

Smart classroom for university students: Improving air quality by integrating wireless sensors in Malaysia

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received July 12, 2021 Received in revised form Nov. 29, 2022 Accepted Dec. 12, 2022 Available online December 31, 2022</p> <p><i>Keywords:</i> Covid-19 Learning efficiency Smart classroom Ventilation system Wireless sensors technology</p> <p>*Corresponding author: Ng Wei Pang Interior Architecture Program, School of Housing, Building and Planning, University Sains Malaysia Email: davidngweipang@hotmail.com</p>	<p><i>In 2020, the COVID-19 pandemic has had a huge impact on the education system in Malaysia, especially at higher education level. A number of public or private universities have carried out online learning classes due to the Covid-19 pandemic and avoid the spread of the virus among university students. Face to-face learning can not be implemented because the learning efficiency in class management decreased. Thus, this study discussed the integration of wireless sensors within the classroom, focusing on improvement of ventilation system and learning efficiency in classroom design. As a result, the goals of this research are to identify the types of wireless sensors that can be used to improve the ventilation system in classroom design, to identify the mechanisms of wireless sensors that can be used to improve the ventilation system in classroom design, and to propose design guidelines for using wireless sensors to improve the ventilation system and learning efficiency in classroom design. Reviews on related topics such as wireless sensor technology and smart classroom will be made via online searching articles and journals. Acquisition of primary data and secondary data will be done via case study of smart classroom from relevant articles and journals.</i></p>

Introduction

The United Nations Sustainable Development Goals (SDG) are a collective agenda which requiring international cooperation efforts. Due to the implication of Covid-19 in 2020, national school closures have been enforced in over 190 countries. Approximately 90% of all pupils (1.57 billion) were away from school, and remote learning options are available in four of the five countries where schools were closed. A report from the department of economic and social affairs of the United Nations, showed the decreasing rate of upper secondary school female students who received education from 39% (2011) to 35% (2018) and for upper secondary school male students who received education is

decreasing from 37.4% (2011) to 34.8% (2018) (United Nations Statistics Division Development Data and Outreach Branch 2020). However, the COVID-19 pandemic has worsened the situation for most countries' education systems, and the end of this pandemic is unknown to the education system because it cannot be predicted. Despite the fact that many schools have provided remote learning to students via virtual classrooms as a result of school closures. Many marginalised students are further disadvantaged by a lack of home access to digital tools, but also a lack of computer-related skills. School closures are caused by the Covid-19 virus, which is capable of spreading through the air in classroom space. Students are at risk of contracting the virus if the

ventilation system of the classroom design is inadequate (Haddad et al. 2021).

In Malaysia, COVID-19 crisis has given huge impacted on high education world. For example, public and private universities have been announced school closures caused by the enforcement of the Movement Control Order (MCO) since March 2020. Face to face learning in university level study are not available and learning process for university students has been affected. Online learning through a virtual classroom is not perfect enough for the student with a poor internet connection at home. Based on the survey that was conducted by the Ministry of Education, which involved 670,000 parents and 900,00 students in Malaysia. The survey showed that only 6% of students have personal computers while 46% of students have smartphones and 36.9% of students do not have any devices that can be used to attend online classes (WOB Partner Content 2021). Through this survey, this 36.9% of students will fall behind in their studies as this will reduce learning efficiency for them through online learning classes. Conducting virtual classroom for university students is to prevent the Covid-19 virus spreading in the enclosed space without a good ventilation system. Covid-19 can be easily spread through airborne droplets and poor ventilation system in enclosed space (UNICEF 2020). This phenomena calls for reviewing the ventilation system in classroom design, especially for tertiary education, in order to protect university students from Covid-19 virus. In this study, the research question that needs to be achieved is to determine the type of wireless sensors that can be useful for improving ventilation systems and learning efficiency in classroom design. Besides, other research question to be achieved is to identify the mechanisms of wireless sensors for improving the ventilation system in classroom design. Moreover, the last objective in this paper is to propose design guidelines for applying wireless sensors to improve the ventilation system and learning efficiency in classroom design.

By referring to most of the articles and journals, most of the research papers discuss wireless sensor technology in residential buildings, office buildings or even laboratory space. For smart classroom research papers, most of them are discussing the mechanisms of the Internet of Things (IoT) to control temperature, humidity and concentration of CO₂ in the learning environment. Most of the research papers also

discuss overseas case studies (Sari, Ciptadi, and Hardyanto 2017). There is no related study on wireless sensors technology in smart classrooms within Malaysia. Thus, there is a research gap that this research paper would like to carry out.

The purpose of this study is to propose design guidelines for applying wireless sensors to classroom design. A review of literature revealed research on the definition of a smart classroom, wireless sensor technology, learning efficiency, and ventilation systems that can be related to Covid-19. Furthermore, the literature review explored how wireless sensor technology can control ventilation system in smart classroom design.

Smart classroom

A Smart classroom is a goal to provide a distinguished educational atmosphere capable of enhancing collaborative learning environments and providing diverse information sources through a variety of interactive resources. In literature, the smart classroom idea originated from a larger concept known as the distance education scheme, which used the Internet as a tool to turn a traditional classroom into an intelligent space outfitted with various hardware and software components (Al-Hunaiyyan, Al-Sharhan, and Alhajri 2017). According to the research by Al-Sharhan (2016), he presented a comprehensive model and approach to the smart classroom world in the framework of technology enhanced learning (TEL). He stressed that the idea of smart classrooms could not be confused with a traditional classroom, which was once filled with such educational devices such as projectors and overheads. According to Bajracharya, Blackford, and Chelladurai (2011), a smart classroom is a classroom that has been outfitted with IoT sensors that can be used to track and assess students' success and productivity.

According to Diaz León et al. (2016) study, the smart classroom promotes knowledge transfer by using technical developments in signal processing, web technology, hardware and software. The design concepts of the smart classroom interactive relationship between learners and lecturers in order to allow the lecturer to educate more efficiently and to make the process more conducive to teaching and learning (Saini and Goel 2020; J. Yang et al. 2018). A typical smart classroom offers features for improved presentation, more student engagement,

improved interaction, a better physical environment, and more real-time feedback.

Bautista and Borges (2013) defines smart classrooms as technology-enhanced classrooms that offer opportunities for teaching and learning by integrating learning with technological instruments. Computers, classroom management software with assistive listening devices, networking, and audio/visual capabilities are examples of these tools. A smart classroom is made up of many modules that work together to create an immersive and interesting learning experience that enhances instructional practice, develops students' skills, raises their academic level, and allows for more involvement in the learning process. Thus, it was further deduced that smart classrooms have high technology devices in classroom design which are able to promote engagement between students. It seems to suggest that the implementation of wireless sensors technology in smart classrooms needs to be further discussed.

Wireless sensors technology

Recently, the advancement of wireless sensor technologies has innovated in the field of home automation, enabling autonomous interior design and implementation of decoration automation systems. A Wireless Sensors Network (WSN) is a collection of spatially distributed sensor nodes that are linked together through wireless communication (Akyildiz et al. 2002). These sensors are capable of both computation and sensing, and they can also communicate with one another. The ultimate aim of WSNs is often to gather sensing data from all sensors to specific sink nodes and then conduct further analyses at these sink nodes (Emary and Ramakrishnan 2013). A wireless sensor network usually consists of three components: sensor nodes, gateways, and observers (user). Gateways and observers are linked together using a special network or, more generally, the internet (figure 1).

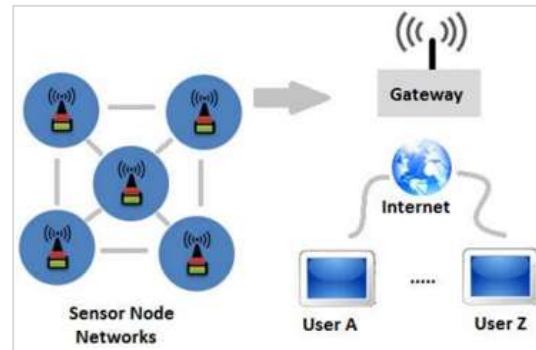


Figure 1. Wireless Sensor Network (WSN)
Source: (Kocakulak and Butun 2017)

According to Spachos and Hatzinakos (2016), a real-time monitoring system has been proposed in order to monitor carbon dioxide concentration in a room through a wireless sensor network. The proposed device was able to report an increase in carbon dioxide levels and monitor carbon dioxide concentrations in real time through sensor nodes. The system framework is shown as figure 2.

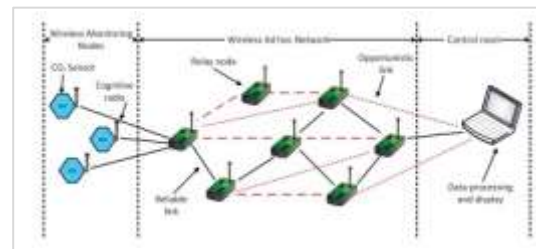


Figure 2. System framework of indoor CO₂ monitoring system
Source: (Spachos and Hatzinakos 2016)

The suggested method outperforms a simple tracking system. Another study by Y. Yang et al. (2021) evaluates both stationary sensing (CO₂ sensors) and mobile sensing (robot with CO₂ sensors) in real-world experiments conducted in a laboratory room. According to the findings of this study, mobile sensing has a greater sensitivity to detecting CO₂ sources than stationary sensing. Thus, the wireless sensors network managed to control the air quality in space. But further research needs to be done on the implementation of wireless sensor networks for controlling ventilation systems in space.

Classroom design and learning efficiency

Learning efficiency is an index to measure the accuracy of performance and learning time speed (Clark, Nguyen, and Sweller 2005). Performance improvement refers to the result of interaction

between learner and study plans, which improves the accuracy and speed of learner (Clark, Nguyen, and Sweller 2005). The SCALE-UP research Project, according to Beichner and Saul (2003), explored the studio-style classroom setting and how its characteristics facilitate cooperation between classes in the learning environment. This studio style classroom setting is a type of classroom design in which students can observe and research physical phenomena in groups, giving teachers a third choice. The SCALE-UP project is an innovative solution to classroom design that can substitute 4 to 6 hours of activity-based teaching per week, usually in two-hour cycles, for the lecture/laboratory style. SCALE-UP curriculum architecture would divide students into organised cooperative classes so that they can converse and communicate spontaneously.

Other study investigated Iowa State University's renovated active learning space, as well as the relationship between this architecture and students' engagement climate and behavior factors (Rands and Gansemer-Topf 2017). The International Space University's classrooms are the subject of this research, which has transitioned from a conventional classroom with fixed seats and no classroom technology to a compact configuration and seating configurations with additional technology to facilitate students' learning (Ascione et al. 2021). There are no fixed desks or student workstations in the active learning classroom since it is a modular and responsive classroom design. These ALC features enable students and desks to shift and communicate in the classroom. Students were able to communicate with each other and their mentor by frequent social contact, allowing them to exchange, spread, and co-construct information, resulting in a sense of community and commitment.

Ventilation system and Covid-19

In general, according to an article from the Canadian Centre for Occupational Health and Safety (16 June, 2021), ventilation is a mechanical system in a building that takes in fresh external air and eliminates contaminated indoor air (Government of Canada 2016). Ventilation is an engineering control that is used to remove or regulate particles such as fumes, dust, vapour, or even tiny particles such as viruses or bacteria that are discharged in an indoor work environment. Based on an interview conducted by Stephanie Desmon (29 September, 2020) with a ventilation

specialist and assistant professor, Mrs Ana Maria Rule, in this discussion, they discuss indoor ventilation systems, which may help limit the spread of Covid-19 but may also make matters worse. Mrs Ana Maria Rule indicated in an interview session that a good ventilation system capable of controlling and filtering out the virus Covid-19 using high-efficiency filters. Poor ventilation systems, on the other hand, may allow the virus to propagate in an enclosed environment (Rogers and Bloomberg 2020).

According to a Centers for Disease Control and Prevention article (2 June, 2021), upgrading ventilation systems in public areas such as schools or commercial buildings can minimise viral propagation and exposure risk (Centers for Disease Control and Prevention 2019). This article suggests some methods for improving ventilation, such as increasing the introduction of outdoor air (open windows or doors), using fans to increase the effectiveness of open windows, and ensuring the ventilation system operates properly and provides acceptable indoor air quality for each space's current occupancy level. Furthermore, rebalance or alter HVAC systems to enhance central air filtering and boost overall airflow to occupied areas. As a result, it can be stated that a proper ventilation system in an enclosed environment may regulate and filter the virus Covid-19 from spreading. As a result, additional research into ventilation systems and WSN can aid in improving the air quality in an enclosed environment (Anastasi et al. 2021).

Method

John Creswell's methodology for this study will be based on the qualitative method, and only one research technique will be used (Creswell and Creswell 2018). The techniques are case studies for smart classroom. Three different case studies will be analysed to determine the mechanisms of wireless sensors used in the smart classroom for improving ventilation system and learning efficiency in classroom design. Primary and secondary data will be collected and analysed from case study techniques. Following an analysis of the wireless sensor mechanisms from case studies, new design guidelines are proposed to improve the ventilation system and learning efficiency for Malaysia's smart classroom.

This study mainly focuses on how the wireless sensors technology is able to improve the ventilation system in smart classrooms for university students in Malaysia. A good ventilation system in smart classrooms is able to prevent transmission of the virus Covid-19 and reduce the risk of university students being infected by Covid-19. More study on humidity or temperature inside the smart class design can be carried on in order to improve this study in the future.

Result and discussion

In this discussion part, three case studies have been examined. Some criteria were considered while locating these case studies, such as the use of smart ventilation or demand-controlled ventilation, the discussion of indoor air quality, and the use of wireless sensor networks in classroom design.

Case studies 1 – Secondary school in Sydney, New South Wales, Australia

This study was conducted in Sydney, Australia, which has a humid subtropical climate with cold winters and warm summers, according to the Koppen Geiger climate classification (Kottek et al. 2006). This study was done in two adjacent classrooms with the same orientation and similar features from April 2018 to May 2019. The secondary school students in the surveyed classrooms ranged in age from 12 to 17 years old, and each classroom could accommodate between 7 and 25 students depending on the subject. The factory calibrated Air Quality Eggs version 2 Model D sensors were used to monitor the indoor air temperature (Ta), relative humidity (RH), and carbon dioxide levels in the survey classroom in order to measure the indoor air quality and temperature. The factory calibrated Air Quality Eggs version 2 Model D sensors were used to monitor the indoor air temperature (Ta), relative humidity (RH), and carbon dioxide levels in the survey classroom in order to measure the indoor air quality and temperature. In each classroom, these egg sensors were wall-mounted roughly 2.3 metres above the floor level, giving real-time air quality data and positioned in a well-ventilated location away from direct sunlight and severe moisture exposure. A smart demand-controlled mechanical extract ventilation (DCV) unit with

cloud connection capability, as well as a window ventilator, were placed in the test classrooms (A). The DCV unit regulated air extraction based on CO₂, RH, Ta, and TVOC using four valves attached to the device at the end of the extract duct.

The results of the CO₂ measurements in this study before and after the installation of the ventilation system revealed a substantial drop in CO₂ concentrations in both tested classrooms. The CO₂ levels in both classrooms were identical prior to the installation of the DCV system in the test classroom, with a maximum CO₂ concentration ranging between 2370ppm and 2418ppm. The peak CO₂ concentration in classroom A was decreased to 1335ppm after the DCV system was installed, but the maximum measured CO₂ concentration in the neighbouring classroom without a DCV was 2981ppm at the same time. Lower CO₂ levels in classroom A suggest a higher ventilation rate and improved indoor air quality, which is consistent with prior research. This case study found factory calibrated Air Quality Eggs version 2 Model D sensors capable of monitoring indoor air temperature (Ta), relative humidity (RH), and carbon dioxide (CO₂) in a classroom. A smart demand-controlled mechanical extract ventilation (DCV) device may also be applied to regulate the CO₂ concentration in the classroom design. Furthermore, some installation guidelines for these egg sensor devices are known, such as that the device must be installed away from direct sunlight and excessive moisture exposure, and it must be installed in the classroom at a height of about 2.3 meters above the floor level for real-time monitoring of air quality data.

Case study 2 – Engineering classroom of University of Pisa, Largo Lucio Lazzarino, Pisa, Italy

Various engineering classrooms at the University of Pisa were investigated to determine the association of air quality measures such as temperature, relative humidity, and CO₂ content, as well as how they fluctuate with varying levels of occupancy. The selected institutions had nine classrooms of various sizes, with all but one having high ceilings (more than 5m high). Sensors monitor interior air quality indicators such as temperature, relative humidity, and carbon dioxide content in the building chosen for this investigation. The CO₂ concentration, temperature, and humidity sensors are from the

C.A 1510 model instrument. This device is a physical quantity measuring equipment that measures carbon dioxide concentration in the air, interior temperature (T), and relative humidity (RH). In addition, the studied classrooms employed a building management control system to create a convenient trade-off between comfort and energy usage. For building management systems, the data collected from sensors and occupants enables the Building Management System (BMS) to evaluate energy consumption due to both the lighting system and HVAC operation (for temperature and ventilation control), indoor comfort conditions, and direct interaction with the various active systems. Sensors capture environmental data from the building, which is supplemented by sensors from inhabitants who have installed the building application. In addition, BMS can regulate lighting systems. For example, the lighting system might give simple ON/OFF options, decrease the amount of delivered light, or even more advanced degrees of control, such as the light changing colour, changing the length of colour, altering the duration of hues, or connecting the light control with music.

The findings of this case study revealed that this facility employed a building management system (BMS) to regulate air quality in the classroom using the C.A 1510 model instrument and occupancy sensors. This study also illustrated the principles of a building management system that integrates sensors and an IoT system to enhance both the air quality within the classroom and the energy efficiency of the building. Additionally, the CO₂ concentration may be utilised to activate the ventilation system on demand via the BMS system. For example, when a predefined threshold value (1500ppm) is reached, the BMS will automatically turn off the classroom ventilation system. This can aid in lowering energy usage and avoiding energy waste. Furthermore, it will activate the air ventilation based on the projected occupancy of the classroom.

Case study 3 – Classroom of University of Campobasso, Italy

Campobasso University is located in an Italian rural city in the south, near the Apennine Mountains. The structure was constructed in the early 1990s and consists of two blocks with a rectangular shape and six storeys connected by an atrium capped with a dome. This structure has

seven new classrooms, increasing the ability to deliver face-to-face education. For the new classrooms in this building, a conventional HVAC system with a mixed air-water system was proposed. Furthermore, the design and administration of the HVAC system is based on a basic rule: balance heat loads while providing appropriate ventilation of outside air (OA) to optimize indoor air quality. Re-circulation in centralised air conditioning systems should be avoided to limit the hazards of contamination from one room to another in the same building supplied by the same HVAC system. As a result, without the proper functioning of appropriate filters, re-circulation of air in a centralised air handling unit might allow pathogen transfer from a polluted environment to another.

In order to design the ventilation system in the classroom, this study provided some design alternatives for improving the ventilation system. Avoid centralized systems, for example, because they will cause re-circulation of air in an enclosed space, and the air channels can serve as a route for airborne transportation from one classroom to another. Furthermore, omitting room terminals allows for design simplification, such as eliminating the requirement to collect water condensed by fan coils. Additionally, it allows for the use of several HVAC systems in a single building. Moreover, providing a distinct rooftop for the classroom allows for optimum ventilation, micro-climatic control, re-circulation operation, heat recovery, and management of the thermodynamic conditions of the supply air. In this case study, the air distribution system designs for ventilation systems were also researched. Ceiling square diffusers, wall mounted grilles, wall mounted nozzles, and ceiling linear slot diffusers are examples of air distribution system systems.

According to the findings of this study, the ceiling linear slot diffusers are the configuration that provides the best outcomes in terms of air distribution uniformity and purity. As a result, this arrangement assures that the breathing air moves vertically. It lessens the chance of pollutants spreading across the whole indoor environment. Although this case study is not about sensor technologies for air quality, it is about how to enhance the ventilation system in the classroom during the Covid-19 period. In this case study, certain design criteria or principles for establishing a ventilation system in a building are discussed. Furthermore, this study investigates

building energy simulations (BES), which is an energy analysis of alternative HVAC for boosting ventilation to eliminate pathogens.

Results

According to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHAE), several ventilation design requirements must be considered in classroom ventilation during this Covid-19 period. The following are the ASHAE ventilation design recommendations for educational facilities (Aftab et al. 2017; Heebøll, Wargocki, and Toftum 2018).

(1) Follow the current ASHRAE 62 standard or local ventilation guidelines for minimum outside air needs, which take into account rising outside air capacity beyond the code minimum, as determined by a study conducted by a competent HVAC specialist. (2) Consider the following difficulties while replacing Dedicated Outdoor Air Systems (DOAS), which increase ventilation capacities over the legal minimum and influence operation and equipment sizing due to energy recovery system failure or filter loading. (3) Deactivate any Demand Control Ventilation (DCV) and implement the design of outside air flow to occupied spaces (DOAS) during the Pandemic Covid-19. (4) Apply and use outdoor air quality sensors or reliable web-based monitoring for outdoor pollution information as part of the new ventilation operation.

The suggested concept principles would be used to define the study's research issues and goals. It is significant because it can provide a healthy learning environment by integrating wireless sensor technologies, promoting good ventilation and energy conservation in the classroom, and thereby improving learning efficiency for university students in smart classrooms during the Covid-19 pandemic. This research is critical to helping turn conventional classrooms into smart classrooms and reducing total energy use, which will provide a healthy learning environment for university students to study in order to promote face-to-face learning in tertiary education.

The findings will highlight the importance of embedding wireless sensor technology into classroom architecture in an attempt to optimise classroom air quality. Smart classrooms will be able to suck out air inside the classroom and purify the air with the help of wireless sensors, preventing airborne droplets containing Covid-19

from entering the classroom. This undoubtedly aims to reduce the risk of students being infected with the Covid-19 virus. Furthermore, a good ventilation system aids in the improvement of students' learning performance.

Conclusion

This study detailed suggestions for incorporating wireless sensors into classroom design to improve the quality of air inside the learning environment. Since Covid-19 can be transmitted by airborne droplets, most university students take their classes online. The ventilation system inside the smart classroom can be changed with the aid of smart classroom to prevent sick building syndrome. It is possible to monitor the lighting brightness and ventilation system in the classroom by incorporating wireless sensory technologies into the classroom architecture. This will serve to create a more relaxed working atmosphere for university students and increase learning performance in the classroom. Furthermore, new architectural requirements are proposed, and sensory equipment is used in classroom design to increase structural performance and conserve resources. The study findings have a certain reference value for architectural design experts, academics, and educators looking for better learning environment design in the classroom. It also aids educators in improving classroom management.

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Author(s) contribution

Ng Wei Pang contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

A. Ghafar Ahmad contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

