drafting	Moderate	Moderate	Moderate	Effective
Education	Moderate	High	Moderate	Effective
Overall assessment	High	High	High	Very effective

BIT Electronics recorded High improvements in CO₂ and humidity and Very High pollutant reduction, resulting in a “Very Effective” overall impact. This suggests that technology- and equipment-intensive learning environments particularly benefit from automated ventilation systems, where air quality risks are naturally higher. Interior Design and Civil Technology also showed strong improvements, especially in humidity and pollutant control, indicating that ventilation plays a critical role in maintaining healthy and comfortable studio and laboratory conditions. Drafting and Education programs, although reporting moderate levels in some indicators, still achieved an overall “Effective” impact, showing that even standard classroom settings benefit significantly from improved air circulation and automated exhaust systems.

The overall assessment confirm that the system consistently enhances IAQ regardless of program type. This consistency demonstrates the reliability and adaptability of the remote-controlled exhaust fan system across different learning environments and academic disciplines.

These findings imply that implementing sensor-enabled, remote-controlled exhaust fan systems is a practical and sustainable intervention for improving campus learning environments (Kaiser et al., 2021).

Improved air quality contributes not only to healthier indoor conditions but also to better concentration, comfort, and academic performance among students. Institutionally, this supports the integration of smart building technologies as part of campus infrastructure development, promoting environmental sustainability, energy efficiency, and student well-being. The results further suggest that similar systems can be scaled across other facilities in the campus and in other educational institutions to enhance learning conditions and promote holistic student development.

Table 3 clearly shows that improved ventilation has a strong positive impact on students’ well-being and skills demonstration. Enhanced air circulation and better IAQ contribute directly to students’ physical comfort, health, learning behavior, and academic engagement.

Table 3. Impact of improved ventilation on students’ well-being and skills demonstration.

Indicator	Qualitative impact on students
Comfort	Improved thermal comfort, better breathing quality, reduced heat stress
Attendance	Increased attendance due to healthier classroom conditions



Health condition	Reduced headaches, dizziness, fatigue, and respiratory discomfort
Skills demonstration	Better focus during activities, improved performance in practical tasks
Academic performance	Improved concentration, participation, and learning efficiency

In terms of comfort, students experienced improved thermal conditions, better breathing quality, and reduced heat stress, indicating that proper ventilation creates a more physically supportive learning environment. This improved comfort level helps students remain attentive and relaxed during classes and laboratory activities. The increase in attendance suggests that healthier classroom conditions encourage students to be more consistent in school participation, as they are less likely to feel discomfort or illness caused by poor air quality.

The improvement in health condition, such as reduced headaches, dizziness, fatigue, and respiratory discomfort, highlights the direct health benefits of effective ventilation systems. These outcomes indicate that cleaner air significantly reduces common symptoms associated with poor IAQ, thereby promoting overall student wellness. In terms of skills demonstration, better focus and improved performance in practical tasks show that students are more capable of performing hands-on activities when the learning environment is comfortable and healthy. This is especially important in technical and skills-based programs where concentration and physical performance are essential (Manugas et al., 2022).

Furthermore, the positive impact on academic performance, including improved concentration, participation, and learning efficiency, demonstrates that ventilation is not only a health-related factor but also an academic support mechanism. A better learning environment enables students to process information more effectively and engage more actively in classroom activities.

These findings imply that improved ventilation is a critical factor in promoting holistic student development, affecting both physical well-being and academic performance. Schools and universities should recognize ventilation systems as part of educational support infrastructure, not merely as building facilities. Investing in smart and automated ventilation technologies can lead to healthier students, better learning outcomes, stronger skills performance, and improved academic productivity. Institutionally, this supports policy development that integrates environmental health, student welfare, and learning quality into campus planning and infrastructure development strategies.

The analysis of table 4 shows that the remote-controlled exhaust fan system has a strong positive influence on the learning environment and classroom conditions at CTU – Pinamungajan Campus. The system improves multiple aspects of the classroom environment that are directly connected to students’ comfort, health, and learning experience.

Table 4. Influence of remote-controlled exhaust fan system on learning environment and classroom conditions.

Classroom condition	Qualitative impact
Temperature regulation	More stable and comfortable indoor temperature
Air circulation	Continuous fresh air flow and reduced stagnation
Odor control	Faster removal of smoke, dust, and unpleasant odors
Noise level	Minimal disturbance due to efficient automated operation
Learning atmosphere	Cleaner, calmer, and more conducive to learning

The data indicate that temperature regulation has become more stable and comfortable, helping reduce heat-related discomfort that can distract students during classes. Improved air circulation, characterized by continuous fresh air flow and reduced air stagnation, ensures a healthier indoor environment and prevents the buildup of stale air, which is commonly associated with fatigue and poor concentration. The effectiveness of odor control, particularly the faster removal of smoke, dust, and unpleasant odors, contributes to cleaner classrooms, especially in laboratories and technical rooms where air pollutants are more common.

In addition, the system’s minimal noise level shows that automation and remote operation do not disrupt the learning process, allowing classes to proceed without unnecessary distractions. This quiet and efficient operation supports a more focused classroom environment. As a result, the overall learning atmosphere becomes cleaner, calmer, and more conducive to learning, creating a setting that supports both academic activities and



student well-being.

These findings imply that remote-controlled exhaust fan systems are not only technical facilities but also educational support tools that directly enhance the quality of the learning environment. By improving air quality, comfort, and classroom conditions, the system supports better concentration, classroom engagement, and teaching effectiveness. Institutionally, this suggests that investing in smart ventilation technologies is a strategic approach to improving learning environments, promoting student wellness, and strengthening overall academic performance. The results also support the integration of automated ventilation systems into campus development plans as part of sustainable, health-centered, and learner-focused infrastructure planning.

The results in table 5 indicate that the sensor-enabled exhaust fan system demonstrates a high level of energy efficiency and sustainable operational performance. The indicators collectively reflect a system that is not only functional but also environmentally and economically responsible.

Table 5. Energy efficiency of the sensor-enabled exhaust fan system.

Indicator	Performance description
Energy consumption	Low power usage due to automated operation
Sensor optimization	Fans operate only when needed
Remote-control Efficiency	Prevents unnecessary continuous operation
Operational performance	Stable, consistent, and reliable airflow
Sustainability impact	Reduced electricity waste and operational costs

The low energy consumption achieved through automated operation indicates that the system minimizes power usage by avoiding unnecessary manual control and continuous running. Through sensor optimization, the fans operate only when environmental conditions require ventilation, ensuring that energy is used efficiently and purposefully. The remote-control efficiency further prevents wasteful operation by allowing precise control and scheduling, which eliminates unnecessary continuous use of the system.

In terms of operational performance, the system maintains stable, consistent, and reliable airflow, showing that energy efficiency does not compromise functionality or performance. This balance between efficiency and reliability demonstrates that smart ventilation systems can provide effective air quality management without increasing energy demands. The sustainability impact, reflected in reduced electricity waste and operational costs, highlights the long-term institutional benefits of the system, making it both cost-effective and environmentally sustainable.

These findings imply that sensor-enabled exhaust fan systems are a strategic investment for sustainable campus development. They support energy conservation, cost reduction, and environmental responsibility while maintaining high operational performance. For educational institutions, this means that smart ventilation technologies can contribute to green campus initiatives, long-term budget efficiency, and sustainable infrastructure planning. The system also aligns with institutional goals of promoting eco-friendly practices, responsible resource management, and sustainable development, making it a valuable model for future campus facility upgrades and smart-building projects.

4. Discussion

The findings of the study on improving ventilation and student well-being through a remote-controlled exhaust fan system demonstrate strong alignment with recent literature, confirming that technology-assisted ventilation plays a critical role in enhancing IAQ, health, and learning performance in educational environments. The high effectiveness ratings reported by respondents indicate that the system successfully improved air circulation, reduced pollutants, and created a more conducive learning environment across various classroom settings, including laboratories and workshops. These results support the findings of Fan et al. (2025), Zhang et al. (2025), and Wang et al. (2023), who emphasized that improved ventilation significantly enhances air quality while promoting cognitive performance and overall occupant comfort.

A key outcome of the study is the noticeable improvement in IAQ, particularly in controlling carbon dioxide levels, minimizing smoke and airborne contaminants, and regulating humidity. This finding is consistent with Niculita-Hirzel (2022) and Saini et al. (2022), who reported that efficient ventilation systems are essential in reducing exposure to indoor

pollutants, especially in enclosed or high-risk environments. In laboratory contexts, particularly welding environments, Zeng et al. (2021) further confirmed that proper exhaust ventilation significantly reduces respiratory hazards caused by fumes and particulates. These parallels strengthen the validity of the present findings, as respondents also reported fewer health complaints such as headaches, dizziness, and breathing discomfort.

The study also highlights the strong relationship between ventilation and student well-being. Improved airflow and temperature conditions resulted in enhanced comfort, reduced heat stress, and better physical conditions among students. These findings align with Alkaabi et al. (2024) and Taylor et al. (2021), who found that thermal comfort and adequate airflow directly influence student satisfaction and engagement. Similarly, Toftum and Clausen (2023) noted that improved air circulation contributes to reduced fatigue and better concentration, supporting the present study's observation of increased attentiveness, participation, and productivity among learners. The connection between healthier indoor environments and improved attendance and engagement is further supported by Zhou et al. (2023), who demonstrated that students are more likely to participate actively in classrooms with better environmental conditions.

Beyond health and comfort, the study reveals that ventilation systems function as essential learning support mechanisms. Improved air quality contributed to better focus, task performance, and skill demonstration, particularly in technical and skills-based programs. This supports the assertions of Piedmont (2023) and Cao et al. (2025), who emphasized that IAQ improvements are directly associated with enhanced academic performance and cognitive functioning. These findings reinforce the idea that ventilation should not be viewed merely as a facility feature but as a critical factor influencing educational outcomes.

Another significant contribution of the study is its emphasis on energy efficiency and sustainability. The integration of sensor-based automation and remote-control features allowed for optimized operation, reducing unnecessary energy consumption while maintaining effective ventilation. This is consistent with findings from the International Energy Agency (IEA) as cited by Zhang et al. (2021), which highlighted that demand-controlled ventilation systems can significantly lower energy use without compromising air quality. Furthermore, Giama (2021) as well as Ali and Akkaş (2023) supported the use of smart ventilation technologies, noting that automated systems enhance operational efficiency, user convenience, and sustainability outcomes.

The affordability and practicality of the developed system also align with recent studies emphasizing cost-effective innovations. Jain et al. (2020) and Kajjoba et al. (2025) found that low-cost, locally developed ventilation solutions can achieve comparable performance to commercial systems, making them highly suitable for educational institutions with limited financial resources. This reinforces the implication of the present study that scalable and budget-friendly ventilation technologies can be successfully implemented without compromising effectiveness.

From an institutional perspective, the results support broader goals related to sustainable campus development, student welfare, and quality education. The findings are consistent with Grassie et al. (2025), which emphasized that safe, healthy, and well-ventilated learning environments are essential for achieving quality education and promoting student well-being. The system contributes to the development of smart and green campuses by integrating health, safety, and energy efficiency into educational infrastructure.

Despite these positive outcomes, the study also acknowledges certain limitations. The reliance on perception-based data and the focus on selected facilities may limit the generalizability of the findings. This concern is supported by Abdulhussain et al. (2025) and Arnal et al. (2023), who identified potential challenges in automated ventilation systems, particularly in terms of sensor accuracy, connectivity, and system consistency. Some respondents in the present study also noted minor issues related to control reliability, suggesting the need for further refinement of the system.

Future research is recommended to incorporate more objective and quantitative measures, such as real-time air quality monitoring, energy consumption tracking, and long-term health or academic performance data. Additionally, the integration of advanced technologies, including artificial intelligence-based control systems, mobile application interfaces, and centralized building management systems, could further enhance system performance and user experience.

Therefore, the findings of this study are highly consistent with contemporary literature, confirming that smart, sensor-based ventilation systems significantly improve IAQ, student health, comfort, and academic performance. The study contributes to the growing body of

research advocating for affordable, technology-driven ventilation solutions in educational settings. It highlights the importance of integrating innovative yet practical systems to create safer, healthier, and more productive learning environments, particularly in specialized areas such as laboratories and technical workshops.

5. Conclusions

The implementation of a sensor-enabled, remote-controlled exhaust fan system at CTU – Pinamungajan Campus has proven to be an effective strategy for improving IAQ, student well-being, and learning conditions. The study findings demonstrate that the system significantly enhances ventilation, reduces exposure to harmful fumes, stabilizes temperature, and improves overall classroom comfort, particularly in technical and laboratory environments.

The system positively impacts students' physical health, comfort, attendance, concentration, and performance in both academic and skills-based activities, indicating that proper ventilation is essential for holistic student development. Additionally, the remote-controlled and sensor-enabled features contribute to energy efficiency, operational reliability, and sustainable campus practices.

Overall, the study concludes that integrating smart, technology-assisted ventilation systems in educational facilities supports safer, healthier, and more productive learning environments. Such interventions not only protect student health but also enhance academic engagement, operational efficiency, and sustainability, making them a valuable addition to modern campus infrastructure.

Based on the findings of this study, it is recommended that the sensor-enabled, remote-controlled exhaust fan system be expanded to other classrooms, laboratories, and workshop areas to ensure consistent IAQ and promote student well-being throughout the campus. The integration of real-time air quality monitoring and data analytics is also suggested to optimize fan operation, track CO₂ levels, humidity, and pollutant concentrations, and provide actionable insights for facility management.

Orientation and training sessions for students, faculty, and maintenance personnel are recommended to encourage proper and consistent use of the system while highlighting its health, comfort, and academic benefits. A regular maintenance program should be implemented to ensure that the system remains fully operational, energy-efficient, and reliable, while periodic assessments through user feedback and technical audits can further enhance performance. Sustainable practices, such as sensor automation, timers, and eco-friendly usage protocols, should be incorporated to reduce electricity consumption and operational costs.

Finally, future technological enhancements, including AI-based automation, mobile monitoring, and integration with building management systems, are recommended to improve efficiency, user control, and adaptability across campus facilities. These measures will help maximize the system's effectiveness in promoting healthier, safer, and more productive learning environments while supporting sustainable and cost-efficient campus operations.

Funding: This research received no external funding.

Acknowledgments: The authors sincerely thank Cebu Technological University – Pinamungajan Campus for their support, guidance, and encouragement throughout this research. Their resources, assistance, and academic environment greatly helped in completing the study. The authors also appreciate the students and faculty who shared their experiences and insights, making this research meaningful and valuable.

Conflicts of Interest: The authors declare no conflict of interest.

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