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# Designing IoT-based Smart Weather System to Promote Critical Thinking Skills

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**Abstract** – The role of education in promoting global warming awareness is important to enable students to understand and address the impact of global warming. The use of Internet of Things (IoT) with collaborative learning strategies can enhance students' understanding of global warming. This study aimed to develop an IoT-based smart weather system enhancing the critical thinking skills of elementary students. It consists of weather-measuring sensors that capture data on temperature, humidity, air pressure, light intensity, and altitude. The data is stored in the Blynk cloud and displayed on smartphones. The IoT devices are placed in three different geographic locations. This paper presents the system design, including the system architecture and user interfaces. The data captured by the IoT sensors from the three measurement sites form the foundation to promote the development of collaborative learning.

This result implies the need for teachers to creatively establish learning strategies in various subjects to improve students' critical thinking skills.

**Keywords** – IoT, Global warming, Smart weather, Critical thinking skills, Collaborative learning.

## 1. Introduction

The Industrial Revolution (IR4.0) has changed the global economic landscape, ushering in a new era of global technology. To meet the challenges of IR4.0, the world's workforce must be equipped with an understanding of scientific and mathematical principles, practical knowledge of technology and engineering, and problem-solving skills [1]. One of the technologies of IR4.0 is Internet of Things (IoT). IoT is described as scenarios in which network connectivity and computing capabilities are extended to objects, sensors, and ordinary items that are not often thought of as computers, allowing these devices to generate, share, and consume data with no human intervention [2]. An IoT system consists of three components that enable seamless connections, namely, hardware, middleware, software [3].

IoT in education can be classified into two categories. The first category is about providing courses to teach essential knowledge on computer science, and the second category is about using IoT as a tool to manage academic infrastructure [4]. With IoT, schools will be connected, and students will get access to learning materials, thus paving the way for collaborative learning. On the other hand, teachers can use the data obtained from the IoT devices as

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parameters for problem-solving questions that assess students' critical thinking skills and other activities for them. As a teaching aid, IoT can be implemented in teaching and learning using robots [5], [6], [7], data loggers [8], and wearable devices [9], [10].

The use of educational technology such as IoT creates opportunities for new and creative ideas to improve the teaching and learning of both students and teachers [4]. The use of IoT as a science educational technology has many advantages. First, it promotes hands-on learning as students will perform practical activities in the classroom. For example, students can use IoT devices to collect and analyze data and present their findings on a laptop or smartphone. Furthermore, it can provide elementary school students with numerous opportunities to perform collaborative activities and experiments with other students, thus improving their learning experience [11]. As IoT is a network of devices that captures data in real time, students can improve their collaboration activities. Using IoT devices, students can collaboratively communicate, have access to data, analyze the data, and present their findings in real time [12].

Global warming is an important environmental issue that poses risk to humanity. It generally occurs as a result of human activities, such as deforestation and burning of fossil fuels that release carbon gases into the atmosphere. Ultimately, global warming induces climate change, which causes prolonged droughts, melting glaciers, rising sea levels, etc. Education plays a vital role in promoting awareness of global warming, climate change, and its impact to the planet among students [13], [14], [15]. The use of IoT can be seen as an opportunity for teachers to enhance students' understanding of global warming. Students can use IoT sensors to capture data that could be used as indicators of global warming and, using their higher-order thinking skills, to propose the appropriate solutions. By using IoT, the learning strategies designed by the teachers can encourage collaborative learning with different schools. The skills of elementary school students in connecting, comparing, and explaining various weather indicators as part of understanding global warming can indicate learning success [16].

This paper presents the design of the IoT-based smart weather system that captures data on temperature, humidity, air pressure, light intensity, and altitude. IoT is still rarely used in teaching and learning as it is not considered as a common educational technology like mobile application, virtual reality, and augmented reality [17]. Thus, this study promotes the use of IoT as a tool for students to collaborate with other students in enhancing their understanding and creating awareness on global warming.

## 2. Methods

Figure 1 presents the system architecture of the IoT-based smart weather system. The system consists of an IoT device, Blynk cloud that receives data from the IoT device, and a mobile application for the display of the data. The mobile application was developed using the Blynk app, which can be downloaded at [http://j.mp/blynk\\_Android](http://j.mp/blynk_Android) for Android smartphones or [http://j.mp/blynk\\_iOS](http://j.mp/blynk_iOS) for Apple smart devices.



Figure 1. IoT-based smart weather system architecture.

The Blynk platform was used to control the IoT device, display sensor data, and store and visualize the data. The Blynk cloud manages the communications between the IoT device and the smartphone. The IoT device is also equipped with a microcontroller board with a built-in Wi-Fi module that sends data to the Blynk cloud for processing and then to the Blynk app for display. Figure 2 presents the block diagram of the IoT-based smart weather system.

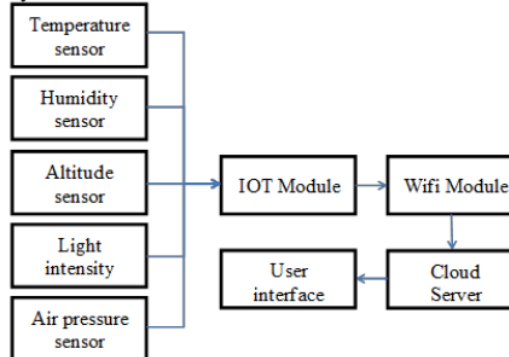


Figure 2. Block diagram of the IoT-based smart weather system

Table 1 presents the microcontroller board and the sensors as well as the indicators that it measures in this study.

WeMOS D1 is an Arduino-compatible board with a built-in ESP8266 Wi-Fi Module that can send the data captured by the sensors to the Blynk cloud via Wi-Fi. The sensors attached to the WeMOS D1 ESP8266 microcontroller board are as follows: DHT22, a temperature and humidity sensor; GY-BMP280, a sensor module that captures the altitude

and air pressure data; and BH1750, a sensor that measures light intensity in lux. The data from the sensors are displayed on the smartphone through user interfaces developed using the Blynk app.

Table 1. Sensors and indicators.

Device Name/Sensors	Indicators
DHT22	Temperature Humidity
GY-BMP280	Altitude Air pressure
BH1750	Light intensity
Wemos D1 ESP8266	IoT & Wi-Fi module

### 3. Results

The IoT-based smart weather system was used by students in learning about topics related to climate. The system consists of an IoT device that measures temperature (Celsius), humidity, altitudes (meter), air pressure, and light intensity (lux). Figure 3 presents the schematic diagram of the IoT-based smart weather system.

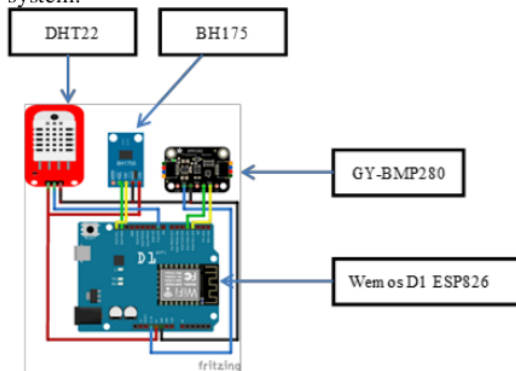


Figure 3. Schematic diagram of the IoT-based smart weather system

The IoT device was placed in three different locations for 24 h. The three locations were as follows: an area that is 8 km from Mount Merapi at SD Muhammadiyah Girikerto, a plain in Yogyakarta City at SD Muhammadiyah Danunegaran, and an area that is 1 km from the beach of Samudera Indonesia at MI Muhammadiyah Garongan. Students can download and activate the app using a barcode. When the sensors are triggered, the data will be sent through the Blynk cloud to the student's smartphone installed with the activated Blynk application. Students can monitor the readings of the data using the Blynk application on the smartphone and use the data for their learning in class. To use the Blynk application, the users must scan the barcode as presented in Figure

4. This will connect the Blynk application to the Blynk server that receives the data from the IoT device.



Figure 4. Barcode to activate the smart weather system

The weather readings captured by the IoT device were monitored in the Blynk application through a user interface. Figure 5 presents the user interface of the smart weather system, the Blynk application. The user interface consists of six main areas, namely, location, temperature indicator, humidity indicator, light intensity indicator, altitude indicator, and air pressure indicator.

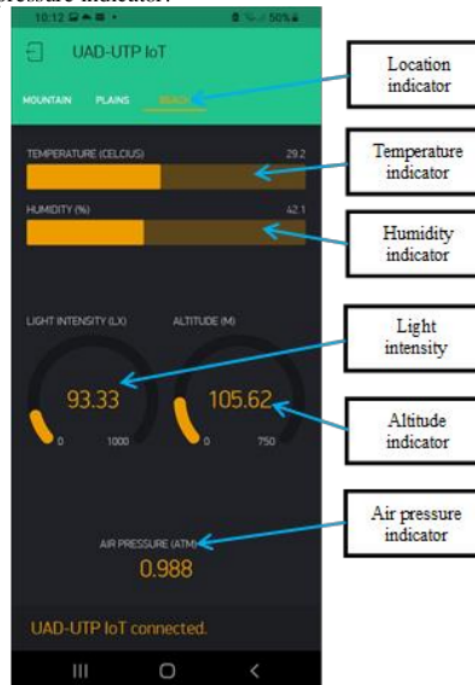


Figure 5. Indicator monitoring at the interface

Figure 6 presents the flowchart of the IoT-based smart weather system. First, the IoT device needs to be turned off and a connection established with the Blynk application installed on the student's smartphone.

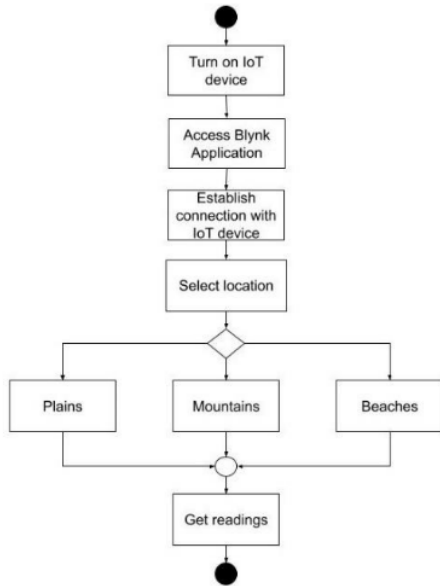


Figure 6. IoT-based smart weather system flowchart

Students can choose the location readings by selecting the option Mountain, Plains, or Beach in the Location area. When a user selects a particular location, the readings for all indicators will be displayed. The readings for temperature and humidity are displayed in a horizontal bar chart. The light intensity and altitude indicators are displayed in a gauge chart, and the value of the air pressure indicator is expressed in number format.

#### 4. Discussions

IoT can connect a network of smart devices through specific communication standards and protocols. In the classroom, teachers can use IoT devices in various learning strategies. Because the IoT devices are connected and data from the devices can be shared, collaboration between students is possible. Furthermore, collaboration is critical for student in the 21st century. In terms of the subjects, IoT devices are suitable for use in project-based learning for STEM-based subjects [18]. The flexibility of IoT devices enables students to collaborate in groups to solve problems and perform other classroom activities.

In this study, an IoT-based smart weather system that can be used by teachers in collaborative learning is proposed. The setup for collaborative learning is presented in Figure 7. In Figure 7, the IoT devices are placed in three areas with different geographical features. The IoT device captures data on temperature, light intensity, air pressure, and humidity and sends it to the cloud. The cloud servers store and

analyze the data. Students from various schools can access the data through the Blynk app.

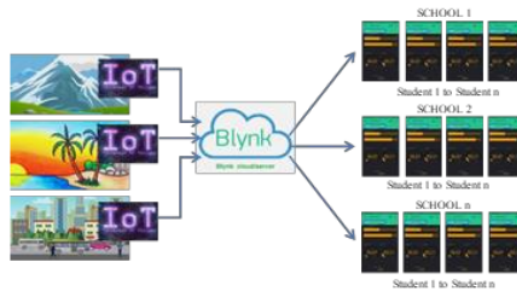


Figure 7. The setup for the use of IoT in collaborative learning

The students can view the data anywhere and anytime. As the IoT devices are placed in the three areas for 24 h, the students can see the data at a given time and location as well as the data changes every time. For example, students can determine the highest temperature in a given location at a particular time, the temperature differences between two locations, and the justification for such differences. The findings such as the highest and lowest readings at a given location and at a given time and the differences in the readings make it possible to establish collaborative activities. Teachers can design activities that allow students from other schools to collaborate. The groups can consist of students from one school or different schools. The teachers provide worksheets in digital or printed forms for the students to record their findings. Based on the findings, students can collaborate by making inferences on their observations and, finally, deriving conclusions. The teachers can guide the students by making the students understand the reading changes in a certain period of time in areas with different geographical features. This will also help students develop their higher-order thinking skills.

Teachers can use the IoT data differently depending on the level of education. In low-grade classes, teachers can encourage students to think critically and analytically on the IoT data by reading, analyzing, and interpreting the data. For example, teachers can provide simple activities with questions, such as when the highest temperature occurred. For college students, the IoT data can be used to explore various phenomena related to global warming and weather with different levels of depth of analysis [19], [20].

The IoT-based smart weather system provides real-time data for the students to work on. Real-time data can introduce students to real weather problems. Students can compare various quantities and indicators that are read to draw various possible explanations of the phenomenon creatively. Figure 8

presents an example of reading on January 6, 2022, at 10.12 local time from the three locations.



Figure 8. Weather indicator data results at a specific time

These readings allow the teachers to develop various activities. Nonetheless, activities can be created in various ways depending on the issues introduced to the students. This learning strategy was developed by referring to learning theories related to resonance [21], [22]. Tests with various approaches have also been conducted by other researchers with significant results with specific learning models [23], [24].

In this study, plains, mountains, and beaches were the selected locations to place the IoT device. Nonetheless, the IoT devices can also be placed in other locations with different geographical features. Owing to the portability of the IoT device, it can be placed anywhere and affixed to other devices to be used more widely for learning and practical purposes in everyday life. The sensors installed on this IoT can also be used in various sectors, not only in education but also in other fields, particularly in agriculture, fisheries, and livestock [25], [26], [27].

## 5. Conclusion

The advances of IoT and cloud technologies have opened new possibilities for collaborative learning. This study presents the use of IoT in facilitating teaching and learning. The IoT-based smart weather system was developed to allow students to measure temperature, humidity, air pressure, light intensity, and altitude. The data captured by the IoT device is stored in the cloud, thus making it available for sharing with other users. The IoT device was placed in three locations with different geographical features to obtain different readings at a given location in a given time. These differences form the basis for developing critical thinking skills in collaborative learning. Students from various locations can monitor data in real time to complete the learning activities designed by the teacher. The students can compare the readings and relate them with the conditions of

those locations to solve problems or make inferences during their learning. Existing studies have demonstrated that collaborative learning can facilitate the growth of soft skills, increase academic performance, and enhance the learning experience of students. Nonetheless, the teacher's creativity is essential to provide a collaborative learning environment using this IoT. This study presents the design of the IoT-based smart weather system. Thus, it is hopeful that the use of IoT in the teaching and learning of weather will promote students' awareness of climate change and global warming.

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