Herbs Go Digital: IoT Monitors Temperature and Humidity Automatically

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Abstract

This article aims to demonstrate the use of the Internet of Things (IoT) in a company by installing sensor devices to monitor environmental conditions automatically and continuously. Before IoT devices, monitoring processes relied heavily on inconsistent manual inspections. In the herbal and pharmaceutical industries, temperature and humidity monitoring are essential. The DHT11 and DHT22 sensors are used in conjunction with the ESP32 microcontroller to facilitate real-time temperature monitoring. The collected data is recorded in a MySQL database and displayed through HTML and PHP-based web dashboards. This article compares the performance of both sensors and discusses their potential mass application in enterprises. This IoT system implementation changes the monitoring process from manual to automated and continuous, enabling historical data collection for further analysis. The results show that IoT integration can improve efficiency and accuracy in monitoring enterprise environmental conditions.

Keywords— IoT, Monitoring, Database, DHT11, DHT22

1. INTRODUCTION

Industry 4.0, often called the Fourth Industrial Revolution, is considered the era of digital transformation and digitalization of the entire industrial ecosystem. The Industrial Revolution is based on the concepts of automation, physical, cyber systems, cloud computing, cognitive computing, and artificial intelligence, supported by the various components and systems used to operate them [1]. In realizing Industry 4.0, we often hear about artificial intelligence (AI). Artificial intelligence is one of the inventions that has the potential to change the world. Currently, artificial intelligence is used in almost all commercial operations. Artificial intelligence is a system that stimulates machine intelligence, where the intelligence is artificial intelligence obtained after conducting an in-depth data analysis process that involves serious and thorough consideration [2]. Towards the implementation of artificial intelligence systems, one of the important things is the collection of data that is carefully trained and processed to form certain patterns that are understood by machines. Processed data is obtained through various methods, such as direct observation, interviews, input data recording, and image recording, and one of them can be taken with an Internet of Things (IoT) system [3, 4, 5]

In Indonesia, several companies base their products on herbal products. This leads to the need for very strict supervision of the environmental conditions of the production process, starting from taking raw materials and processing them into finished goods. This happens, for example, in the production of cosmetics with natural ingredients from different regions and in the production of food and medicines that require an environment that guarantees raw materials for the production process to permissible standards [6,7]. Environmental temperatures and humidity greatly determine the durability and quality of raw materials and finished products [8].

One of the biggest problems in the Indonesian industry with herbal raw materials is the very high humidity in Indonesia compared to other countries in general[9]. Therefore, temperature and humidity monitoring are the main features that affect the raw materials and finished materials process and become products with durability that conform to the company's target without damage, so the monitoring process needs to be carried out continuously. Similarly, a database is needed to document temperature and humidity data over long periods to serve as a reference in analysing the environment each time changes. This can be done with current technology using Internet of Things (IoT) technology. The Internet of Things (IoT) is a connected device where the device is equipped with sensors and systems attached that make it possible to send messages to other devices connected to the network [10].

In previous research, the use of the Internet of Things in temperature and humidity monitoring has been applied but has not been implemented optimally, and the use of databases for storing recorded results still uses third parties, as shown in Table 1.

Table 1. IoT Utilization Research

Year	Reference	Content of the study	GAP Research
2021	[11]	In this study, a tool was built to monitor and control temperature and humidity with an online system using an ESP8266 Wi-Fi module with the ESP8266-01 series using a DHT-22 sensor.	The sensor data storage and processing system in this study uses a third party where the data is sent to Thingspeak and Thingsview.
2022	[12]	Conducting research by building a monitoring system for temperature and humidity of server room conditions using a Raspberry Pi microcontroller and DHT-11 sensor, sensor result data is sent to Telegram.	In this study, temperature storage in a particular database was not discussed, so the recorded data could not be called for evaluation for several days or months.
2023	[13]	Conducting research by building a temperature and humidity monitoring system using NodeMCU ESP8266 and DHT 11 sensors in the drug storage room	This research used the Blynk IoT platform available on smartphones and the MIT App Inventor. On the Blynk IoT site, a dashboard of temperature, humidity, and drug storage room measurement data is displayed in real-time.

This research will show how IoT systems have changed the manual monitoring process with automated and continuous monitoring in the enterprise environment. The device was built in the laboratory environment of a herbal medicine industry company in Indonesia using an ESP32 microcontroller. Data for December 2024 shows that ESP32 prices are very affordable, ranging from IDR 45,000 to IDR 65,000, and easily found on various marketplace platforms. The ESP32 consists of an MCU (microcontroller unit) with Wi-Fi and a Bluetooth network stack that enables the construction of IoT applications. The ESP32 hardware, temperature sensor, 5000 mAh 3.7V rechargeable battery, and LCD I2C will be assembled to display temperature and humidity values directly to users.

In addition to ESP-32, the study also used DHT11 and DHT22 sensors to detect temperature and humidity. DHT11 sensors sell for 10,000 to IDR 25,000, while DHT22 sells for 20,000 to IDR 45,000. This study aims to compare the response values of the two sensors to determine which is more effective and efficient if applied masse in a corporate environment, both in terms of price and sensor performance.

The sensor can read temperature and humidity because it is specially designed with a sensitive component called a thermistor. A thermistor is a special type of resistor that is very sensitive to temperature changes. When the temperature changes, the thermistor resistance in the DHT11 and DHT22 sensors also changes according to their characteristics. If the temperature increases, the resistance of the thermistor decreases, and if the temperature decreases, the resistance increases. This change in resistance is converted into a change in voltage by an electronic circuit inside the sensor. This circuit produces a voltage that varies with the change in thermistor resistance. This voltage is then converted into a digital value representing the temperature [14].

This research resulted in IoT products being able to record temperature and humidity data automatically. The resulting data is then collected in a database on the company's storage servers. The database used is MySQL, and by using XAMPP software, the data in MySQL can be integrated into the company's local web network [15]. This allows individual room temperature and humidity values as well as second-second recording data to be displayed. The local web is built using the PHP programming language, so users can easily monitor results through the local web dashboard. The data recorded by the sensor device is stored and evaluated. The evaluation process is carried out by comparing the values of the DHT11 and DHT22 sensors against calibrated hygrometers that have been used in the corporate environment. The evaluation also includes an acceptance range according to each sensor's data set. In addition, verification and suitability of sensor performance are carried out by comparing the values that appear on the tool with the values that appear on the local web.

2. RESEARCH METHODS

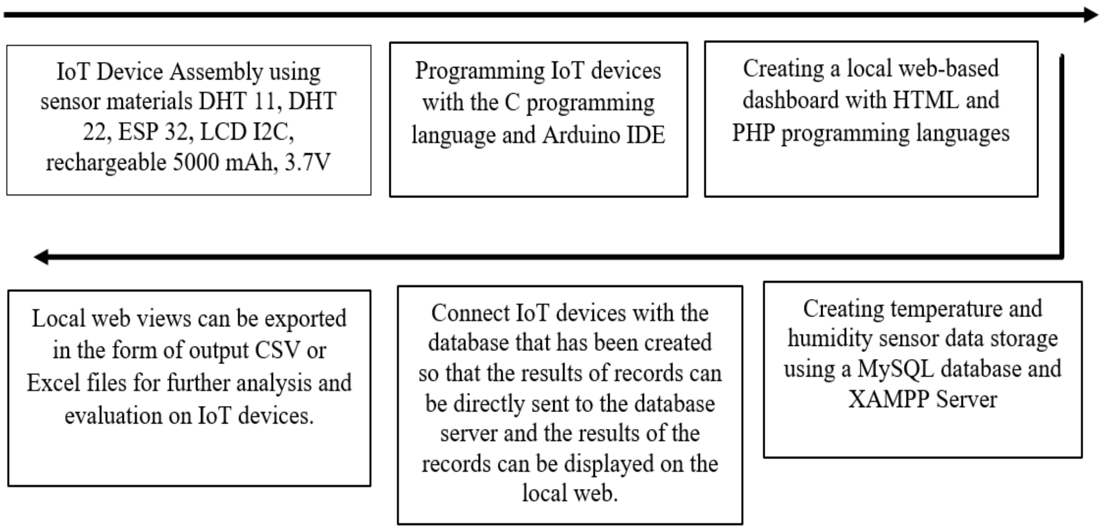

Figure 1. The Internet of Things architecture was created in an industrial setting

Figure 1 shows the research roadmap involved in building an IoT Hygrothermometer device system, which will be explained further as follows:

2.1. IoT Device Assembly

IoT devices are assembled as illustrated in Figure 2.

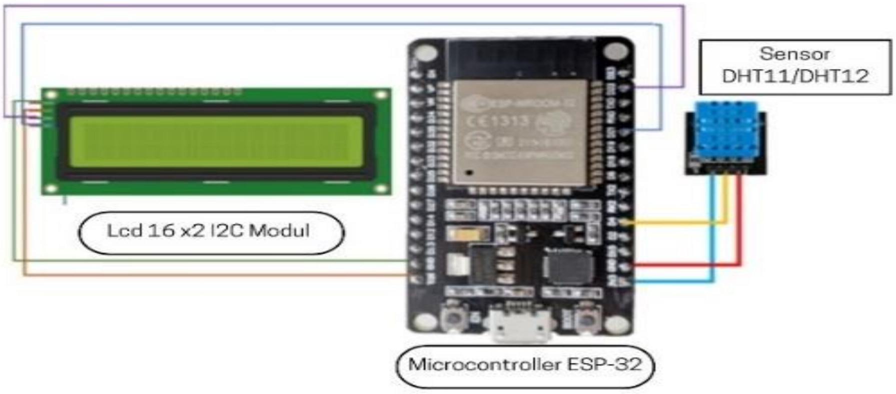

Figure 2a. IoT device assembly scheme

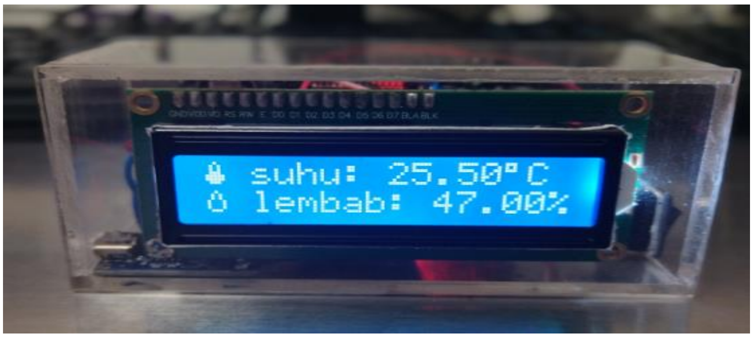

Figure 2b. IoT hygrothermometer device assembly results

In the process of developing Internet of Things (IoT) products, several electronic devices are used, such as an LCD 16x2 with an I2C module, an ESP32 microcontroller board, a DHT11 sensor from Asair, and a DHT22 sensor. Based on the datasheet provided, the Humidity Sensor and DHT11 are capable of reading data in the temperature range of 0–50 °C with a tolerance range of ±2 °C and a humidity reading range of 20–80% with a tolerance range of ±5%. Furthermore, the DHT 22 Sensor can take temperature data readings with a range of -40–90 °C with a tolerance range of ± 0.5 and a humidity reading range of 0–100% with a tolerance range of ±5% [16].

After the assembly of electronic devices is complete, the next step is to make software for the ESP 32 microcontroller. Device programming uses the C programming language, which functions to control hardware, communicate with I2C, and configure Wi-Fi networks to upload data records obtained to the database, which can then be displayed on the dashboard page of the local web that has been created [17]. The device program code can be accessed on the GitHub page: https://github.com/Yosia2023/codehigrotermometerIoT.

2.2. MySQL database creation

The sensor data receiving system is stored in a MySQL database. This storage system is relatively secure, fast-accessed, and capable of handling large volumes of data. The system offers an advantage over previous research that relied on third-party storage platforms such as ThingSpeak. ThingSpeak is a platform that allows the reception, analysis, and visualization of IoT device sensor data in the form of graphs and diagrams[18,19]. The ThingSpeak storage system relies on the cloud infrastructure provided by the service provider, so data security depends on platform policies. Additionally, ThingSpeak has limitations in storage capacity, especially for free accounts, and requires additional fees for storage upgrades. In contrast, storing sensor data on a company-owned server ensures better control, simplifies the evaluation process, and allows users to analyze the data as per specific needs at a lower cost and more efficient process[20]. The database storage structure is shown in Figure 3.

Table structure | Relation view

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra	Action
1	id	int			No	*None*		AUTO_INCREMENT	Change Drop More
2	suhu	decimal(10,1)			No	*None*			Change Drop More
3	kelembaban	decimal(10,2)			No	*None*			Change Drop More
4	waktu	varchar(100)	utf8mb4_0900_ai_ci		No	*None*			Change Drop More
5	tanggal	varchar(10)	utf8mb4_0900_ai_ci		No	*None*			Change Drop More

Figure 3. IoT device sensor data storage table structure

2.3. *Data record display layout*

Temperature and humidity data are displayed on a locale-based web page with a layout dashboard as shown in Figure 4.

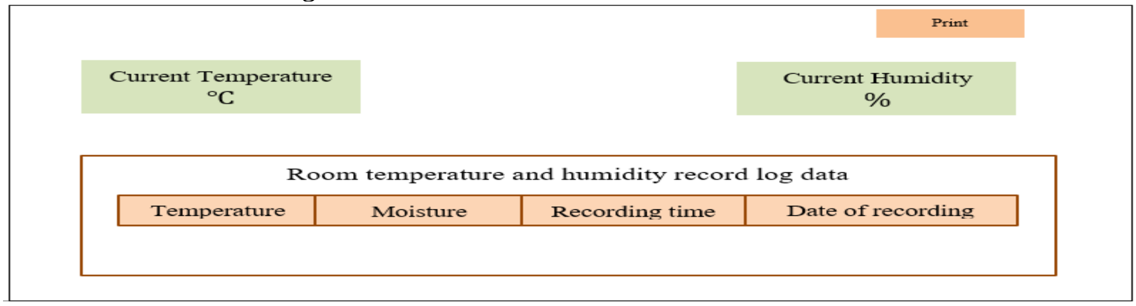

Figure 4. IoT device temperature and humidity recording dashboard

The dashboard is built with HTML and PHP programming languages. The temperature and humidity records stored in the database will be displayed on the dashboard. Temperature and humidity log data can be exported as an Excel or CSV file by pressing the print button on the web page. Export results can be processed to evaluate room temperature and IoT device performance. The dashboard UI view is evaluated by dividing the questionnaire among users in the form of a Google form to evaluate the UI thoroughly. There are 15 questions and 13 questions in the form of a score range of 1-5, with an example question. Is the dashboard display attractive and easy to understand? (Scale 1-5) Does color selection make reading easier? (Scale 1-5) and 2 questions about what to like and dislike about the dashboard[21].

2.4. *IoT hygrothermometer device evaluation*

The evaluation of IoT devices is carried out in several steps, as follows: Checking the correction value of each sensor; ensuring measurement accuracy that the correction values for the measured parameters correspond to those specified in the range of technical data of the device; Verify the display of the local web dashboard against the recording results on the LCD screen of the IOT hygrothermometer device. In comparison with a calibrated hygrothermometer, an observation is made to determine whether there is a significant difference in measurement values between the two devices by comparing the results of the IoT hygrothermometer with the results of the pre-calibrated hygrometer.

3. RESULT AND DISCUSSION

The hygrothermometer IoT device with MySQL storage data stored on the company's internal server was successfully implemented. The cost of manufacturing the device is shown in Table 2. Table 2 shows the cost required to build a sensor compared to the procurement of a conventional hygrothermometer:

Table 2. The production cost of IoT hygrothermometer compared to the cost of purchasing conventional devices

Item	Hygrothermometer IoT DHT11	Hygrothermometer IoT DHT22	Conventional Hygrothermometer
Microcontroller Esp-32	IDR 45,900	IDR 45,900	
Temperature and humidity sensors	IDR 9,900	IDR 21,447	
Battery	IDR 35,000	IDR 35,000	
Cable jumper	IDR 2,500	IDR 2,500	
Hides	IDR 490	IDR 490	
Acrylic	IDR 30,000	IDR 30,000	
Device price	IDR 123,790	IDR 135,337	IDR 1,350,000

Table 2 shows a price comparison in the manufacture of devices with different sensor types. The price is a choice from the marketplace, with the lowest price accessed in December 2024. The manufacturing price of the device is the basis for calculating ROI by analyzing the impact of system implementation on the company's bottom line. The application of the Internet of Things (IoT) system for temperature and humidity monitoring has a major advantage, namely in saving labor costs that were previously used for manual recording. Based on calculations, the annual labor cost savings for manually recording temperature and humidity are estimated to reach IDR 3,120,000 each year. Where each person in charge of the room is given a salary of IDR 10,000 each day to record temperature and humidity, this task is carried out for 6 working days in one week. By using IoT systems equipped with sensors such as DHT11 and DHT22, companies can replace manual processes with continuous, automated monitoring.

Table 2 shows that IoT devices with DHT11 sensors are priced at IDR 123,790, while IoT devices with DHT22 sensors are slightly more expensive at IDR 135,337. The use of the DHT22 sensor is slightly more expensive, as it offers better accuracy with a wider temperature range and smaller measurement errors. In this article, we will look further at whether the results of recording the temperature and humidity between the two sensors have a significant difference if implemented in a laboratory room in a company. Based on the calculated value, the ROI for the manufacture of devices with both sensors shows significant advantages. The calculation of the return on investment (ROI) value uses a formula to compare the net benefits generated with the initial investment cost[22] In this case, the net benefit is in the form of annual labor cost savings of IDR 3,120,000, while the investment cost for IoT devices with DHT11 sensors is IDR 123,790, and for IoT devices with DHT22 sensors is IDR 135,337. Based on calculations, the ROI for DHT11 is, $\frac{\text{IDR } 3{,}120{,}000}{\text{IDR } 123{,}790} \times 100\ \% = 2{,}520\ \%$ and the ROI value for the DHT22 sensor is $\frac{\text{IDR } 3{,}120{,}000}{\text{IDR } 135{,}337} \times 100\ \% = 2{,}301\ \%$.

The ROI value for DHT11 is slightly higher, at 2520%, when compared to DHT22 with an ROI value of 2301%. This result shows that the investment in IoT systems provides a return of more than 23 times the cost incurred within one year. These results indicate that the use of IoT technology in temperature and humidity monitoring provides significant advantages, not only in terms of time and labor efficiency but also in reducing the potential losses that can arise due to slower manual monitoring and are prone to human error. Therefore, these IoT systems not only reduce operational costs but also improve reliability and speed of response to environmental changes that can affect product or process quality.

The selection between the DHT11 and DHT22 sensors will be further analyzed to see if there are any significant differences in temperature and humidity measurements, especially concerning their accuracy and precision. The results of this analysis will help determine which sensors are more appropriate to use in mass devices so that they can support more optimal cost efficiency.

IoT hygrothermometer devices can record temperature and humidity in the room. The recorded results are directly sent to the server and stored in the database. The stored data is displayed in real-time using the local pages of the website. Performance testing of IoT hygrothermometer devices by comparing the temperature and humidity sensor values generated by the DHT 11 and DHT22 sensors with the temperature and humidity sensors from the calibrated hygrothermometer with the results in Figure 5a, b.

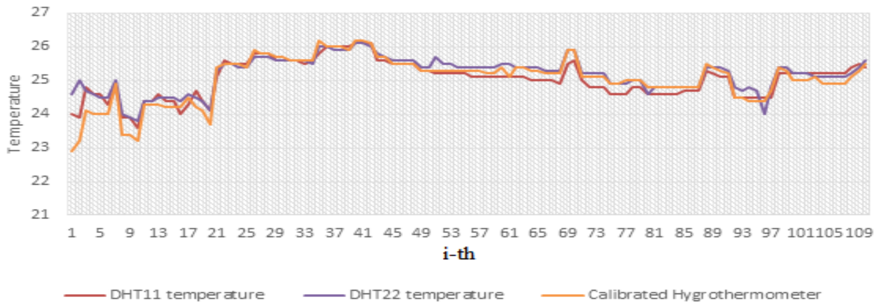

Figure 5a. Comparison of temperature sensor values on IOT hygrothermometers and calibrated hygrothermometers.

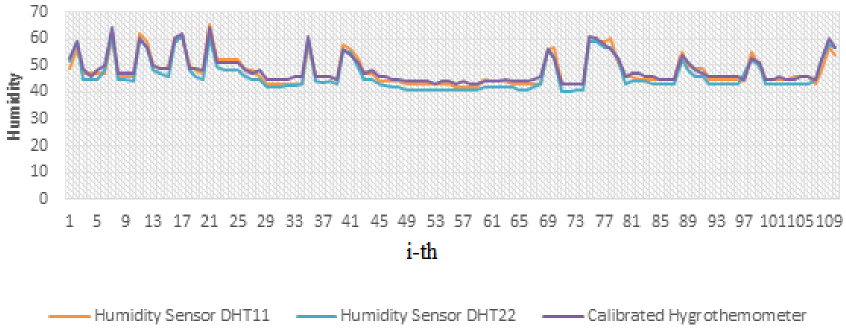

Figure 5b. Comparison of moisture sensor values on IOT hygrothermometers and calibrated hygrothermometers.

The correction range on each sensor meets the acceptance requirements and follows the dataset. Distorted results are only seen on the DHT22 sensor, where the temperature at the beginning of the experiment has an error range of 3 degrees from the actual value, even though the tolerance limit of the temperature sensor value is ± 2. However, on subsequent observations, the error range tends to be stable and is within the range of the DHT22 dataset. This phenomenon can occur because, in the early stages, the device takes time to reach a stable point. Based on the tolerance range values obtained from measurements, both DHT11 and DHT22 sensors can be used in the company's laboratory environment, which has a regulated room temperature range of 20 ± 3 °C and a humidity tolerance range of 45–65% [23].

Further evaluation is carried out by calculating the standard deviation on each sensor [11,20]. The correction results obtained from the calculation of the sensor value of the calibrated hygrothermometer are denoted by X_1, and the correction value for each observation is calculated as the average value and denoted by $\bar{x}$. Based on the average error value obtained, the data variance value is calculated [24]. The variance value is obtained from the square of the difference between the error value and the mean. The variance value describes a measure of how data is distributed. The variance value is a measure of data variability; this value shows that the greater the variance value, the higher the fluctuation of data from one data point to another. From the variance value of the data obtained, the standard deviation value, better known as the standard deviation, is the square root of the data variance value. The smaller the standard deviation value, the value in the sample data tends to be close to the average value. However, as the standard deviation increases, the sample value varies. An example of calculating the value of the standard deviation is shown in Table 3.

Table 3. Standard deviation calculation on each sensor

No.	**Temperature**		**Variant Error**			
	DHT11 temperature	**Calibrated Hygrothermometer**	X_1	$\bar{x}$	$X_1 - \bar{x}$	$(X_1 - \bar{x})^2$
1	23.99	22.9	1.09	0.195364	0.894636	0.800374
2	23.9	23.2	0.7	0.195364	0.504636	0.254658
3	24.8	24.1	0.7	0.195364	0.504636	0.254658
4	24.6	24	0.6	0.195364	0.404636	0.163731
.....	....	....	......	......	....	....
$\bar{x}$	25.04	25.05	0.1954		$\sum$	3.4097
No.	Humidity		Variant Error			
	DHT11 humidity	Calibrated Hygrothermometer	X_1	$\bar{x}$	$X_1 - \bar{x}$	$(X_1 - \bar{x})^2$
1	49	53	4	1.218182	2.781818	7.738512
2	56	59	3	1.218182	1.781818	3.174876
3	47	49	2	1.218182	0.781818	0.61124
4	47	46	1	1.218182	-0.21818	0.047603
.....	....	....	......	......	....	....
x̄	47.92	48.5	1.2182		$\sum$	114.7636
Data	Temperature		Variant Error			
	DHT22 temperature	Calibrated Hygrothermometer	X_1	$\bar{x}$	$X_1 - \bar{x}$	$(X_1 - \bar{x})^2$
1	24.6	22.9	1.7	0.174545	1.525455	2.327012
2	25	23.2	1.8	0.174545	1.625455	2.642102
3	24.7	24.1	0.6	0.174545	0.425455	0.181012
4	24.6	24	0.6	0.174545	0.425455	0.181012
.....	....	....	......	......	....	....
x̄	25.18	25.05	0.1745		$\sum$	7.4487
Data	Humidity		Variant Error			
	DHT22 humidity	Calibrated Hygrothermometer	X_1	$\bar{x}$	$X_1 - \bar{x}$	$(X_1 - \bar{x})^2$
1	51.4	53	1.6	2.175455	-0.57545	0.331148
2	58.9	59	0.1	2.175455	-2.07545	4.307512
3	45	49	4	2.175455	1.824545	3.328966
4	45	46	1	2.175455	-1.17545	1.381693
.....	....	....	......	......	....	....
x̄	46.40	48.5	2.1754		$\sum$	98.1037

Table 3 shows data from temperature and humidity measurements using two types of sensors, namely DHT11 and DHT22, which are compared with calibrated hygrothermometers to select the best sensor at an economical price on the IoT device built. The columns in the table include: a) Data, which is the response generated by each sensor, with measurements taken on temperature and humidity sensors; 110 data taken for analysis and evaluation; b) Sensor (DHT11/DHT22), which indicates the type of sensor used and the result of the test response; c) calibrated hygrothermometer, which is a calibrated hygrothermometer that is referred to as a reference value; d) X_1 - $\bar{x}$ (Deviation), which shows the difference between the sensor measurement results (X_1) and the average value of the sensor data ($\bar{x}$); e) $(X_1 - \bar{x})^2$ (Square of Deviation), which indicates the value of the deviation squared to calculate the variant. The calculation of the uncertainty value in the measurement is done using the standard deviation formula, i.e. $s = \sqrt{\frac{1}{n-1}(X_1 - \bar{x})^2}$. We obtain the deviation standard for temperature on the DHT11 sensor, DHT22 sensor, Humidity on the DHT11 sensor, and Humidity on the DHT 22 sensor are 0.1769, 0.26141, 1.0261, and 0.94870, respectively.

The results of IoT hygrothermometer measurements show that the temperature correction value on the DHT11 sensor is 25.04 ± 0.1769, while on the DHT22 sensor, it is 25.18

± 0.26141. The humidity value on the DHT11 sensor is 47.92 ± 1.0261, and on the DHT22 sensor it is 46.40 ± 0.94870. Based on these results, there is no significant difference between the performance of DHT11 and DHT22 sensors in data recording. We conclude that both sensors are effective for data recording. A further consideration in mass deployment in the company is the price of each sensor, so we decided that in mass production, we use the DHT11 sensor type to increase the optimal ROI value.

The next evaluation of IoT devices is to verify the difference between the data displayed on the local web dashboard and those displayed on the LCD of the IoT device[25]. The test was carried out by comparing the sensor value against the website display, which is shown in Figure 6. The results of this test must be the same so that there are no errors when users monitor and analyze temperature and humidity in the company environment. The test results are listed in Table 4.

Table 4. Temperature and humidity display confirmation.

No	Date	Time	LCD Display	Web Temperature Display (°C).	LCD Humidity Display (%RH).	Web Humidity Display (%)
1	5/28/2024	8:09:23	24.3	24.3	51.3	51.3
2	5/28/2024	8:09:32	24.4	24.4	48.8	48.8
3	5/28/2024	8:09:40	24.3	24.3	48.2	48.2
4	5/28/2024	8:09:48	24.4	24.4	47.9	47.9
5	5/28/2024	8:09:57	24.4	24.4	48.1	48.1
6	5/28/2024	8:10:05	24.4	24.4	48.8	48.8
7	5/28/2024	8:10:14	24.4	24.4	49.8	49.8
8	5/28/2024	8:10:23	24.5	24.5	50.4	50.4
9	5/28/2024	8:10:31	24.5	24.5	51.1	51.1
10	5/28/2024	8:10:40	24.6	24.6	52.4	52.4
11	5/28/2024	8:10:48	24.6	24.6	53.5	53.5
12	5/28/2024	8:10:57	24.6	24.6	54.1	54.1
13	5/28/2024	8:11:05	24.7	24.7	54.6	54.6
14	5/28/2024	8:11:14	24.7	24.7	55.5	55.5
15	5/28/2024	8:11:22	24.8	24.8	56.4	56.4
16	5/28/2024	8:11:30	24.8	24.8	57.2	57.2
17	5/28/2024	8:11:39	24.8	24.8	57.6	57.6
18	5/28/2024	8:11:48	24.9	24.9	57.8	57.8
19	5/28/2024	8:11:56	24.9	24.9	58.3	58.3
20	5/28/2024	8:12:04	25	25	58.6	58.6

Figure 6. The IoT hardware for monitoring temperature and humidity, along with its dashboard (the name of the observation Room is written in Indonesian as Ruang Instrumentasi, i.e., Room of Instrumentation; suhu means temperature, and lembab means humidity.

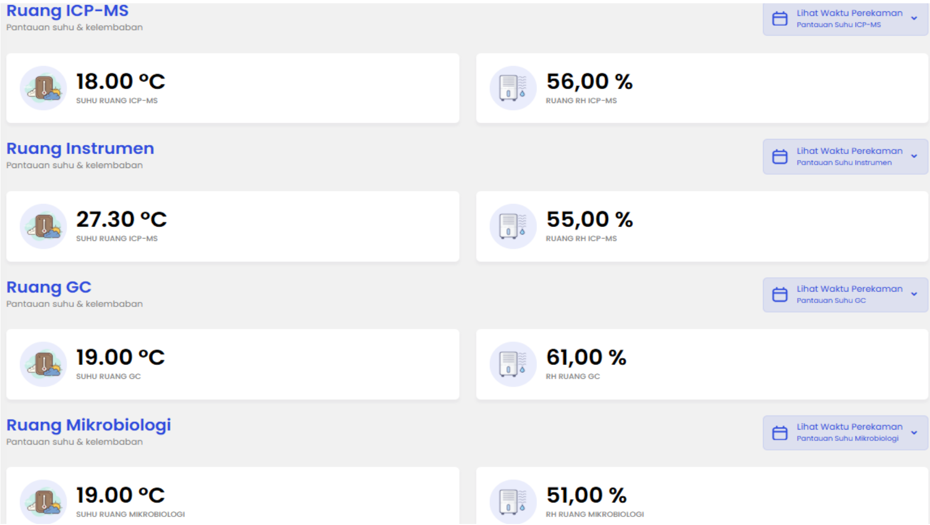

Figure 7. The name of the room is written in Indonesian, namely ICP-MS Room, Instrument Room, and GC Room Microbiology Room, which shows four different rooms displayed simultaneously.

Based on the test results in Table 4, it shows that the readings displayed on the LCD screen of IoT devices are the same as the values on the local web dashboard. These results show that IoT hygrothermometer devices can send and display data in real-time according to observed environmental conditions. Devices can be installed in multiple rooms. The local web dashboard can receive data from temperature and humidity records simultaneously. The results of the implementation are depicted in Figure 7.

Recording the condition of the room no longer needs to be done by visiting each location where the hygrometer is placed. We only need to access the locally created website and see the desired monitoring location collectively. The experiments here can be extended to different types of sensors for the necessary monitoring based on IoT technology. So far, we have only used IoT as evidence of how manuals can be done more efficiently with IoT. We implement security protocols to protect data and prevent unauthorized access within Internet of Things (IoT) systems. IoT device data temperature and humidity can be secured by implementing several simple but effective methods. First, use secure credentials such as strong, specific, and confidential usernames and passwords to prevent unauthorized access to the database. Second, encrypt data during transmission using HTTPS or TLS protocols to protect data confidentiality from eavesdropping. Third, we separate the IoT device network from the main network through a guest network configuration on the router to restrict access from other devices. Furthermore, we perform regular firmware updates to close security gaps. This combination of methods ensures that temperature and humidity data remain safe without the need for large device resources.

Apart from the device function, testing is also carried out on dashboard users. Based on these tests, we can get feedback and evaluations directly from users. Evaluations are carried out periodically to support continuous improvement. The following is the result of the final evaluation of the temperature and humidity monitoring dashboard assessment conducted by 10 users, as shown in Table 5.

Table 5. User assessment of IoT device user interfaces

Respondent ID	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	q11	q12	q13
63000601	4	5	5	4	4	4	5	5	4	5	4	5	4
63000602	3	4	3	3	3	3	4	4	3	3	4	4	3
63000603	5	5	4	5	4	5	5	4	5	5	3	5	5
63000604	4	4	4	4	4	4	4	4	4	4	4	4	4

63000605	3	3	3	3	3	3	3	3	3	3	3	3	3
63000606	5	5	5	5	5	5	5	4	5	5	3	5	5
63000607	4	4	4	4	4	4	4	4	4	4	4	4	5
63000608	3	3	3	3	3	3	3	4	3	3	3	3	5
63000609	4	4	4	5	5	5	5	5	5	5	5	5	5
63000610	4	4	4	4	4	4	4	4	4	4	4	4	4
Average score	3.9	4.1	3.9	4	3.9	4	4.2	4.1	4	4.1	3.7	4.2	4.3

Based on Table 5 of the evaluation of the IoT dashboard, most respondents gave a positive assessment with an average score ranging from 3 to 5 for various aspects tested, such as visual appearance, functionality, and ease of use. Visual aspects such as attractive appearance, color selection, and text size were rated quite well, with most respondents giving a score of 4 or 5. In terms of functionality, elements such as logical layout, clarity of features, and informative data logs also get appreciation. Other advantages mentioned include simple design, easy-to-understand navigation, as well as features that work well. However, several areas still need to be improved, including the addition of features such as data filters and export options, increased clarity of print features, and optimization of the display to make it more comfortable, especially related to color selection. Additionally, the accessibility and use of the dashboard on mobile devices require further refinement to make it more responsive. By improving these aspects, the IoT dashboard is expected to provide a more optimal experience, support user needs, and make it easier to monitor data efficiently and effectively.

4. CONCLUSION

This article discusses the use of IoT in enterprises to monitor temperature and humidity, which are key components of monitoring environmental conditions. Initially, the company faced difficulties with this monitoring and needed an automated and continuous system. Therefore, simple IoT devices were developed. The results show that the device successfully monitors multiple rooms simultaneously, thereby improving monitoring efficiency and sustainability. The study also compared DHT11 and DHT22 sensors, finding that the two sensors gave readings that did not differ significantly and conformed to the company's tolerance limits. DHT11 is recommended for mass production because it is cheaper and meets company standards. With the calculation of the ROI value of 2520%, it has a potential profit of 25 times the investment value. With inexpensive hardware and an understanding of IoT coding, companies can build highly usable systems. In practical terms, IoT is proven to be able to solve the problem of monitoring temperature and humidity in industry. Confirmation and validation of the IoT-Hygrometer show that the temperature and humidity correction values are still within the tolerance range, and the connection between the IoT-Hygrometer and the database is working properly. Tests showed the deviation of the DHT11 sensor was 25.04 ± 0.1769 for temperature and 47.92 ± 1.0261 for humidity, while the DHT22 showed 25.18 ± 0.26141 for temperature and 46.40 ± 0.94870 for humidity. This proves that the device is used effectively and provides the expected accuracy. The results of the evaluation of 10 users of the user interface have a positive rating with an average rating range of 3.7-4.3. This result shows that the IoT dashboard has a good appearance and functionality, although several aspects need to be improved to improve the convenience and efficiency of use.

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