IoT-based Environmental Monitoring with Data Analysis of Temperature, Humidity, and Air Quality

Jacquline Waworundeng *[1]
Informatika, Fakultas Ilmu Komputer, Universitas Klabat
Airmadidi, North Sulawesi, Indonesia
e-mail: ***[1] jacquline.morlav@unklab.ac.id**

Abstract

Environment monitoring has been linked to the use of the IoT. To raise awareness for the environment, the IoT system is built as an instrument tool based on a Prototyping model with an experimental approach. The hardware consists of sensors, microcontrollers, a Wi-Fi modem, powered with solar cells, and electricity integrated with IoT platforms Blynk and ThingSpeak. The prototype detectors were installed in two different locations at the Universitas Klabat. The IoT systems can store data, display information, and send push notifications as alerts to the user's smartphone when critical conditions emerge. In the two locations for a specified time of May 2023, the data analysis shows average temperatures are 28,39˚C and 28,44˚C, where 28˚C is the optimal value. The average humidity shows 90,18%RH and 85,28%RH. These humidity values are critical because the humidity outside 40-60%RH can significantly impact health. The average air quality shows 59,62 AQI as "moderate" and 3.7 AQI as "good". While "good" air quality is the best, "moderate" is safe because only when a value higher than 100 is unhealthy. The IoT system can help to monitor and provide real-time information about the environmental parameters.

Keywords—sensor, microcontroller, Blynk, ThingSpeak, push notification.

1. INTRODUCTION

Environmental monitoring with IoT technology has grown rapidly with the use of sensors and devices to collect and analyze data to provide information about environmental conditions. According to the United Nations Economic Commission for Europe (UNECE), "environmental monitoring is a tool to assess environmental conditions and trends, support policy development and its implementation, and develop information for reporting to national policymakers, international forums, and the public" [1]. Other references define environment monitoring as the task of recording atmospheric parameters in a specific location over some time [2-6]. Environmental conditions such as temperature, humidity, and air quality are essential parts of physical health.

"Extreme temperatures most directly affect health by compromising the body's ability to regulate its internal temperature. Temperature extremes related to heat can also worsen chronic conditions such as cardiovascular disease, respiratory disease, cerebrovascular disease, and diabetes-related conditions" [7]. The human body has a normal core temperature on average is 37˚C and to maintain this temperature without the help of warming or cooling devices, the surrounding environment needs to be at about 28˚C [8]. Research and research translation are critical to further understanding the effects of temperature change on human health. In addition, research on early warning systems or heat wave response plans can help prepare individuals, workers, and communities [9].

Another factor that affects physical health is humidity. "Relative Humidity (RH) is defined as the amount of water vapor present in the air, expressed as a percentage of the amount needed for saturation at the same temperature". The optimal humidity ranges from 40-60%RH.

Conditions outside the ideal range of 40–60%RH can have impacts on health because it can promote infectious transmission and can cause respiratory diseases [10].

While temperature and humidity are important factors for a healthy environment, air quality is also another concern. According to the National Institute of Environmental Health Sciences, “air pollution is a major threat to global health and prosperity”. “Air pollution exposure is associated with oxidative stress and inflammation in human cells, which may lay a foundation for chronic diseases and cancer” [11]. Decreased air quality is a factor that can cause various types of disease, therefore it is necessary to observe the air quality in the community environment. Air quality has standard values that also affect human health. Air Quality Index (AQI) values show levels 0-50 (Good), 51-100 (Moderate), 101-150 (Unhealthy for Sensitive Groups), 151-200 (Unhealthy), 201-300 (Very unhealthy), and 301-500 (Hazardous) [12].

Universitas Klabat, abbreviated as Unklab, is a private university founded, managed, and supervised by the Union of Eastern Indonesia Seventh-day Adventist Church through Yayasan Universitas Klabat which is located in Airmadidi Atas, North Minahasa district, North Sulawesi Province in Indonesia. This university is well-known as a green campus that has an environment with plants and trees that reduce air pollution as well as promote wellness and health. The university never had any research about outdoor environmental monitoring as well as no tools or devices to collect and provide data to be further analyzed about environmental parameters such as temperature, humidity, and air quality. As the initiated project, this research could fill the gap, raise awareness about the Unklab environment, and provide information to the university and the community surround. This research is conducted to monitor, measure, and analyze the environmental conditions in Unklab, to support and provide evidence by data about the tagline Green Campus.

With the rapid development of technology especially in the IoT field, it can be used to design a tool and system that can monitor the environmental conditions which therefore can increase awareness of a healthy environment. In this research, there are three environmental parameters being examined namely temperature, humidity, and air quality. In the previous research “Design Prototype Detector of Temperature, Humidity, and Air Quality using Sensors, Microcontrollers, Solar Cells, and IoT” [13], the researcher designed and built the tool as a prototype detector to monitor the environmental conditions. This research is an extended study, that implements the process of collecting data from the prototype detector, storing it in the IoT cloud, and providing push notifications to the user’s smartphone about crucial parameters as alerts for unhealthy environment conditions. As an extension, this research provided a simple data analysis about the average calculation of temperature, humidity, and air quality specifically in two locations in the Unklab environment.

Several prototype detectors and IoT-based systems have been developed by the researcher to monitor the temperature, humidity, and air quality in different cases [14-19]. Other related research discussed advances in smart environment monitoring systems using IoT and sensors and analyzed the trends [20]. Research [21-22] addresses environmental sustainability, the future, and opportunities of IoT in smart cities convergence of Artificial intelligence, and Big Data technologies. There is research that emphasizes the IoT system design and the development of low-cost hardware or prototype, used for environment monitoring [23-31]. This research has a fundamental purpose of using IoT technologies as a part of collecting, acting, and analyzing data in its scope.

Technically, this extended research has the state of the art to implement the environmental monitoring system through the use of two prototype detector hardware integrated with two IoT platforms Blynk and ThingSpeak. The two prototypes have a similar construction but are placed in two different outdoor locations in the Unklab environment. The prototype collects data from its sensors, processes it in the microcontrollers, and sends the data to the IoT Cloud. The real-time data is then displayed on the user’s smartphone or computer. There are push notifications as an alert when the environment parameters (temperature, humidity, and air quality) are in critical condition. Further, the data in the IoT cloud is analyzed in a simple way as a comparative measurement to conclude whether any similarities or differences. The findings would be evidence to support whether Unklab is a green campus with a good environment or the opposite.

2. RESEARCH METHODS

This research is based on the prototyping model [31] with an experimental approach. Figure 1 shows the prototyping model started with a quick plan, modeling quick design, construction of prototype, and communication. In previous research [13], the stage was conducted until the stages of construction of the prototype. Through this extended research, the next stages of the prototyping model are then continued to stage deployment delivery and feedback then to the stage of communication. Stage deployment delivery and feedback related to the installment of the prototype detectors, act on data by sending push notifications and collect data to analyze. From the data analysis, the information about the Unklab environment will be on the stage of communication, as the results will be delivered to the university and its community through this research paper.

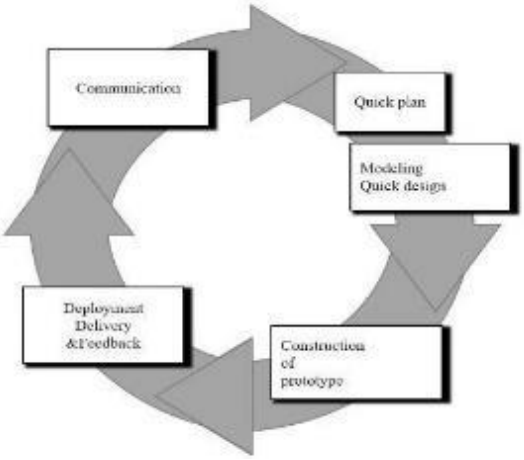


Figure 1. Prototyping model [31]

This research is an extension of the previous research [13] which focused on the design and building of the prototype detector as a hardware tool to measure the environmental conditions related to temperature, humidity, and air quality. However, it does not describe the software interface, push notification features of the IoT platforms, and data analysis. In this research, the user interface was set up in two IoT platforms Blynk and ThingSpeak The main highlight is the integration of the prototype detector using Blynk and ThingSpeak which can be implemented outdoors in two different locations at Unklab, to measure the temperature, humidity and air quality. The data obtained from the prototype were stored in the IoT cloud of Blynk and ThingSpeak which were then analyzed. The purpose of using two prototype detectors is to get data from two different locations and then compare those data to measure whether the parameters have differences or similarities.

The two prototype detectors were placed outdoors in two different locations at Unklab as shown in Figure 2, on May 2023. The first location is at the main entrance near the main road and the second location is around the Pioneer Chapel.

The research instrument is divided into two stages, namely data types and data collection techniques. The data types consist of primary data and secondary data. Primary data were collected from the two detectors based on the measurement within the two locations. Primary data consists of the recorded value of temperature, humidity, and air quality which is sent and stored in the IoT cloud. Secondary data was collected from the literature such as books, journals, and articles. Data collection techniques are conducted based on the measurement value from the detectors which are then sent to the two IoT platforms. The data on temperature, humidity, and air quality can be displayed rather in Blynk and ThingSpeak.

The detector is assembled from hardware components such as temperature and humidity sensor (DHT22), air quality sensor (MQ135), microcontrollers (Arduino Uno R3 and Wemos ESP32), step-down converter LM2596, relay, solar cells, and a USB modem. In the software parts, the detector is supported by IoT platforms Blynk and ThingSpeak to monitor the environment parameters, and send and store the data in IoT cloud-based.

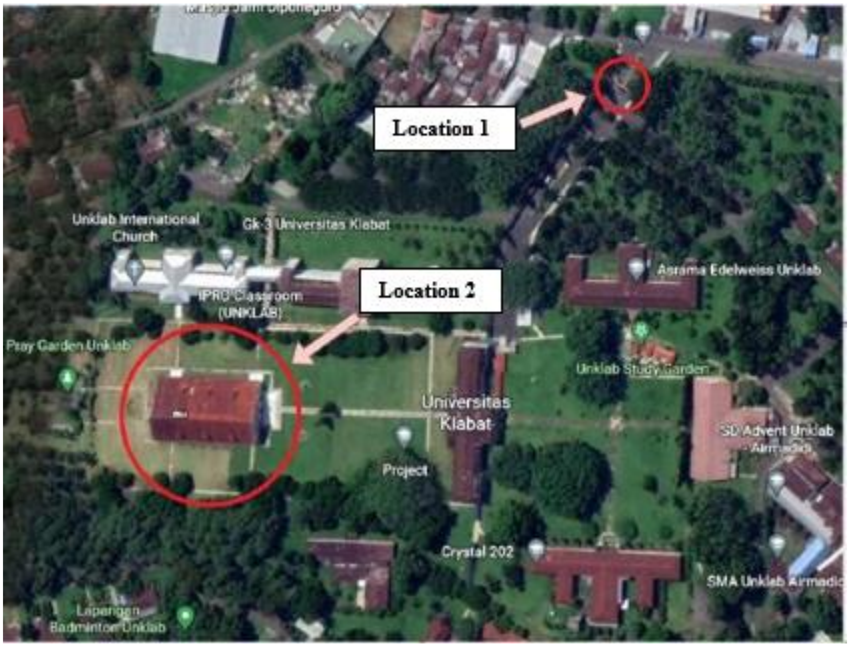


Figure 2. Two locations for Iot Prototype detectors at the Unklab environment

3. RESULT AND DISCUSSION

The results and discussion section explain the design, implementation of the detector, and measurement analysis of temperature, humidity, and air quality.

3.1. System Design

Based on the previous research [13], the detector is integrated with IoT platforms which are shown in the use case diagram, circuit schematic, and hardware implementation with the functional test of the prototype. The prototype detector has been tested and it will function according to its purpose so it is ready to be used in the measurement of environment conditions.

The use case diagram in Figure 3 uses two IoT platforms Blynk and ThingSpeak. ThingSpeak is used to collect real-time data on temperature, humidity, and air quality data in graphic visualization for further analysis. Blynk is used to provide warnings via push notification to the user's smartphone when the system detects temperature, humidity, and air quality conditions that are in critical condition.

Figure 4 shows the system design with hardware components and Figure 5 shows the prototype detector which has been discussed in previous research [13]. The functions of the prototype detector which is connected to ThingSpeak and Blynk are determined by the program code which runs on two microcontroller boards namely Arduino Uno R3 and Wemos ESP32. Arduino Uno R3 handles the function of the reading data from the temperature sensor (DHT22) and air quality sensor (MQ135).

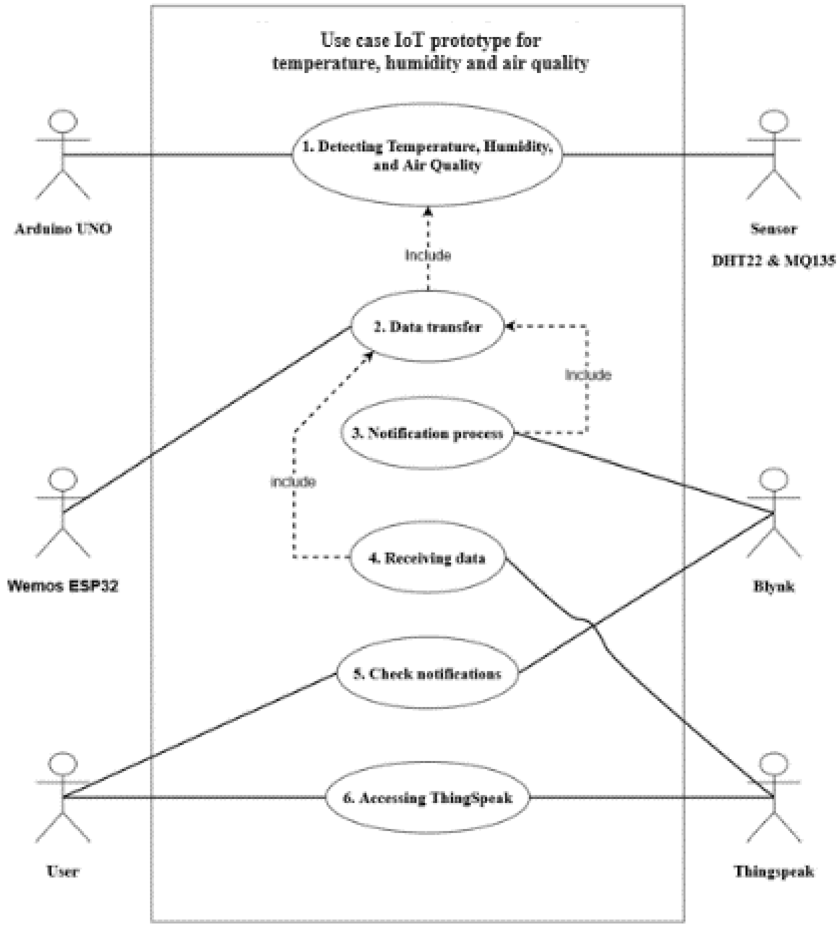


Figure 3. Use Case Diagram of the system [13]

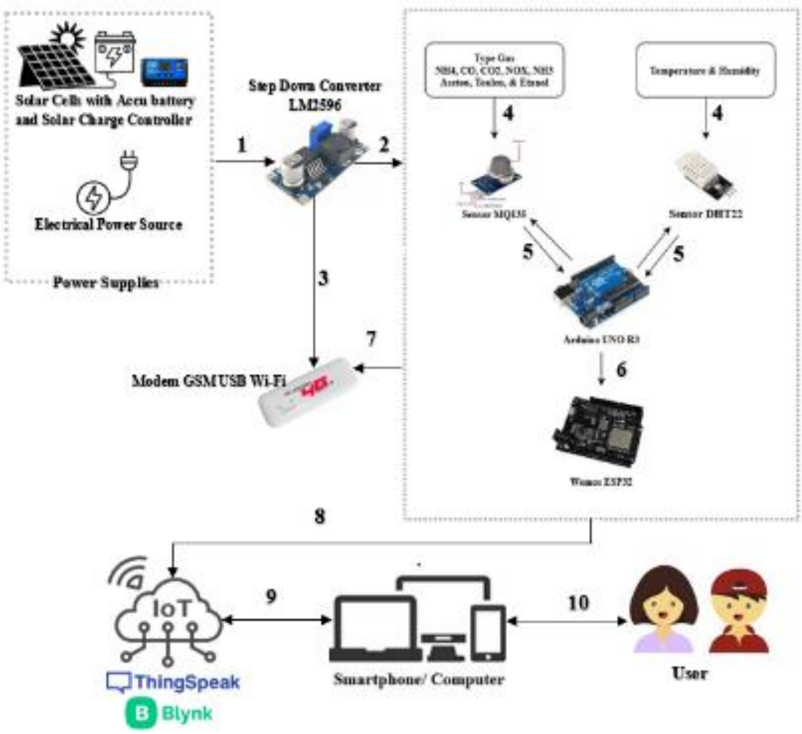


Figure 4. System design with IoT platform ThingSpeak and Blynk [13]

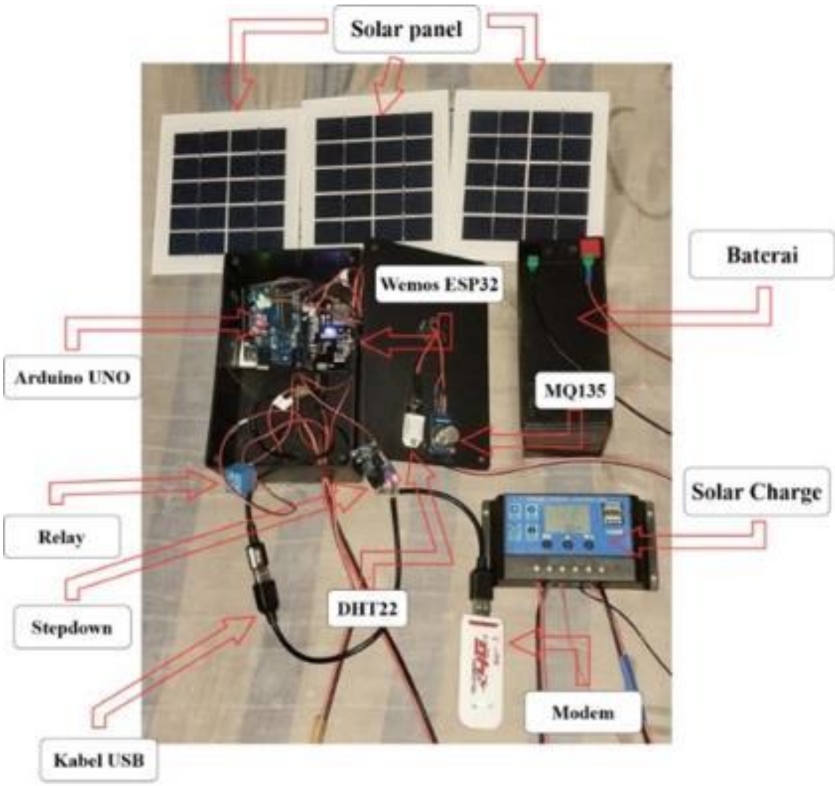
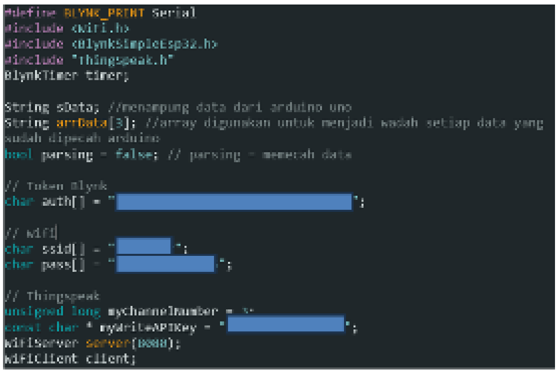


Figure 5. Prototype detector [13]

Figure 6(a), shows a part of the program code in Arduino Uno for reading data from DHT22 and MQ135. The second controller board Wemos ESP32, is used to accommodate the data from Arduino Uno R3. Program code in Wemos ESP32 must be set up with a token from Blynk which is provided when the user creates an account and project. With this token, the prototype can send data to the Blynk application. ThingSpeak provides an API key, which will be set up in the code of Wemos ESP32 so that the prototype can send data to ThingSpeak. Figure 6(b) shows part of the code for the Blynk token and API key from ThingSpeak. The token and API were hidden for security purposes. Figure 6(c) shows the section code of Wemos ESP32 to send data to the IoT cloud of Blynk and ThingSpeak.

(a) Section code in Arduino Uno R3



(b) Section of code in Wemos ESP32

```
void sendSensor() {
  while (Serial.available() > 0) {
    char in = Serial.read();
    sData += in;
  }

  sData.trim();

  if (sData != "") {
    int index = 0;
    for (int i = 0; i <= sData.length(); i++) {
      char delimiter = '#';
      if (sData[i] != delimiter)
        arrData[index] += sData[i];
      else
        index++;
    }

    if (index == 2) {
      //Upload ke Blynk APP
      Blynk.virtualWrite(V6, arrData[0]);
      Blynk.virtualWrite(V7, arrData[1]);
      Blynk.virtualWrite(V8, arrData[2]);

      //Upload ke thingspeak
      ThingSpeak.setField(4, arrData[0]);
      ThingSpeak.setField(5, arrData[1]);
      ThingSpeak.setField(6, arrData[2]);

      int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);

      if (x == 200) {

        Serial.println("Channel update successful.");

      }
```

(c) Section code in Wemos ESP32 to send data to Blynk and ThingSpeak

Figure 6. Code program in Arduino Uno R3 and Wemos ESP32

3.2. Implementation of ThingSpeak Interface

The integration of the prototype detector with ThingSpeak started with creating an account and then logging in to create a channel in ThingSpeak. There are three parameters (temperature, humidity, and air quality) to be measured. As the two prototype detectors will be placed in two locations then the ThingSpeak interface needs to be set up with six record fields to visualize the data in graphic forms. Figure 7 shows the six fields set up in the ThingSpeak channel. Fields 1 to 3 are used to record the 3 parameters in the first location and fields 4 to 6 are used to record the same parameters in the second location. The first location is named Pos 1 and the second location is named Pos 2. ThingSpeak channel provided the Application Programming Interface (API) key which is used in the programming of the prototype detector. This API key made it possible to gather data from the prototype detector and then pass it on to the ThingSpeak cloud in the channel created previously.

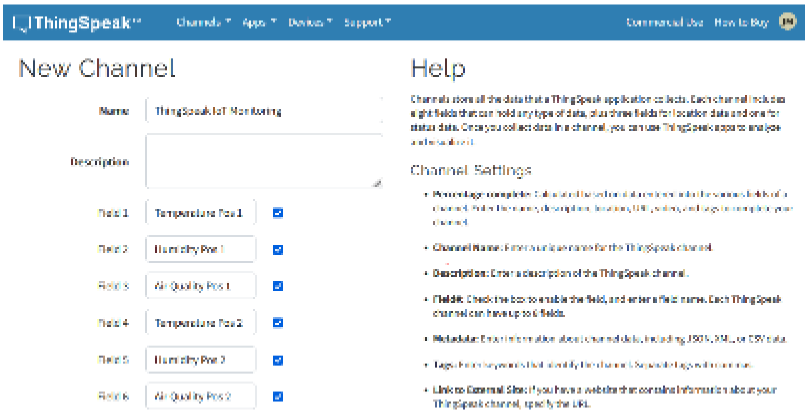


Figure 7. Setup a channel and six fields for data

Figure 8 shows the graphic visualization of recorded data of temperature, humidity, and air quality in two locations namely Pos 1 and Pos 2. It also proves that data from the prototype detector can be received and displayed in ThingSpeak. The red dots show changes in the data value of temperature, humidity, and air quality is recorded.

Figure 8. ThingSpeak graphic visualization of temperature, humidity, and air quality data in Pos 1 and Pos 2

3.3. Implementation of Blynk Interface

Blynk is an application with the ability to monitor the prototype detector through an Android or iOS smartphone. In this research Android smartphone is used for the Blynk application. The function of the Blynk application is to provide push notifications to smartphone users when the prototype detector measures the condition of temperature, humidity, and air quality in critical conditions. Figure 9(a) shows the interface of the Blynk application with 14 widgets. Six value display widgets, six super chart widgets, one notification widget, and one eventor widget. 12 widgets for visualization of the temperature, humidity, and air quality and two widgets for push notification messages. The two highlighted yellow boxes in Figure 9(b) show the notification widget (left side) and the eventor widget (right side).

Figure 10 shows the feature of notification when the value of temperature, humidity, and air quality is in critical conditions. In this case, the critical conditions are: (a) temperature is more than 30°C; (b) humidity is more than 84%; (c) air quality is more than 101. Figure 5 shows the notifications message in Bahasa Indonesia.

(a) (b)

Figure 9. The Blynk application interface shows the value of temperature, humidity, and air quality

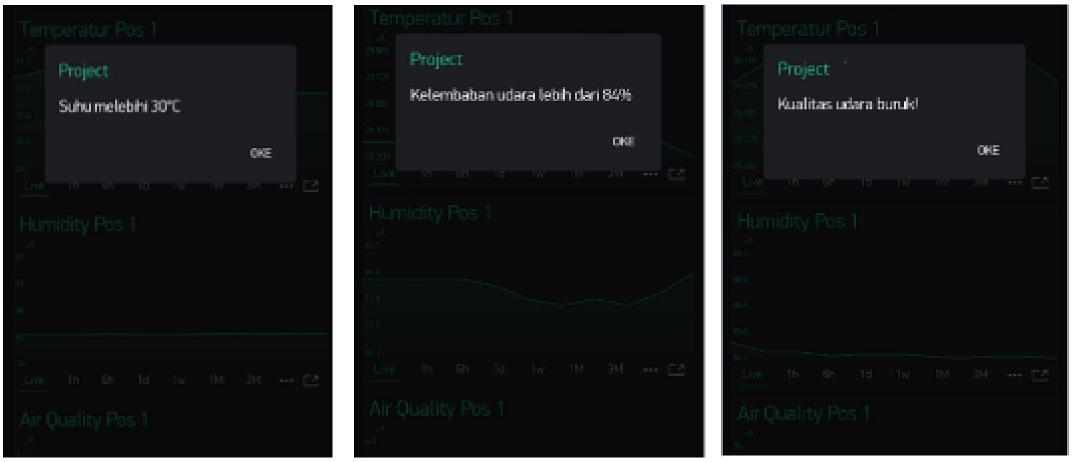
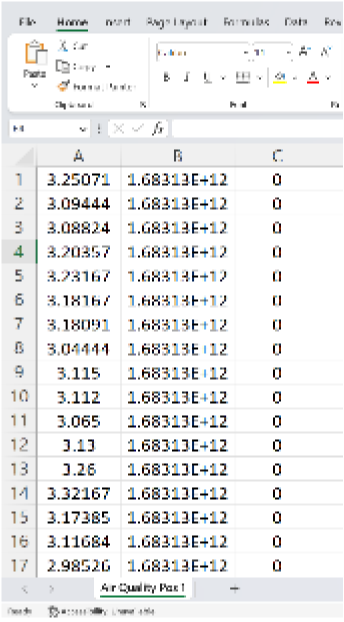


Figure 10. The Blynk application interface shows the notification messages

3.4. Data analysis of temperature, humidity, and air quality

The two prototype detectors are being placed in two different locations named Pos 1 and Pos 2 in Unklab on May 2023, as sampling data to be analyzed. The recorded data is provided by Blynk and ThingSpeak. Even though Blynk and ThingSpeak are different platforms, the recorded data of temperature, humidity, and air quality are gathered from the same prototype detectors. Therefore, its measurement shows the same values. To analyze, the data can be taken either from ThingSpeak or Blynk. Both platforms can generate data and export it in CSV format file. The researcher chooses Blynk to generate the data from its cloud. From the super chart widget in the Blynk application, the data can be sent to the user's registered email. To analyze the data, open the email and download the file. Figure 11 shows the exported CSV file from Blynk for air quality data. The data in the "A" collum shows the air quality and the "B" collum shows the timestamp in Unix format. The researcher needs to get the timestamp of the data. The temperature and humidity are following the same steps to get its data.



	A	B	C
1	3.25071	1.68313E+12	0
2	3.09444	1.68313E+12	0
3	3.08824	1.68313E+12	0
4	3.20357	1.68313E+12	0
5	3.23167	1.68313E+12	0
6	3.18167	1.68313E+12	0
7	3.18091	1.68313E+12	0
8	3.04444	1.68313E+12	0
9	3.115	1.68313E+12	0
10	3.112	1.68313E+12	0
11	3.065	1.68313E+12	0
12	3.13	1.68313E+12	0
13	3.26	1.68313E+12	0
14	3.32167	1.68313E+12	0
15	3.17385	1.68313E+12	0
16	3.11684	1.68313E+12	0
17	2.98526	1.68313E+12	0

Figure 11. CSV format file from Blynk App

The data in the CSV file is raw data. Therefore, it needs to be processed to get the information about temperature, humidity, and air quality with its timestamp. Figure 12 shows how to convert the time in “B” collum and how to calculate the average value. To convert the time, choose all the cells in “B” collum and format it to "m/d/yyyy h:mm". After changing the cell format, enter each cell with the formula "=(((“cells CSV”/1000)+19800)/86400)+DATE(1979,1,1)" and the timestamp for each data can be viewed. After the conversion, then calculate the average value using the "AVERAGE" formula in Excel as shown in Figure 13.

The data taken from the CSV file, show 1616 recorded data for each temperature, humidity, and air quality in two different locations. Figure 13 also shows the results of the data analysis which is simplified in Table 1.

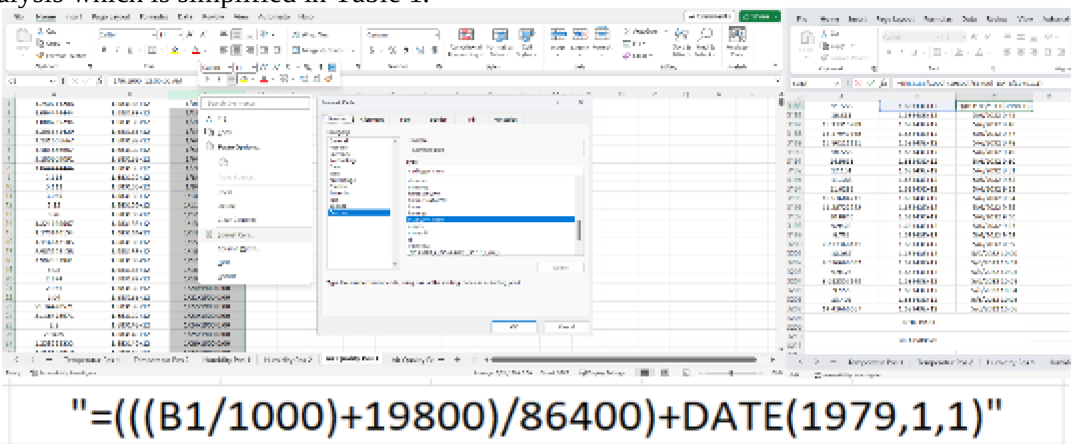
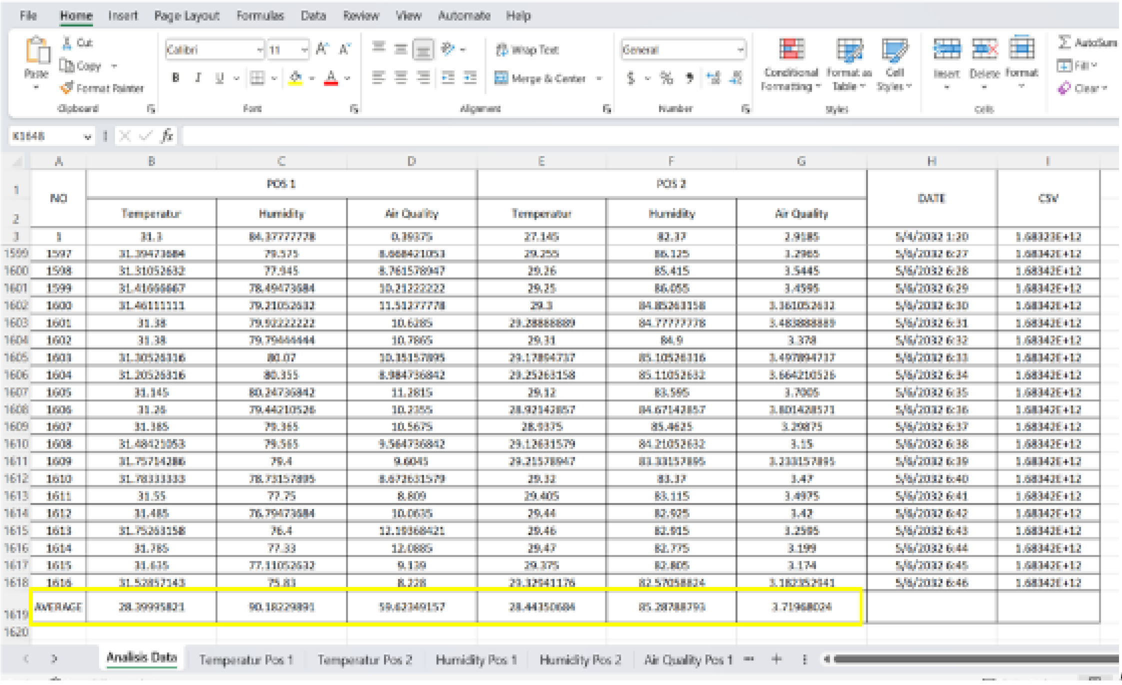


Figure 12. CSV format file was taken from the Blynk and the process of converting the Unix timestamps



NO	POS 1 Temperatur	POS 1 Humidity	POS 1 Air Quality	POS 2 Temperatur	POS 2 Humidity	POS 2 Air Quality	DATE	CSV
1	31.3	84.37777778	0.39375	27.145	82.37	2.9185	5/4/2023 1:20	1.68323E+12
1597	31.39473684	79.575	8.668421053	29.255	86.125	3.2965	5/6/2023 6:27	1.68342E+12
1598	31.31052632	77.945	8.761578947	29.26	85.415	3.5445	5/6/2023 6:28	1.68342E+12
1599	31.41666667	78.49473684	10.21222222	29.25	86.055	3.4595	5/6/2023 6:29	1.68342E+12
1600	31.46111111	79.21052632	11.51277778	29.3	84.85263158	3.361052632	5/6/2023 6:30	1.68342E+12
1601	31.38	79.92222222	10.6285	29.28888889	84.77777778	3.483888889	5/6/2023 6:31	1.68342E+12
1602	31.38	79.79444444	10.7865	29.31	84.9	3.378	5/6/2023 6:32	1.68342E+12
1603	31.30526316	80.07	10.35157895	29.17894737	85.10526316	3.497894737	5/6/2023 6:33	1.68342E+12
1604	31.20526316	80.355	8.984736842	29.25263158	85.11052632	3.664210526	5/6/2023 6:34	1.68342E+12
1605	31.145	80.24736842	11.2815	29.12	83.595	3.7005	5/6/2023 6:35	1.68342E+12
1606	31.26	79.44210526	10.2355	28.92142857	84.67142857	3.801428571	5/6/2023 6:36	1.68342E+12
1607	31.385	79.365	10.5675	28.9375	85.4625	3.29875	5/6/2023 6:37	1.68342E+12
1608	31.48421053	79.565	9.564736842	29.12631579	84.21052632	3.15	5/6/2023 6:38	1.68342E+12
1609	31.75714286	79.4	9.6045	29.21578947	83.33157895	3.233157895	5/6/2023 6:39	1.68342E+12
1610	31.78333333	78.73157895	8.672631579	29.32	83.37	3.47	5/6/2023 6:40	1.68342E+12
1611	31.55	77.75	8.809	29.405	83.115	3.4975	5/6/2023 6:41	1.68342E+12
1612	31.485	76.79473684	10.0635	29.44	82.925	3.42	5/6/2023 6:42	1.68342E+12
1613	31.75263158	76.4	12.19368421	29.46	82.915	3.2585	5/6/2023 6:43	1.68342E+12
1614	31.785	77.33	12.0885	29.47	82.775	3.199	5/6/2023 6:44	1.68342E+12
1615	31.635	77.11052632	9.139	29.375	82.805	3.174	5/6/2023 6:45	1.68342E+12
1616	31.52857143	75.83	8.228	29.32941176	82.57058824	3.182352941	5/6/2023 6:46	1.68342E+12
AVERAGE	28.39995821	90.18229891	59.62349157	28.44350684	85.28788793	3.71968024		

Figure 13. CSV format file was taken from Blynk

Table 1. The average value of temperature, humidity, and air quality

Parameters	Location 1 (Pos 1)	Location 2 (Pos 2)
Average Temperature (^{0}Celcius)	28,39	28,44
Average Humidity (% RH)	90,18	85,28
Average Air Quality (AQI)	59,62	3,7

Table 1 shows the comparison of three parameters on average. The average temperature in location 1 is 28,39˚C compared to location 2 is 28,44˚C which is not significantly differ. Based on reference [8] value of 28˚C is considered as normal temperature. The average humidity is quite different with a gap of 4.93%RH between the two locations with the value above 60%. Reference [10], suggests an optimal range of humidity range from 40-60%RH. The humidity value in Unklab during the time of the experiment show exceed to standard. The significant value is the average air quality which shows the AQI between location 1 and location 2. The data show location 2 with a small value of 3.7 which is considered as a "good" air quality according to the standard. While in location 1 shows a 59,62 AQI which is categorized as "moderate" air quality. The air quality in location 1 needs attention because it is close to the main road and is an access route for vehicles entering and exiting with a tendency to increase air pollution.

4. CONCLUSION

This research implements the IoT for environmental monitoring to collect data, act on data by push notification alert, and then analyze the data taken from the IoT cloud. The prototype detector and its IoT system are used to measure the temperature, humidity, and air quality in two different locations in the Unklab environment. The results show that the temperature and humidity do not significantly differ. The temperature is still considered good with an average value of 28˚C. The humidity in the two locations is 85,28 and 90,18%RH which consider a high humidity level because it is above 60%RH as the optimal humidity range from 40-60%RH. In the analysis of air quality, the data shows significant differences. The first location shows a "moderate" air quality index of 59,62 in contrast with the second location with only 3.7 which indicates a "good" air quality index.

These findings concluded that in May 2023, the Unklab environment had an optimal temperature which is considered a good environment temperature. At the same time, data shows high humidity reached level 90,18%RH which potentially impacts health for those who are susceptible to infection and have respiratory diseases. Related to the air quality, the findings show a "good" and "moderate" AQI as evidence to support Unklab's tagline as a green campus. This research provides information to Unklab and its community, which can increase awareness of the importance of measuring environmental parameters of temperature, humidity, and air quality because changes happen and can have an impact on community health. Apart from that, a suggestion to Unklab's top management is to support the environment by planting more and caring for trees to reduce air pollution and nourish a healthy environment.

Further research can be extended with continuous measurement in months or years to track the data trends and analyze them with AI and machine learning.

5. ACKNOWLEDGMENTS

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