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Survey of Atmospheric Environment in Classrooms Assuming University Lectures

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ABSTRACT

Since the novel coronavirus disease (COVID-19) began to spread in Japan, ventilation has become important to prevent the spread of the virus indoors, and university lecture rooms are often mechanically ventilated using ventilation fans or naturally by opening windows and doors. COVID-19 countermeasures have been relaxed, and frequent ventilation is no longer necessary since 2023. Moreover, ventilation is not being carried out as frequently as before. Balance between preventing the spread of the virus through natural ventilation by opening windows and doors, and maintaining an appropriate indoor temperature and humidity needs to be maintained. Here, we investigated the changes in the air environment under various ventilation conditions in university lecture rooms. Thus, the purpose of this research was to use current school equipment to create a more comfortable learning environment and prevent it from becoming unhealthy.

Keywords: Atmospheric environment survey, Temperature, Humidity, Carbon dioxide

1. INTRODUCTION

The average temperature in Japan's summer (June to August) in 2023 will be the highest in northern and eastern Japan and tied for the highest in western Japan since observations began in 1946. The average temperature deviation in Japan from 15 observation points nationwide was +1.76 °C, significantly exceeding the highest in 2010 (+1.08 °C) since 1898 and the highest in the summer[1),2)]. More than 90% of regular classrooms in school types subject to the "Temporary Special Grant for Block Walls and Air Conditioning Equipment" (public elementary schools, junior high schools, compulsory education schools, early secondary education schools, special needs schools, kindergartens, *etc.*) are equipped with air-conditioning (cooling) equipment, and installation has been completed in almost all facilities except in areas that are considered relatively cold[3),4)]. Therefore, measures against heat have been implemented to some extent.

Moreover, the temperature difference between indoors and outdoors is smaller during heating, and the buoyancy that naturally causes ventilation through gaps is also small; therefore, the possibility of indoor contamination with exhaled breath components is higher during heating[5)]. The doors and windows can be opened to increase the amount of natural ventilation in the room; however, according to Aihara *et al.*, when opening windows and ventilating in the summer, the indoor temperature can reach 31 °C even if air conditioning is used, and caution is needed to prevent heatstroke[6)]. Song has investigated the relationship between the indoor environment and learning efficiency in university lecture rooms and stated that learning efficiency decreases when the indoor temperature exceeds 28 °C[7)]. Mechanical ventilation equipment such as ventilation fans (air supply type, exhaust type, simultaneous supply, and exhaust type) is still rarely installed except in some facilities and rooms, and this is because natural ventilation by opening windows is sufficient[8),9)].

In a previous study, Kozaki *et al.* examined the rise in carbon dioxide concentrations in crowded classrooms and found that exposure to high concentrations of carbon dioxide (over 2000 ppm) for 45 min led to an increase in drowsiness, suggesting that drowsiness caused by carbon dioxide also occurs during school class hours[10)]. Moreover, Mimura *et al*. confirmed that rising carbon dioxide levels increase fatigue and decrease concentration[11)]. The classroom environment has a significant influence on learning efficiency. A survey conducted by Satish showed that when the carbon dioxide concentration in the atmosphere was 1000 ppm, decision-making ability was significantly lower than when it was 600 ppm and was even lower when it was 2500 ppm[12)]. Moreover, at carbon dioxide concentrations of 500 ppm or higher, the partial pressure of carbon dioxide in the blood, heart rate, heart rate variability, blood pressure, and peripheral blood circulation increased as the carbon dioxide concentration increased, raising concerns about its effects on health[13)].

Since the onset of the COVID-19 pandemic, ventilation has become important in preventing the spread of the virus indoors, and mechanical ventilation and ventilation by opening windows and doors have frequently been performed. This prevented the spread of the virus in classrooms, as well as increased carbon dioxide concentrations. However, since May 8, 2023, COVID-19 has been classified as a Class V infectious disease, due to which infection control measures have changed to a response based on voluntary efforts that respects individual choice[14)]. Several years have passed since the first confirmed case of COVID-19 in Japan. People have become accustomed to the virus, their awareness of the importance of ventilation has decreased, and ventilation is not being performed as frequently as before. Based on the above, we believe that it is necessary to take action by considering the balance between preventing the spread of the virus and increasing carbon dioxide concentration by opening windows and doors for ventilation and maintaining an appropriate indoor temperature environment.

In a survey of the atmospheric environment assuming a class using a projector, the ventilation amount of the ventilation fan and the required ventilation amount in the classroom under ventilation conditions using only ventilation fans was calculated, and possibility of the standard value of carbon dioxide concentration exceeding was found[15)]. This previous study did not investigate the effect of blinds on the atmospheric environment or the conditions under which no ventilation fans were used, and windows or doors were not opened. Therefore, the blinds not only block light but also reduce ventilation efficiency and may cause an increase in carbon dioxide concentration. We wondered how the atmospheric environment would change under these conditions.

Based on these considerations, we conducted a university lecture and investigated how the atmospheric environment inside the classroom changed depending on how the lecture was used. This study aimed to compare ventilation methods before and after the outbreak of the new coronavirus infection, the impact of closing blinds on air quality, and the condition of no ventilation at all, assuming a school without ventilation equipment, and to consider how to create a more comfortable learning environment and avoid unhealthy conditions.

2. METHODS

2-1 Surveyed facilities

The subject of this investigation was a classroom at K University. Figure 1 shows the classroom layout and measurement locations. The classroom measures 5.7 m in height, 7.3 m in width, and has a ceiling height of 2.4 m (volume is approximately 100 m^3). There are two windows on the southeast side, each equipped with a screen and a blind. The blinds are opened and closed by rolling the top, making it possible to adjust the amount of sunlight and airflow. The opening of each window is 1.5 m long and 0.9 m wide, and the door on the hallway side is 2.1 m long and 1.2 m wide. The ceiling was fitted with two air conditioners (PLFY-P45BM-2; Mitsubishi, Tokyo, Japan) and two mechanical fans (LGH-50RX5; Mitsubishi). The mechanical fans had two inlets and outlets. In addition to the fans, there is one natural ventilation vent (AT-150QRKF2; Melco Airtech, Gifu, Japan) that is always open. The classroom has nine 70 cm high desks in 3 × 3 rows for students, and each desk can accommodate three people; therefore, classes can be held with a maximum of 28 people, including one teacher.

2-2 Measurement conditions

As shown in Table 1, the measurement conditions were as follows: Condition **I**, in which window ventilation was used in addition to a ventilation fan; Condition **II**, in which a ventilation fan and window ventilation were used, as in Condition **I**, but light was blocked using blinds; Condition **III**, in which only a ventilation fan was used; and Condition **IV**, in which no ventilation fan was used and window ventilation was not performed. Under Conditions **I** and **II**, as shown in Figure 1, the windows on the screened side and the door at the entrance were opened. For the other common measurement conditions, the experiment was conducted with the air conditioner set at 26 °C, the ventilation fan set to heat exchange ventilation (which makes it difficult to exhaust cold or warm air generated by air conditioning or heating equipment outside), and an airflow rate of 500 m^3/h (the upper setting of the two levels). Carbon dioxide concentration, temperature, relative humidity, and wind speed were measured. A carbon dioxide monitor and thermal anemometer were placed on a 70 cm-high desk at measurement locations A to E, facing northeast at locations **A** and **B**, and southwest at locations **C**, **D**, and **E**. A carbon dioxide monitor (TOA-CO2MG-001, Toa, Tokyo, Japan) was used to measure carbon dioxide concentration, temperature, and relative humidity, and a thermal anemometer (TM-4001, TENMARS, Taipei, Taiwan) was used to measure wind speed. The values obtained immediately after one minute of measurement were used for carbon dioxide concentration, temperature, and relative humidity, and the maximum value observed during one minute of measurement was used for the wind speed. The carbon dioxide concentration, temperature, and relative humidity were also measured outdoors ten minutes before the start of the experiment, and the experiment was conducted after confirming that the indoor and outdoor data were similar. For the experiment, carbon dioxide concentration, temperature, relative humidity, and wind speed were measured every 15 min from the start of the experiment (zero minutes) to the end (90 min) at five locations (Figure 1), and the order of measurements was changed from **A** to **E** and from **E** to **A** for each measurement to reduce the effect of the measurement order on the data.

2-3 Measurement date, time, and standard value

The measurements were conducted 36 times between July and October of 2023. The Japan Meteorological Agency defines June to August as summer and September to November as autumn[16) , but it was determined that September in Japan in 2023 would have too many summer days, temperatures, and humidity to be classified as autumn; therefore, the 20 results from July to September were classified as summer data and the 16 results from October as autumn data. In addition, measurements were limited to periods with no rain before the start of the experiment. The measurement interval was ninety minutes, which simulated university class time, and in order to see variations depending on the time of day, we conducted two patterns: morning (measurements started by 12 p.m.) and afternoon (measurements started between 12 p.m. and 4 p.m.). As no particular variations depending on the time of day were observed, the morning and afternoon data were analyzed together. The measurements were carried out by two people who waited in the classroom and operated the measuring equipment during the experiment; therefore, we thought that this could also have contributed to changes in temperature and carbon dioxide concentration.

The standard values used as references in this study were the Standard for School Environment and Hygiene stipulated in the School Halth and Safety Act[17)] and the Standards for Environmental Health Management of Buildings stipulated in the Act on Maintenance of Sanitation in Buildings[18)], which are shown in Table 2. As the school building of our university is a specified building stipulated in the School Health and Safety Act, we followed the Standard for School Environment and Hygiene and Standards for Environmental Health Management of Buildings and examined the same values using more strictly specified standards.

3. RESULTS AND DISCUSSION

3-1 Under summer conditions

The CO_2 concentration increased significantly under Condition **IV,** however, it decreased under Conditions **I**, **II**, and **III**. And significantly under Condition **I**. In Condition **II**, the CO_2 concentration was lower than in Condition **III**, even though the blinds were closed (Figure 2). Thus, Condition **I** had the highest ventilation efficiency and closing the blinds in Conditions **I** and **II** reduced ventilation efficiency even when the windows were open. Therefore, even if lectures are held with the windows and doors open as a countermeasure against COVID-19, the effect will be reduced if the blinds are closed owing to the use of a projector. According to Kim et al., installing plants indoors can suppress CO_2 concentration and reduce air pollutants, improving the attention of people in the room[19)]. Although this poses sanitary issues such as scattered soil, it is thought that installing plants in university classrooms will allow students to learn in a more comfortable environment. All the measured data were averaged for each condition, and all patterns were found to be within the standard.

The amount of carbon dioxide exhaled by the occupants was calculated using the amount of carbon dioxide exhaled by high school students and adults (0.022 m^3/h) provided in the School Environmental Hygiene Management Manual[6)]. The amount of carbon dioxide exhaled by the two participants in this experiment was estimated to be 0.044 m^3/h, and approximately 66,000 g of carbon dioxide was exhaled in 90 min, which is thought to have contributed to the increase in carbon dioxide concentration in the classroom. The amount of ventilation in this experiment under Condition **IV** was calculated using the following formula and the indirect measurement method in the same manual[6)]:

$$\mathbf{Q = M \times 1{,}000{,}000 \div (C_t - C_0)}$$

Q: Ventilation volume (m^3/h)

M: Amount of carbon dioxide generated in the classroom (m^3/h) =

Number of people in classroom × carbon dioxide exhalation volume (m^3/h)

$\mathbf{C_t}$: Average carbon dioxide concentration in the classroom after t hours (ppm)

$\mathbf{C_0}$: Carbon dioxide concentration at the start of the experiment (ppm)

The rate of increase in carbon dioxide concentration increases as the number of people in a room increases[15)]. Thus, it was determined that the ventilation volume generated by the ventilation fans in the classroom used in the experiment was approximately 1000m^3/h. Based on the calculated results of the ventilation volume from this experiment, the ventilation volume in the classroom used in Condition **IV**, where neither natural nor mechanical ventilation was performed, was approximately 170 m^3/h. The carbon dioxide exhaled volume, assuming a capacity of twenty-eight people in the classroom used in this experiment, was calculated to be 0.924 m^3/h. In this case, the previous formula was used to calculate the ventilation volume necessary to avoid exceeding the standard value of 1000 ppm in the environmental health management of buildings. The carbon dioxide concentration did not exceed 1000 ppm approximately 90 min after the start of the experiment; therefore, the calculation was performed assuming that the carbon dioxide concentration after 90 min (C_t) was 1000 ppm and the carbon dioxide concentration at the start of the experiment (C_0) was 400 ppm. The required ventilation amount was 1027m^3/h, which means that the ventilations are required for 9.6-times per hour. However, because the ventilation volume of the ventilation fan in the classroom used in this experiment was approximately 1000 m^3/h, the standard value would have been exceeded under Condition **III** when there were twenty-eight people. The ventilation volume in the classroom used under Condition **IV**, where neither natural nor mechanical ventilation was used, was approximately 170m^3/h; therefore, it was thought that ventilation under Condition **IV** was clearly insufficient. As the number of people in a room increases, the carbon dioxide concentration increases, causing drowsiness and fatigue, which leads to a decrease in work efficiency[2)]. It there are many people in a room, it is necessary to increase the airflow using ventilation fans, by opening windows, doors, etc.

The range of temperature fluctuation was small, especially under Condition **I** (Figure 3). Many conditions were outside the standard range up to 30 min after the start of the experiment, post which, all conditions were within the standard range, except for Condition **I**. Moreover, opening windows and doors makes people more susceptible to the effects of outside air, which reduces the effectiveness of air conditioners and makes it impossible to maintain the room temperature at a comfortable level, leading to the risk of heat stroke in the summer.

Humidity increased under Conditions **I** and **II** but decreased under Conditions **III** and **IV**, with a particularly noticeable decrease under Condition **III** (Figure 4). Ninety minutes after the start of the experiment, Conditions **III** and **IV** were within the standard range, whereas Conditions **I** and **II** were outside the standard range. In Condition **I**, during the summer measurements, the humidity was particularly high at measurement location **D**, and the wind was blowing strongly at **D** during times when the humidity was high (Figures 5 and 6). Moreover, the wind blows more easily at **D** than at the other points, and humid air flows from the outside, which has a strong influence and results in high humidity. When windows and doors are open, humidity increases owing to the influence of the outside air and the humid summer air; however, if the windows and doors are closed, they are not affected by the outside air, and the temperature in the room with an air conditioner will decrease the humidity. Furthermore, the results for Condition **III** suggested that the ventilation fan had a significant impact on the decrease in humidity.

The wind speed increased significantly under Condition **I**, with little difference observed under the other conditions (Figure 7). All measured data were averaged for each condition, and the results were within the standard range under all conditions. Thus, air circulates more under Condition **I** than under the other conditions.

3-2 Autumn conditions

The carbon dioxide concentration increased significantly under Condition **IV** and almost no changes were observed under Conditions **I**, **II**, or **III** (Figure 8). When all the measured data were averaged for each condition and compiled, the carbon dioxide concentration was within the standard range for all conditions. Although it is within the standard range, if the windows and doors are closed in a classroom without ventilation, as in Condition **IV**, the carbon dioxide concentration increases, affecting learning efficiency.

The temperature increased under all conditions; however, under Conditions **I**, **III**, and **IV**, the temperature increased while repeatedly rising and falling (Figure 9). This is because the outside temperature is low in autumn. When an air conditioner is used, the room temperature rises, stops when it reaches a certain temperature and starts again when the room temperature drops. Furthermore, the increase in Condition **I** was lesser than those in the other conditions. This is thought to be due to the influence of the outside air (cold autumn air) caused by the opening of windows and doors, resulting in a smaller increase. When all the measured data were averaged for each condition and compiled, the temperature was within the standard range under all conditions.

The humidity decreased significantly only under Condition **I**. There was almost no change under Conditions **II** and **III**; however, it increased slightly under Condition **IV** (Figure 10). When all the measured data were averaged for each condition and compiled, the humidity was within the standard range under all conditions. This suggests that the humidity in autumn is naturally low and that Condition **I**, where windows and doors are open, is most susceptible to the influence of outside air; therefore, the humidity drops significantly. Moreover, the humidity rose slightly under Condition **IV** as the room temperature increased, as the air conditioner and the ventilation fan were not functioning.

The wind speed increased under Condition **I** but did not change much under the other conditions (Figure 11). When all measured data were averaged for each condition, the wind speed was within the standard range under all conditions. Thus, Condition **I** may have had more air circulation compared to the other conditions.

4. CONCLUSION

The autumn data were within the standard range for all items; however, some items in the summer data were outside the standard range. In summer, under Condition **I**, the increase in carbon dioxide concentration can be suppressed compared to other conditions, but the temperature results show that conditions are most susceptible to the influence of outside air, and there is a risk of heat stroke. Under Condition **IV**, the risk of heatstroke is low because the outside air is less likely to affect the room, but the increase in carbon dioxide concentration is the highest. We believe that if there are a large number of people in the room, sufficient ventilation may not be possible, which may have a negative impact on learning efficiency. Conditions **II** and **III** were inferior to Condition **I** in terms of ventilation power but superior to Condition **IV**. Considering the classroom temperature, it was concluded that Condition **III** was the best overall, providing the most comfortable learning environment and lowest possibility of becoming unhealthy.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1) Japan Meteorological Agency. Press release for 2023 -Weather in summer (June to August). https://www.jma.go.jp/jma/press/2309/01b/tenko230608.html#:~:text=%E6%A6%82%E8%A6%81,%E3%81%A7%E5%B0%91%E3%81%AA%E3%81%8F%E3%81%AA%E3%82%8A%E3%81%BE%E3%81%97%E3%81%9F%E3%80%82 (browsed November 2023).
2) Japan Meteorological Agency. Frequently asked questions regarding changes in temperature and precipitation in the world and Japan over time. https://www.data.jma.go.jp/cpdinfo/temp/qa_temp.html#:~:text=%EF%BC%A1%EF%BC%9A15%E5%9C%B0%E7%82%B9%E3%81%AF%E7%B6%B2%E8%B5%B0,%E3%81%AB%E9%81%B8%E5%AE%9A%E3%81%95%E3%82%8C%E3%81%BE%E3%81%97%E3%81%9F%E3%80%82 (browsed November 2023).
3) Ministry of Education, Culture, Sports, Science and Technology. Installation status of air conditioning (cooling) facilities in public school facilities. https://www.mext.go.jp/content/20220928-mxt_sisetujo-000013462_01.pdf (browsed November 2023).
4) Ministry of Education, Culture, Sports, Science and Technology. The future of air conditioning (cooling) equipment in public school facilities. https://www.mext.go.jp/a_menu/shotou/zyosei/mext_00943.html (browsed November 2023).
5) Architectural Institute of Japan, Environmental Engineering Committee, Air Environment Steering Committee, Ventilation and Airflow Subcommittee. Current issues and measures regarding thermal and air environments in schools -To create an environment where children can learn healthily and comfortably. http://news-sv.aij.or.jp/kankyo/s7/school_air_guide.pdf (browsed November 2023).
6) Taemi Gohara, Go Iwashita, Shin-ichi Tanabe. (2022) Behavior of opening windows as a measure for COVID-19 and its impact on ventilation rate in the classrooms of an elementary school in Tokyo. Journal of Environmental Engineering (Transactions of AIJ), 87, 796, 347-358.
7) Song, Seong-ki. (2013) A survey of the learning environment in university lecture rooms. Bulletin of Hiroshima Institute of Technology. Research volume, 47, 73-78.
8) Ministry of Education, Culture, Sports, Science and Technology. Chapter 1 Basic concepts for ventilation planning in school facilities (1). Report on research into ventilation equipment in school facilities, https://www.mext.go.jp/a_menu/shisetu/shuppan/04062201/002.htm (browsed November 2023).
9) Ministry of Education, Culture, Sports, Science and Technology. Introduction. Research report on ventilation equipment in school facilities, https://www.mext.go.jp/a_menu/shisetu/shuppan/04062201/001.htm (browsed January 2023).
10) Tomoaki Kozaki, Nanami Matsuzawa, Kana Kyakutake. (2022) Effect of high carbon dioxide level on psychological performance and arousal level. Japanese Journal of Ergonomics, 58, 2, 76-83.
11) Rio Mimura, Tomoyuki Chikamoto. (2018) Study on the learning environment and learning effects in the classroom (part 9) -The effect of changes in CO_2 concentration and thermal environment on work performance and physiological and psychological values. Technical Papers of Annual Meeting the Society of Heating,Air-conditioning and Sanitary Engineers of Japan, 8, 169-172.
12) Usha Satish. (2012) Is CO_2 an indoor pollutant direct effects of low-to-moderate CO_2 concentrations on human decision-making performance. Environmental Health Perspectives, 120, 12.
13) Kenichi Azuma. (2018) Effects of carbon dioxide inhalation exposure in indoor environments on humans. Indoor Environments, 21, 113-120.

14) Ministry of Health, Labor and Welfare. Health and Medical Care -Responses after COVID-19 is classified as a Class V infectious disease. https://www.mhlw.go.jp/stf/corona5rui.html (browsed November 2023).
15) Jun Kobayashi, Anna Matsumoto, Yuka Fujita, Hideo Sugiyama. (2022) Survey of air quality in classes using projectors. Journal of Shikoku Public Health Society, 67, 73-79.
16) Japan Meteorological Agency. Time-related terms. Forecasting terms, https://www.jma.go.jp/jma/kishou/know/yougo_hp/toki.html (browsed November 2023).
17) Ministry of Education, Culture, Sports, Science and Technology. Theory and practice of "Standard for School Environment and Hygiene". School Environmental Hygiene Management Manual, revised edition for 2018, https://www.mext.go.jp/component/a_menu/education/detail/__icsFiles/afieldfile/2018/07/31/1292465_01.pdf (browsed November 2023).
18) Ministry of Health, Labour and Welfare. Standards for Environmental Health Management of Buildings. Ministry of Health, Labour and Welfare website, https://www.mhlw.go.jp/bunya/kenkou/seikatsu-eisei10/ (browsed November 2023).
19) Ho-Hyun Kim, In-Young Yeo, Jae-Young Lee. (2020) Higher attention capacity after improving indoor air quality by indoor plant placement in elementary school classrooms. Horticulture Journal, 89, 319-327.

Table 1 Classroom status under each condition

Room facilities	Conditions			
	I	**II**	**III**	**IV**
Ventilation fan	ON	ON	ON	OFF
Open windows and doors	+	+	-	-
Open blinds	+	-	+	+

Conditions **I** and **II** are ventilation methods in which windows and doors were opened to prevent the spread of COVID-19.

Condition **III** is the conventional ventilation method that was used before the COVID-19 outbreak.

Ventilation fans are shown as ON when used and OFF when not used.

For windows and doors, + indicates open and - indicates closed.

For blinds, + indicates open, and - indicates closed.

The common conditions were as follows: the air conditioner was set to a temperature of 26 °C, the ventilation fan was set to heat exchange mode, and the airflow was set to 500 m^3/h.

Table 2 Comparison of reference standards and standards used in this study

Items	Standard for School Environment and Hygiene	Standards for Environmental Health Management of Buildings	Standards used in this study
Temperature (℃)	17-28	18-28	18-28
Relative humidity (%)	30-80	40-70	40-70
CO_2 concentration (ppm)	≦ 1500	≦ 1000	≦ 1000
Air flow (m/sec)	≦ 0.5	≦ 0.5	≦ 0.5

In this study, we referred to the Standards for School Environment and Hygiene and the Standards for Environmental Health Management of Buildings, for which we used more strictly defined standard values.

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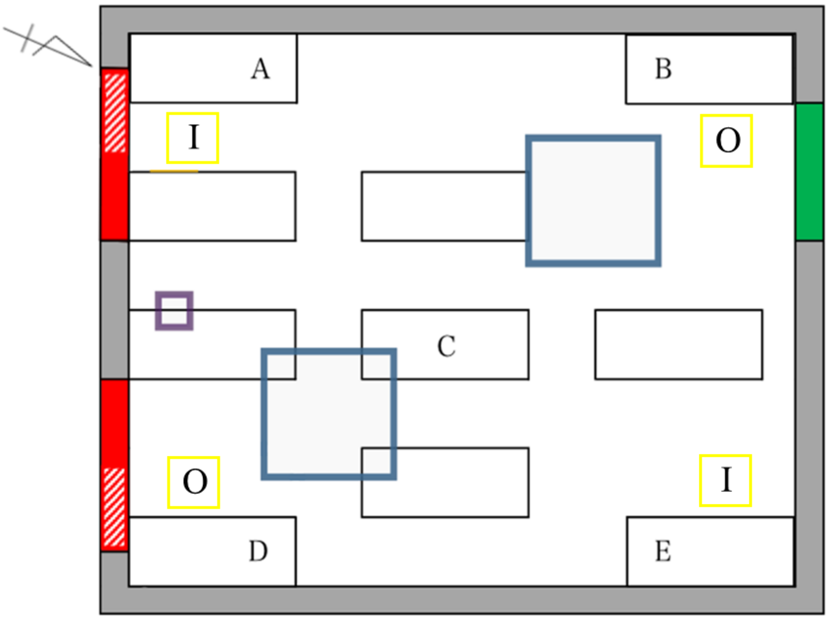

Figure 1 Classroom layout and measurement location

: Air conditioner (ceiling), set temperature; 26 ℃.

: Ventilation fan (ceiling), heat exchange mode.

Air outlet is indicated as "O" and air inlet as "I."

: Ventilation outlet (ceiling).

: Door.

: Window.

Since the window cannot be fully opened, the shaded part (screen side) was opened when ventilating the window.

A-E: Measurement locations.

Desk height: 70 cm.

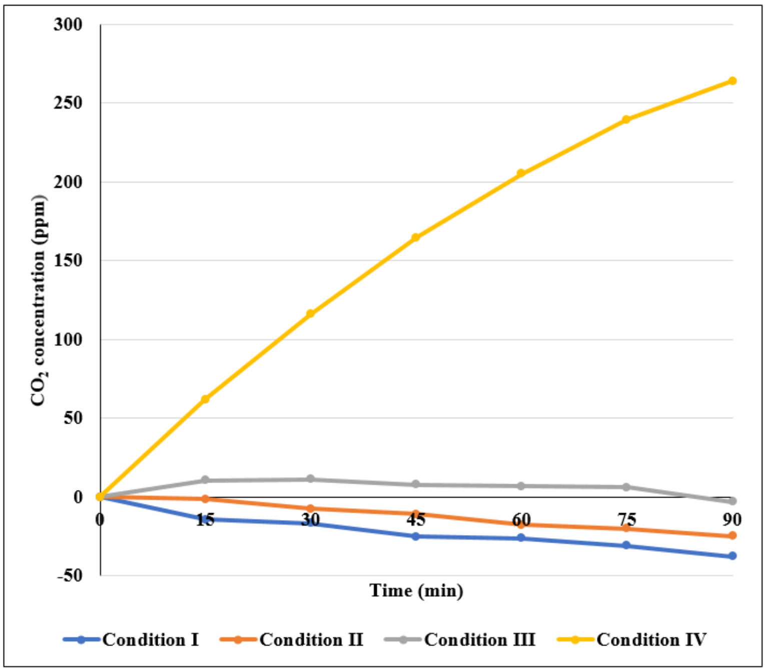

Figure 2 Summer carbon dioxide concentrations by condition

The value immediately after the start of the experiment was set to zero and the data were averaged for each condition.

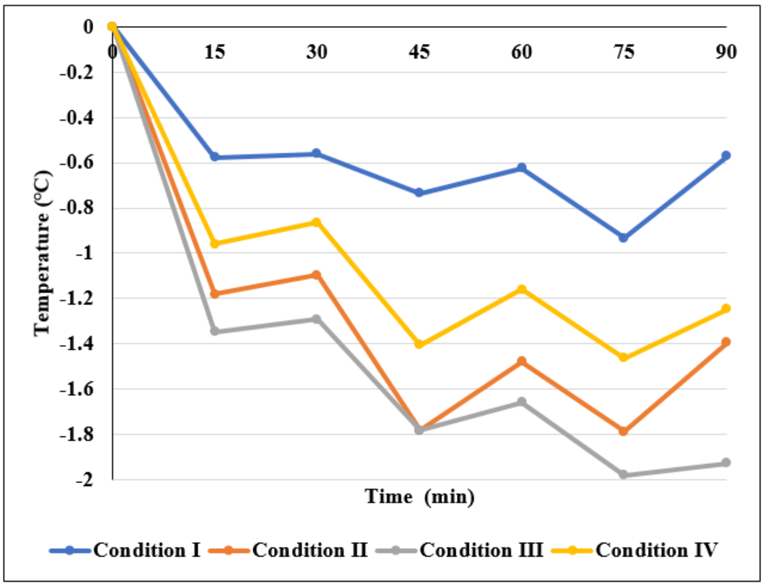

Figure 3 Summer temperatures by condition

The value immediately after the start of the experiment was set to zero and the data were averaged for each condition.

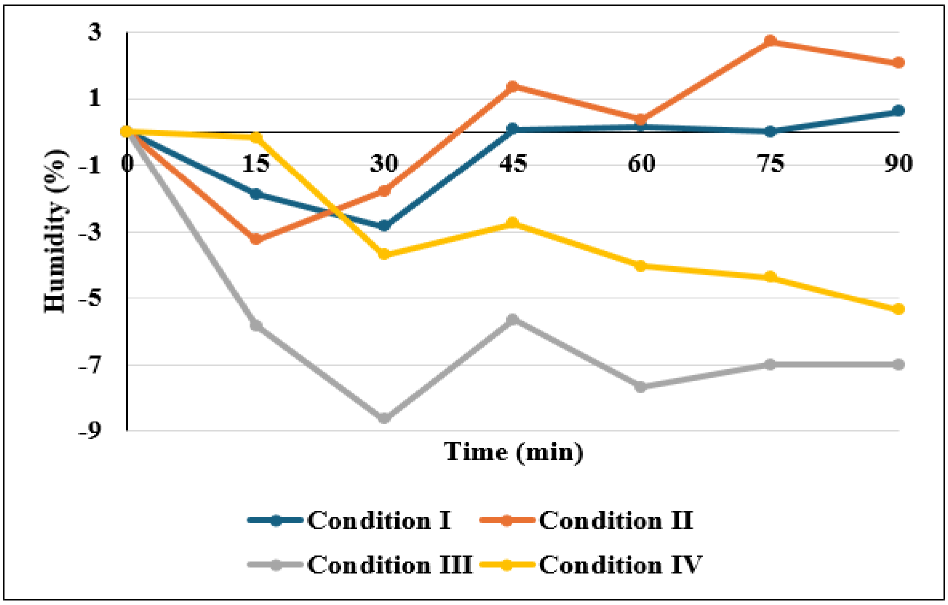

Figure 4 Summer humidities by condition

The value immediately after the start of the experiment was set to zero and the data were averaged for each condition.

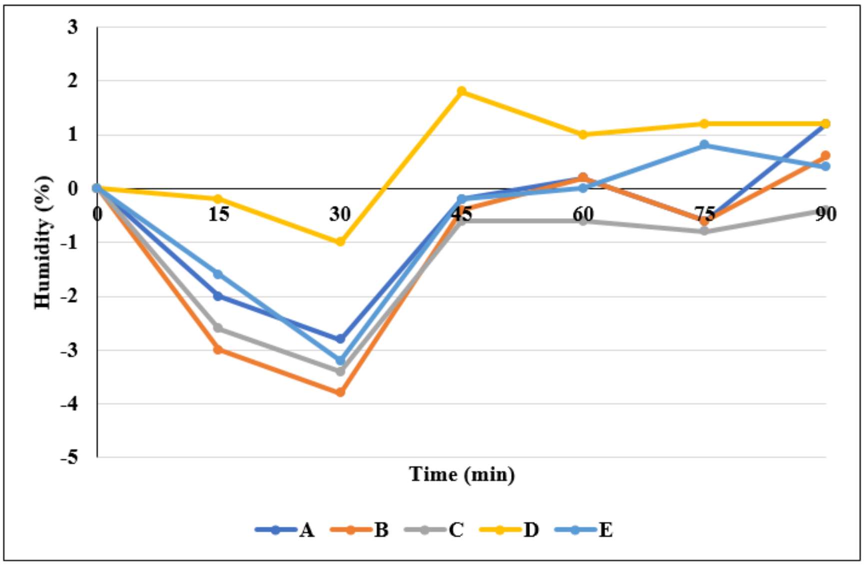

Figure 5 Summer humidities by location (Condition I)

The value immediately after the start of the experiment was set to zero and the data were averaged for each condition.

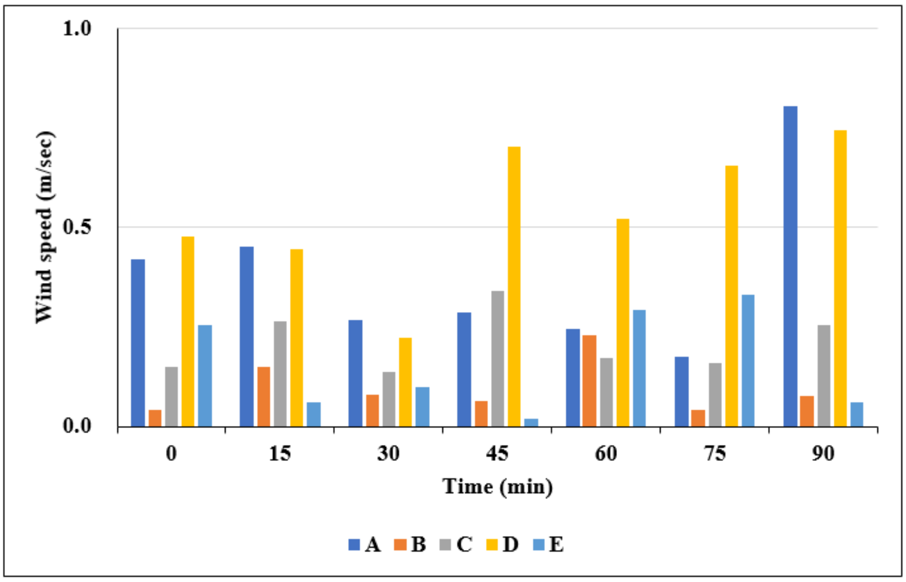

Figure 6 Summer wind speeds by location (Condition I)

The measured data is collected and averaged for each location.

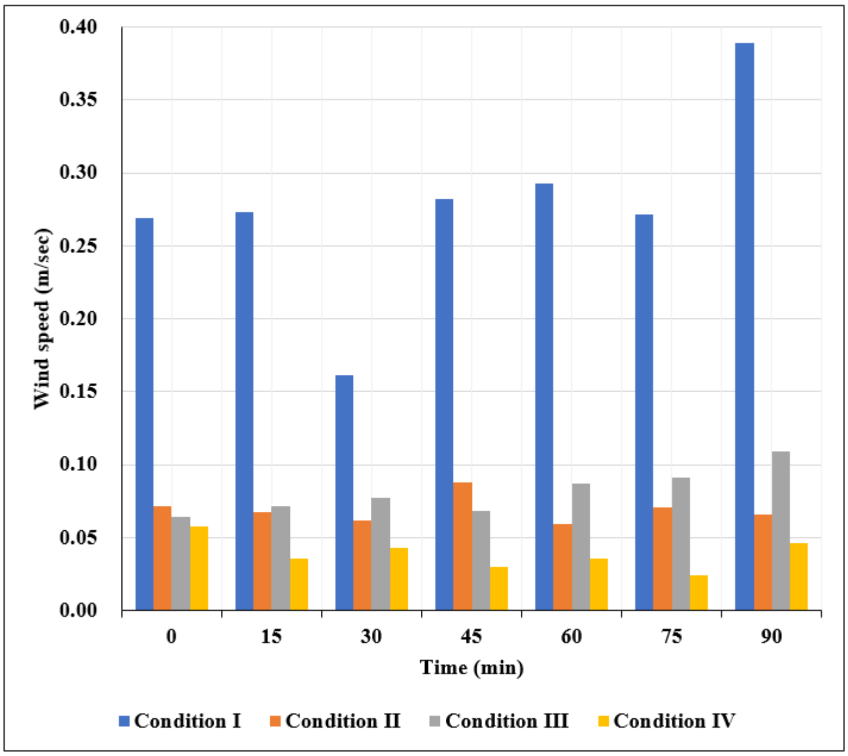

Figure 7 Summer wind speeds by condition

The measured data was collected for each condition and averaged.

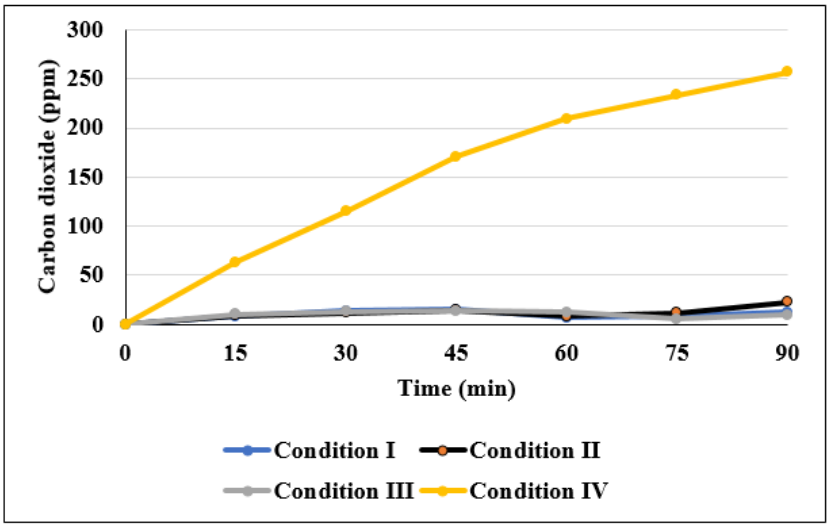

Figure 8 Autumn carbon dioxide concentrations by condition

The value immediately after the start of the experiment was set to zero and the data were averaged for each condition.

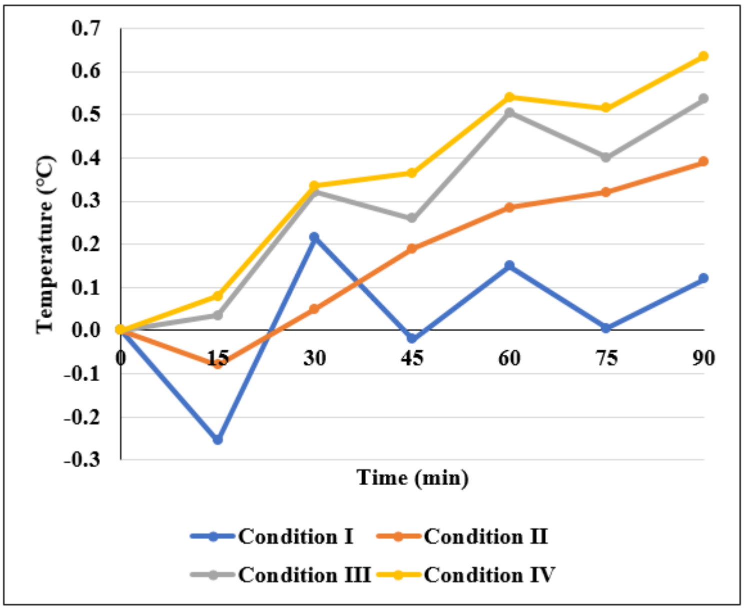

Figure 9 Autumn temperatures by condition

The value immediately after the start of the experiment was set to zero and the data were averaged for each condition.

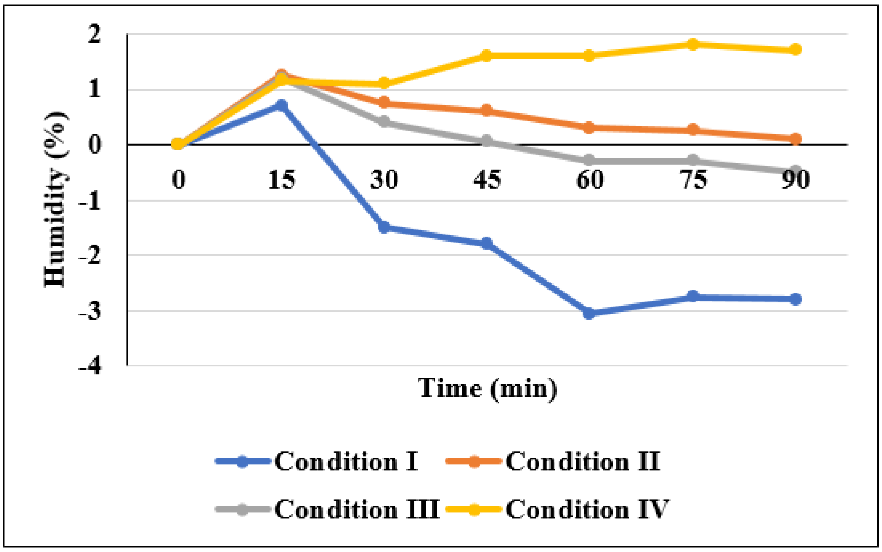

Figure 10 Autumn humidities by condition

The value immediately after the start of the experiment was set to zero and the data were averaged for each condition.

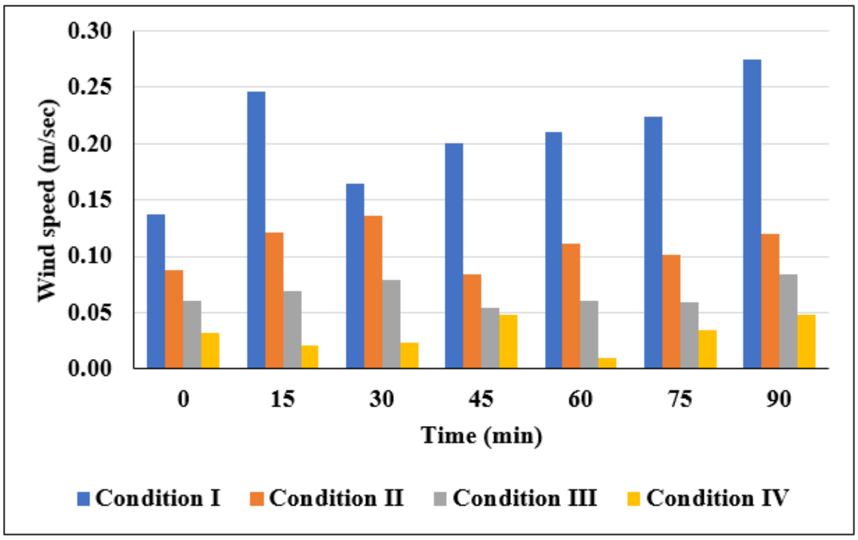

Figure 11 Autumn wind speeds by condition

The measured data was collected for each condition and averaged.

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Conflict of Interest Statement: The authors have no conflicts of interest to declare.