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Internet of Things (IoT) Arduino-Based Classroom Monitoring Utilizes Temperature Sensors And CO2 Sensors

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Abstrak

Kenyamanan suhu ruangan ditentukan oleh kualitas udara dalam ruangan, seperti suhu dan gas CO_2. Penelitian ini bertujuan mengetahui kenyaman dari suatu kelas dengan meninjau jumlah siswa, gas CO_2, dan suhu didalam ruang kelas berbasis Arduino menggunakan sistem IoT otomatis dengan metode Rancangan Acak Lengkap (RAL). Penelitian membuktikan bahwa terdapat pengaruh yang signifikan antara jumlah siswa terhadap konsentrasi CO_2, namun tidak berpengaruh secara langsung terhadap suhu udara di dalam ruangan. Ruang kuliah masih relatif aman namun belum ideal dan membutuhkan penurunan suhu -7oC.

Kata kunci— *Termal , IoT , RAL ,Arduiono*

Abstract

Comfort room temperature is determined by indoor air quality, such as temperature and CO2 gas. This study aims to determine the comfort of a class by reviewing the number of students, CO2 gas, and temperature in an Arduino-based classroom using an automatic IoT system with a Completely Randomized Design (CRD) method. Research proves that there is a significant effect between the number of students on the concentration of CO2, but it does not directly affect the air temperature in the room. The lecture hall is still relatively safe but not ideal and requires a temperature reduction of -7oC.

Keywords— *Termal, IoT, RAL, Arduino*

1. INTRODUCTION

The temperature in a room determines whether or not the activities run in the room are optimal [1]. The ideal temperature is essential for activities in a room to become more optimal. The lack of an ideal temperature in a room will cause a person discomfort to be in the room. Temperatures that are not ideal will affect the occurrence of stress. This stress is in the form of a sensation of discomfort due to the human body's efforts to maintain a constant internal temperature in the body [2].

Comfort is a condition enjoyed by humans, which creates a balance between the temperature of the human body and the temperature of the surrounding environment. Many factors affect the temperature of a room, namely air temperature, radiant temperature, wind speed, humidity, clothing insulation, and metabolic rate. From these factors, air temperature is the dominant factor influencing thermal comfort. Air temperature is related to air quality, where poor air quality in a room can be caused by high levels of carbon dioxide (CO2) originating from the human body's metabolic processes [6,7].

Carbon dioxide (CO_2) is a chemical compound consisting of two oxygen atoms bonded to a carbon atom [8]. This compound is produced by all animals, plants, fungi, and

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microorganisms in respiration and photosynthesis [9–11]. Excessive CO2 concentration in a place can hurt living things around it [9]. In humans, CO_2 exposure can lead to reduced performance and productivity [12,13]. Apart from CO_2, according to [14], air temperature also affects the productivity of a living creature.

Internet of Things (IoT) is a concept that has been widely applied in various fields [15–17], one of which is air quality monitoring [15]. Using the IoT concept, air conditions and quality, such as temperature, carbon dioxide concentration, etc., can be measured and processed into information. Measurement using the IoT concept becomes very easy compared to manual measurements because all processes are carried out automatically [17–19]. IoT, which is generally connected to the Internet, has many advantages, one of which is that data monitoring can be done in real-time [7,15].

Based on the research above, the research team analyzed the health of a teaching and learning room by reviewing CO2 concentrations and air temperature by utilizing automation and IoT using a completely randomized design (CRD) method. RAL, or utterly randomized design (CRD), is a simple experimental design in a homogeneous locatio[17,20]. The experimental design in RAL is said to be random because it has the same opportunity to get treatment and is said to be complete because all treatments designed in the experiment are used [21–23].

Based on the explanation above, the research team decided to use RAL in this study because it has the following criteria:

(1) The factors studied are homogeneous: the number of people, the increase in CO2 concentration, and air temperature.
(2) External factors will be controlled by the research team.

In this study, Arduino devices placed in classrooms will retrieve data from CO2 gas and temperature sensors which are then sent and displayed on a monitoring information system via the internet.

2. METHODS

2.1 Identification of problems and Literature review

At this stage, the research team identifies the research problem and determines the boundaries of the problem discussed in this paper. A literature review is a stage of collecting and reviewing information as a fundamental theory in research. The next step is to find information about the impact of CO2 exposure on human health and the air temperature level on the comfort of occupants in a room. This information will be used as a reference to determine a healthy and ideal classroom for the teaching and learning process. From the theoretical studies conducted, several important points were obtained as follows:

2.1.1 Effect of CO_2 level in the air on the body

According to the Wisconsin Department of Health Services [24], the effects of CO_2 levels in the air and the potential problems that arise for health are as follows:

Table 1 Effect of CO_2 level in the air on the body

Concentration (ppm)	Effect
250 – 400	Normal state outside
400 – 1.000	Typical conditions in an occupied room
1.000 – 2.000	A situation where residents start to feel sleepy
2.000 – 5.000	The situation of residents began to feel stuffy and had headaches. This condition can cause decreased concentration, increased heart rate, and nausea.
5.000	There is another gas in the room.
40.000	Very dangerous for health.

2.1.2 Ideal Room Temperature

Room temperature directly influences the comfort and productivity of the occupants [25–27]. According to Abbasi et al. [27], Extreme air temperatures (too high or too low) can significantly increase the heart rate and respiratory rate of the occupants, which in the long run hurts the person's health.

According to the well-known heating company Vaillant Group [28], determining the ideal room temperature is very complex, but in general, the ideal room temperature is divided as follows:

Table 2 Ideal room temperature

Room	Recommended temperature
Sitting room	20°C - 22°C
Bedroom	16°C - 19°C
Office / Study Room	20°C - 22°C
Entrance	15°C - 18°C
Corridor	15°C - 18°C
Bathroom	22°C - 24°C
Kitchen	18°C - 20°C

From Table 2, it can be said that the ideal classroom temperature is between 20oC - 22oC.

2.1.3 Completely Randomized Design (CRD)

RAL, or utterly randomized design, is a simple experimental design in a generally homogeneous location [20,29]. The experimental design in RAL is said to be random because it has the same opportunity to receive treatment and is said to be complete because all treatments designed in the experiment are used [21–23].

Based on the explanation above, the research team decided to use RAL in this study, considering that the research also had the following criteria: (1) there was only one factor studied that affected the response (homogeneous). The factor in question is the number of people, while the response in question is an increase in CO2 concentration and air temperature; and (2) If external factors can influence the response, the research team can control these factors.

Calculations in the RAL are carried out using the following equations [30–32]:

$$FK = \frac{(T_{ij})^2}{(r \cdot t)} \quad (1)$$

$$JKT = (y_{ij})^2 - FK \quad (2)$$

$$JKP = \frac{(T_S)^2}{r} - FK \quad (3)$$

$$JKG = JKT - JKP \quad (4)$$

where:

FK : correction factor
T_{ij} : The total amount of data
r : number of repetitions
t : number of treatments
JKT : sum of total squares
JKG : sum of squares error
y_{ij} : data for each treatment each repetition
JKP : sum of squares of treatment
T_s : The amount of data for each treatment

The results of the above calculations are then entered into the ANOVA table in the following format:

Table 3 anova table

SK	**DB**	**JK**	**KT**	$\mathbf{F_{count}}$	$\mathbf{F_{table}}$
Treatment	DBP	JKP	KTP	F_{count}	$F_{(0,05)}$
Error	DBG	JKG	KTG		
Total	DBT	JKT			

$$DBP = t - 1 \quad (5)$$
$$DBG = t(r - 1) \quad (6)$$
$$DBT = tr - 1 \quad (7)$$
$$KTP = \frac{JKP}{DBP} \quad (8)$$

where:
SK : source of diversity
DB : degrees of freedom
JK : sum of squares

$$KTG = \frac{JKG}{DBG} \quad (9)$$
$$F_{count} = \frac{KTP}{KTG} \quad (10)$$

KT : middle square (JK-DB)
F_{count}: $KT_{treatment}/KT_{error}$

2.2 Monitoring System Design

In designing the CO2 monitoring system, the researcher made a block diagram, as shown in Figure 1. In this block, the nodes are sensors that will monitor CO2 levels and send data to the database via the server. Nodes on the system can be controlled through a website-based user interface.

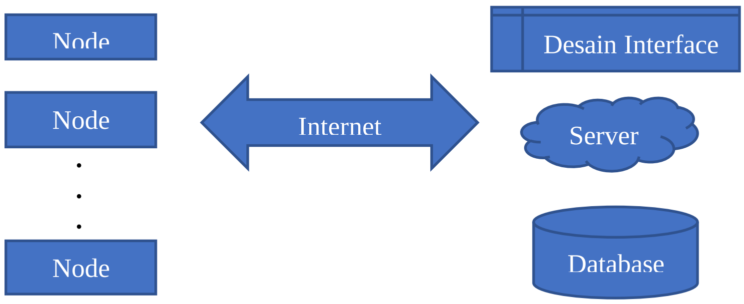

Figure 1 Block Diagram of the monitoring system

System installation is carried out in the room where the research is conducted. The embedded system that is planted in the research area has device specifications: Arduino Uno R3 SMD board, MG-811 Carbon Dioxide sensor, DHT11 thermal sensor, and ESP8266 WiFi adapter with the following architecture:

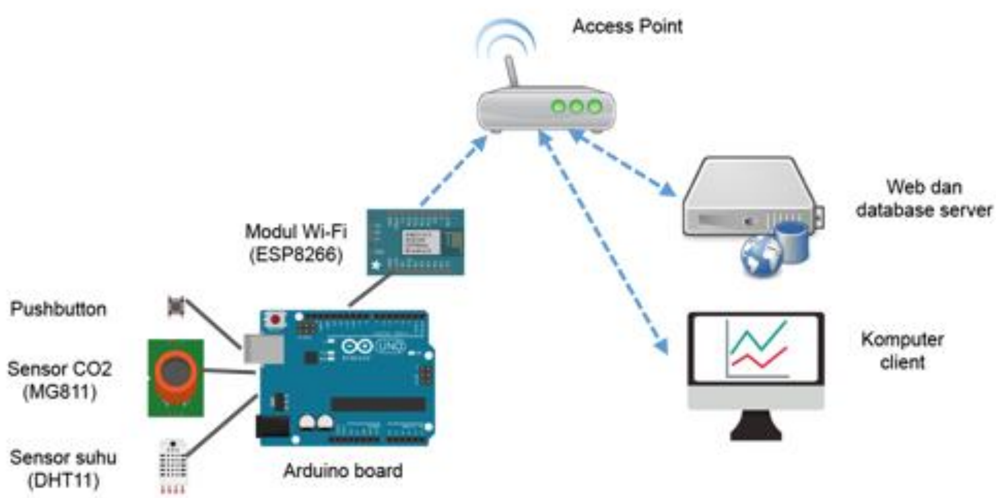

Figure 2 System Architecture

2.3 Data Collection

The study followed the RAL procedure as follows:

(1) The volunteers involved in this study were 35 students from Jambi University;
(2) The researcher divided the thirty-five people into three treatments. In the first treatment, only one person was involved, in the second treatment, there were 18 people, and in the third treatment, there were 35 people involved;
(3) The treatment was repeated three times;
(4) The time interval between each treatment is 30 minutes

In this study, the effect of the number of individuals occupying the classroom (independent variable) on the CO2 concentration and temperature in the room (the dependent variable). In this study, the control variables considered by the research team included: the size of the room, the presence of an air conditioner (AC) and fan, and ventilation. The specifications of the room used in the study are as follows:

1. The room has a width of 7 meters, a length of 10 meters, and a height of 2.9 meters;
2. There are two fans on;
3. There is no air conditioning;
4. No ventilation;
5. At the time of data collection, the window is closed; as well as
6. The door is half open.

2.4 Data Processing

After the data was collected, the research team then processed the data using the RAL method calculations as described in equations (1) to equation (7). At this stage, the calculation results (Fcount) are then matched with Ftable. The results of the comparison according to [33]:

(1) if $F_{count} \leq F_{table}$ 5%, it means that the treatment has no significant effect;
(2) if $F_{count} \geq F_{table}$ 5%, and $F_{count} \leq F_{table}$ 1%, it means that the treatment has a significant effect; and
(3) if $F_{count} \geq F_{table}$ 1%, the treatment has a significant effect.

2.5 Drawing Conclusion

At this stage, a comparison is made between the results obtained and the ideal class's characteristics. The ideal class has a safe CO2 concentration at a reasonable temperature. The obtained CO2 concentration will be compared in table 1, and the air temperature will be compared in Table 2

3. RESULTS AND DISCUSSION

After taking data in one of the lecture rooms of the Faculty of Science and Technology, Jambi University, on February 27, 2020, with three treatments and three repetitions (following the RAL procedure), the following results were obtained:

Table 4 CO_2 Concentration Data Collection Results

Treatment (Person)	**Repetition (ppm)**			**SUM**	**AVG**	**DEV**
	I	**II**	**III**			
1	501	546	542	1589	530	24,9
18	574	650	656	1880	627	45,7
35	657	677	706	2040	681	24,6
Total	1732	1873	1904	5509		

Table 5 Air Temperature Temperature Data Collection Results

Treatment (Person)	Repetition (ºC)			SUM	AVG	DEV
	I	II	III			
1	28	30	30	88	29,3	1,2
18	29	30	31	90	30	1
35	30	32	32	94	31,3	1,2
Total	87	92	93	272		

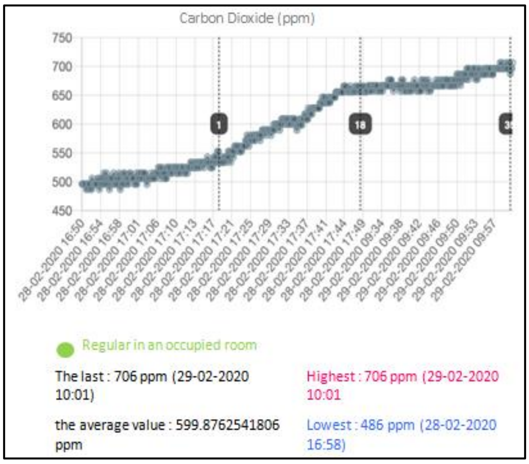

Figure 2. Graph of Monitoring CO_2 Concentration and Air Temperature displayed by the System

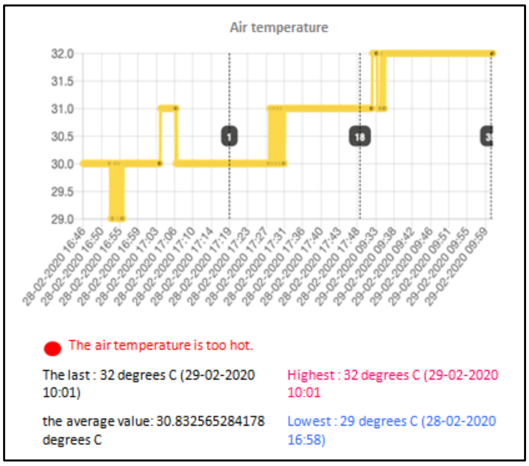

Figure 3. Air Temperature Monitoring Chart displayed by the System

3.1 Effect of Number of Individuals on CO2 Concentration

This section examines whether there is an influence between the number of individuals on the CO_2 concentration in a room. Based on the data shown in table 4, the RAL calculation is carried out as follows:

Correction Factor (Equation 1)

$$FK = \frac{(5509)^2}{(3 \cdot 3)} = \frac{30.349.081}{9} = 3.372.120$$

Total Squares (Equation 2)

$$\begin{aligned} JKT &= (501)^2 + \cdots + (706)^2 - 3.372.120 \\ &= 3.413.607 - 3.372.120 \\ &= 41.487 \end{aligned}$$

Number of Squares of Treatment (Equation 3)

$$\begin{aligned} JKP &= \frac{(1589)^2 + (1880)^2 + (12040)^2}{3} - 3.372.120 \\ &= \frac{3.406.973,67}{3} - 3.372.120 \\ &= 34.853,5 \end{aligned}$$

Sum of Squared Errors (Equation 4)

$$JKG = 41.487 - 34.853{,}5$$
$$= 6.633{,}5$$

Substitute the results into the Anova table

Table 6 Analysis of the Effect of the Number of Individuals on the Concentration of CO_2 in a Room

SK	DB	JK	KT	F_{count}	F_{table}
Treatment	2	34.853,5	17.427	15,757	5.143
Error	6	6.633,5	1.106		
Total	8	41.487			

Determine F_{count} (Equation 5-10)

$$DBP = 3 - 1 = 2$$
$$DBG = 3(3-1) = 3(2) = 6$$
$$DBT = 3(3) - 1 = 9 - 1 = 8$$
$$KTP = \frac{34.853{,}5}{2} = 17.427$$
$$KTG = \frac{6.633{,}5}{6} = 1.106$$
$$F_{count} = \frac{17.427}{1.106} = 15{,}757$$

Hypothesis test:

H_0: There is no influence between the number of students on the concentration of CO_2 in the room.

H_1: There is an influence between the number of students on the concentration of CO_2 in the room.

Test Level: α: 5% = 0,05

Test Criteria: Reject H_0 if $F_{count} > F_{table}$

Decision: 15,757 (F_{count}) > **5.143** (F_{table}), H_0 is rejected and H_1 is accepted

Conclusion: there is a significant effect between the number of students on the concentration of CO_2 in a room.

From the obtained Fcount, when compared with Ftable with an initial test level (α) of 1%, namely 10.924767, it can also be said that the number of students significantly affects the concentration of CO_2 in a room. The results obtained above (conclusions) follow previous studies which state that the density of humans or occupants in a room influences increasing the concentration of CO_2 in the air [34–37].

3.2 Effect of Number of Individuals on Room Temperature

Based on the data in table 6, the following calculations are carried out:

Correction Factor (Equation 1)

$$FK = \frac{(272)^2}{(3 \cdot 3)} = \frac{73.984}{9} = 8.220{,}4$$

Total Squares (Equation 2)

$$JKT = (28)^2 + (30)^2 + \cdots + (32)^2 - 8.220{,}4$$
$$= 13.556 - 8.220{,}4$$
$$= 5.335{,}6$$

Number of Treatment Squares (Equation 3)

$$JKP = \frac{(88)^2 + (90)^2 + (94)^2}{3} - 8.220{,}4$$
$$= \frac{8.234}{3} - 8.220{,}4$$
$$= 2.744{,}6$$

Sum of Squared Errors (Equation 4)

$$JKG = 5.335{,}6 - 2.744{,}6$$
$$= 2.591$$

Substitute the results into the Anova table

Table 7. Table of Analysis of the Effect of the Number of Individuals on Room Temperature

SK	DB	JK	KT	F_{count}	F_{table}
Treatment	2	2.744,6	1.372,3	3,1778	5.143
Error	6	2.591	431,83		
Total	8	5.335,6			

Determine F_{count} (Equation 5-10)

$$DBP = 3 - 1 = 2$$
$$DBG = 3(3 - 1) = 3(2) = 6$$
$$DBT = 3(3) - 1 = 9 - 1 = 8$$
$$KTP = \frac{2.744{,}6}{2} = 1.372{,}3$$
$$KTG = \frac{2.591}{6} = 431{,}83$$
$$F_{count} = \frac{1.372{,}3}{431{,}83} = 3{,}1778$$

Hypothesis test:
H0: There is no influence between the number of students and the room temperature.
H1: There is an influence between the number of students and the room temperature.
Test Level: α: 5% = 0,05
Test Criteria: Reject H0 if Fcount > Ftable
Decision: 3,1778 (Fcount) < **5.143** (Ftable), H0 is accepted and H1 is rejected
Conclusion: there is no significant effect between the number of students and the room temperature.

Judging from previous studies, one factor that influences the increase in room temperature is the high concentration of CO_2 in the air [38–40]. Suppose the results obtained in table 4 are examined and compared with the increase in the average temperature in table 5. The increase in room temperature is not directly affected by the number of occupants (HO is accepted) but is influenced by CO2, the number of occupants of the room. Because the increase in CO2 concentration in the air is not too rapid, so the temperature of the room temperature does not increase significantly.

3.3 Health and Study Room Ideals

After the research was conducted, in table 4 and table 5, it is known that for the experiment with 35 students, the average CO2 concentration was around 681 ppm and the room temperature was around 31.3oC. Compared to the average value of CO2 concentration obtained in table 1, it can be said that the study room where this research was conducted is still relatively safe. Compared to table 2, room temperature is not included in the ideal category. The room temperature seen in table 5 is 29.30 C. This value is still far from the ideal study room temperature of 20^oC - 22oC (table 2). Considering that the sample study room where this research was conducted does not have air conditioning, it is highly recommended that the placement of the air conditioner meet the standards of the ideal study room.

4. CONCLUSIONS

This study concludes that there is a significant effect between the number of students on the concentration of CO2 gas in the teaching and learning room, and there is no direct effect for increasing room temperature. The study room where the research is carried out is not yet ideal but is still relatively safe.

For further research, it is necessary to consider control variables such as time of data collection, morning, afternoon, and evening. In addition, it is also recommended to compare the measurement accuracy of the system used with conventional CO2 concentration and air temperature measuring instruments.

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