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Monitoring Tools Using DHT11 Sensor, Soil Moisture Sensor and Motion Sensor

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Abstract- This study aims to develop an IoT-based plant monitoring tool that integrates DHT11, soil moisture, and PIR sensors to monitor environmental parameters such as temperature, air humidity, and soil moisture in real-time. This system uses the NodeMCU ESP8266 microcontroller as the main component and utilizes the Thinger.IO platform for data visualization. The development method applied is the ADDIE model, which includes the stages of needs analysis, system design, prototype development, implementation, and evaluation. The test results show that this tool has a high level of accuracy, with minimal error on each sensor. The integration of this IoT-based system makes it easy for users to monitor plant environmental conditions remotely, thus supporting more efficient modern agricultural management. The limitations of this system include the need for a stable internet connection and the potential for noise interference on multisensors. Recommendations for further research are system optimization against noise interference and large-scale implementation for higher efficiency.

Keywords: *Internet of Things,* DHT11 Sensor, Soil Moisture, PIR, Thinger.IO, Plant *Monitoring*

1 Introduction

Monitoring environmental conditions is one of the challenges in crop cultivation. Factors such as air temperature and soil moisture can affect plant growth and crop yields (Fiqa et al., 2021). According to data from the Food and Agriculture Organization (FAO), around 14% of global crop yields lost every year due to lack of optimal environmental management (FAO, 2022). This is important for Indonesian agriculture, because Indonesia is an agricultural country that emphasizes food needs to meet the demands of a growing population (Ayu, 2022).

During the land conditioning process for plant cultivation, monitoring of environmental parameters that directly affect plants is required. One important parameter that needs to be monitored is the temperature and humidity in the land area (Defriyadi & Surapati, 2014). On the other hand, the development of Internet of Things (IoT) technology has provided new opportunities to create a more efficient and real-time monitoring system (Hoffman, 2020). IoT-based tools allow farmers to access environmental data remotely, so they can make faster and more accurate decisions (Noor, 2024). Several studies related to wireless temperature and humidity monitoring systems have been conducted previously. One example is the Arduino Uno and Xbee-based telemetry system designed with storage using an SD Card, capable of operating for up to 432 days (Susanto et al., 2013). In addition, a similar system has been applied to a wireless sensor network with a database managed using PHP (Ardianto & Sumiharto, 2012). Finally, the application of a temperature and humidity *monitoring system* was also found in mushroom cultivation, using the ATMega328 microcontroller as its main component (Nugroho, 2014).

Therefore, the development of a tool that combines temperature and humidity sensors (DHT11), soil moisture, and motion detectors using sensors (PIR) can be an alternative choice in plant cultivation. This

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system not only provides comprehensive data, but is also equipped with a motion detection-based LCD control feature. With data integration on the IoT Thinger.IO platform, this tool is expected to be able to increase the efficiency of plant management and support the implementation of modern technology-based agriculture.

2 Research methodology

2.1 Sensor

A sensor is a device used to detect physical or chemical changes in the surrounding environment and convert them into signals that can be analyzed (Magfira et al., 2024). Sensors have various types, each of which is designed to measure a specific parameter, such as temperature, humidity, or movement. Sensors work based on certain physical principles, for example, a temperature sensor works by measuring changes in resistance or voltage that are affected by temperature, while a soil moisture sensor measures electrical conductivity that is affected by water content in the soil.

Sensors can be classified based on how they measure or detect physical phenomena, such as optical sensors, temperature sensors, humidity sensors, gas sensors, and many others. Sensors play an important role in *monitoring systems* because they provide accurate and real-time data, which can be used for a variety of applications, from home automation to smart farming and environmental management (Mahendra et al., 2024). Here is a more detailed explanation of the types of sensors used:

a. DHT11 Sensor
   The DHT11 sensor is used to measure air temperature and humidity. This sensor is designed for applications with low power consumption, high stability, and compatibility with IoT-based systems. The DHT11 has a measurement accuracy of ±1°C for temperature and ±5% for relative humidity, making it an ideal choice for real-time environmental monitoring applications. The data generated by this sensor is used to determine air conditions in the plant area, which directly affect physiological processes such as photosynthesis and respiration. With this data, users can monitor air temperature and humidity consistently, as well as adjust actions such as the use of automatic sprinklers (Fathulrohman & Saepulloh, 2019).

b. Soil Moisture Sensor
   Soil moisture sensors are used to measure soil moisture levels. The working principle of this sensor is based on the electrical conductivity of the soil, where the soil resistance value changes according to its water content. When the soil is dry, the resistance increases, while when the soil is wet, the resistance decreases. This sensor provides accurate data on soil conditions, helping farmers manage the water needs of plants. With consistent monitoring, the system can help prevent overwatering which causes water waste or under-watering which can inhibit plant growth (Putra et al., 2021).

c. PIR (*Passive Infrared*) Sensor
   PIR sensors are used to detect human or animal movement around the device. PIR detects changes in infrared radiation emitted by moving objects, making this device very effective in identifying activity around the monitoring area (Tempongbuka & Sompie, 2015).

2.2 *Liquid Crystal Display* (LCD)

Liquid Crystal Display (LCD) is a display technology that uses liquid crystals to display information. LCD works by changing the orientation of the liquid crystals under the influence of an electric field to modulate the light passing through the screen. One of the main advantages of LCD is its low power consumption compared to other display technologies, such as *Cathode Ray Tube* (CRT) or *Light Emitting Diode* (LED) (Ridarmin, 2019).

LCDs are widely used in various electronic devices, such as televisions, computer monitors, and portable devices due to their ability to produce high-quality images and good energy efficiency. LCD modules can display a variety of information, including numbers, letters, and symbols, in a format that is easy for humans to read. LCDs are generally used in applications where important information needs to be displayed directly on the device, such as monitoring temperature, humidity, and system status (Sejati & Anshori, 2019).

2.3 Thinger.Io

Internet of Things (IoT) is a concept that connects various physical devices to the internet, allowing them to communicate with each other and share data without requiring direct human intervention. IoT involves the use of sensors, devices, and digital platforms to collect, manage, and analyze data generated by connected devices (Selay et al., 2022).

IoT enables real-time automation and monitoring in various fields, such as agriculture, health, transportation, and smart homes. Using this technology, connected devices can exchange information with each other and adapt to existing conditions without human intervention. In agriculture, IoT is used to monitor environmental conditions, crops, and irrigation, which helps in more efficient and productive management (Erwin et al., 2023(.

Thinger.IO is an IoT platform that provides solutions to connect and manage IoT devices easily and efficiently. This platform allows devices to communicate over the internet and allows users to monitor and control devices remotely. Thinger.IO supports various types of devices and sensors, such as temperature, humidity, and motion sensors, which can be integrated into IoT-based applications (Raharaja, 2021).

Thinger.IO provides an intuitive user interface, allowing users to access sensor data in real-time via a web application or smartphone. The platform offers a variety of features, including data storage, graphical visualization, and setup and management of connected devices. One of Thinger.IO's strengths is its ease of integration with various hardware and communication protocols, such as Wi-Fi, Bluetooth, and others, making it an excellent choice for IoT implementations in various fields, including smart agriculture (Raharaja, 2021).

2.4 NodeMCU

NodeMCU is an ESP8266 microcontroller-based development platform designed to simplify the creation of Internet of Things (IoT) devices. NodeMCU is an open-source project that provides firmware with support for the Lua programming language and a development board with a user-friendly interface. The platform comes with built-in Wi-Fi connectivity and supports a variety of communication protocols such as I2C, SPI, and UART. NodeMCU also features GPIO (General Purpose Input/Output) to control hardware, making it a popular choice for a variety of IoT applications. With extensive documentation and a large user community, NodeMCU is suitable for both beginners and experienced developers.

The ESP8266 is the core of NodeMCU. The ESP2866 is a low-cost Wi-Fi microcontroller developed by Espressif Systems. It is designed to enable electronic devices to connect to a Wi-Fi network without the need for additional controllers. The ESP8266 is equipped with a Tensilica Xtensa L106 32-bit RISC processor with a speed of up to 160 MHz, 64 KB of RAM, and up to 4 MB of Flash capacity, depending on the model. In addition, the ESP8266 has low power consumption and supports network protocols such as TCP/IP and HTTP. Due to its flexibility, the ESP8266 is often used in applications such as smart home systems, cloud-based sensors, and other automation devices.

NodeMCU and ESP8266 are an ideal combination for IoT project development. NodeMCU leverages the capabilities of ESP8266 to provide a more practical and user-friendly development platform. With its small size, reliable connectivity capabilities, and power efficiency, ESP8266-based NodeMCU has become a popular solution for small to medium-scale IoT projects (Doni & Rahman, 2020).

2.5 ADDIE Development Model

The ADDIE model is a framework used in the development of instructional design and technology systems. ADDIE is an acronym for the five main stages that make up the development process, namely Analyze, Design, Develop, Implement, and Evaluate. The ADDIE development model can be seen in Figure 1.

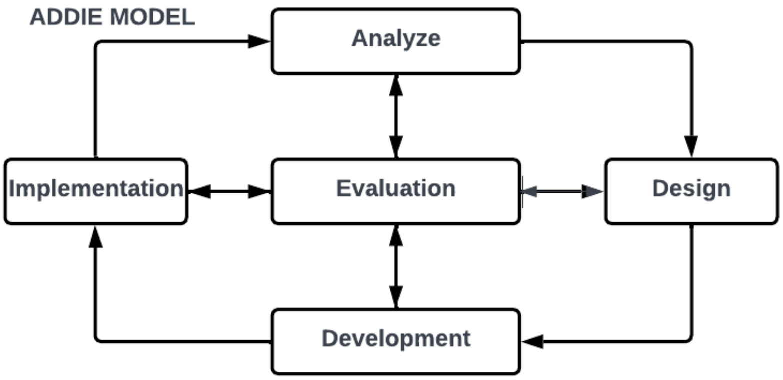

Figure 1: ADDIE Model Development Research Design

The explanation of the ADDIE components is as follows (Cahyadi, 2019):

a. *Analyze*
The first stage in ADDIE is to analyze the needs and determine the objectives of the system development. At this stage, the problem to be solved is identified and stakeholders are involved to set criteria and expectations.

b. *Design*
The design phase involves creating a clear plan of the system components, interfaces, and interactions needed to meet the needs that have been analyzed.

c. *Develop*
At this stage, a system prototype is built based on the design that has been made. During this stage, system components such as hardware and software are developed and tested to ensure functionality.

d. *Implement*
Implementation involves applying the developed system into a real environment and testing its performance in the field.

e. *Evaluate*
The evaluation stage is carried out to assess the effectiveness of the system and provide feedback that can be used for further improvement. Evaluation can be done through trials, collecting user data, and analyzing the results obtained.

3 Results and Discussion

monitoring tool using the ADDIE development model has produced an effective system in monitoring various environmental parameters such as temperature, air humidity, soil moisture, and movement detection around the tool. This tool integrates the DHT11 sensor, soil moisture sensor, and PIR sensor, and displays data through the IoT Thinger.IO platform. The following are the results and a more in-depth discussion regarding each stage of tool development based on the ADDIE model.

3.1 *Analyze* (Analysis)

The first stage of the ADDIE model is analysis, which will be carried out by researchers at this stage is to conduct a needs analysis and task analysis. The ADDIE development model begins the process by analyzing the need to create a new product. This analysis includes an evaluation of the deficiencies or incompatibilities of existing products with user needs and technological developments. In addition, this stage also aims to determine the feasibility and technical requirements needed in developing new products (Akhlak, 2024).
This analysis stage involves the use of the SWOT method, needs analysis to identify problems and determine the specifications of IoT-based plant *monitoring tools* .

Table 1: SWOT analysis of IoT-based plant *monitoring tools*

Analysis Category	Analysis
STRENGTH **(Strength)**	Can increase food productivity by automatically *monitoring temperature, soil and air humidity using the IoT system.*
WEAKNESS **(Weakness)**	For efficient non-stop use, integration with WiFi is required, which means that production will involve routine costs.
OPPORTUNITY **(Opportunity)**	This tool has the opportunity to be used on a large scale so that it can produce good results
THREADS **(Threat)**	Because it uses third-party assistance in the IoT system, control is not entirely in the hands of the developer.

3.2 *Design*

Media development design is the process of studying problems and then designing alternative solutions. This study aims to develop an IoT-based plant *monitoring tool* . The flow of making a garden *monitoring tool* carried out in this study can be seen in Figure 2.

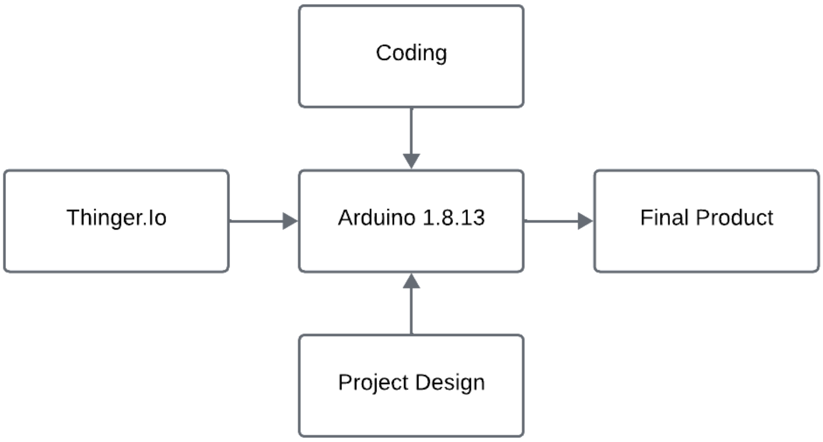

Figure 2: Design Flow of Development of IoT-Based Plant *Monitoring Tool*

In this study, researchers used several development flows, namely designing *the project* , preparing thinger.io, applying coding combined in Arduino 1.8.13 using the NodeMCU Esp8266 *microcontroller* .

3.3 *Develop* (Development)

monitoring tool development flow , this development stage focuses on discussing the stages in detail. Tool development begins by combining the physical parts of the tool into a unit that researchers call *a design project.* This part is the main component containing the aesthetics of the tool. All electronic devices used are combined and can be seen in Figure 3.

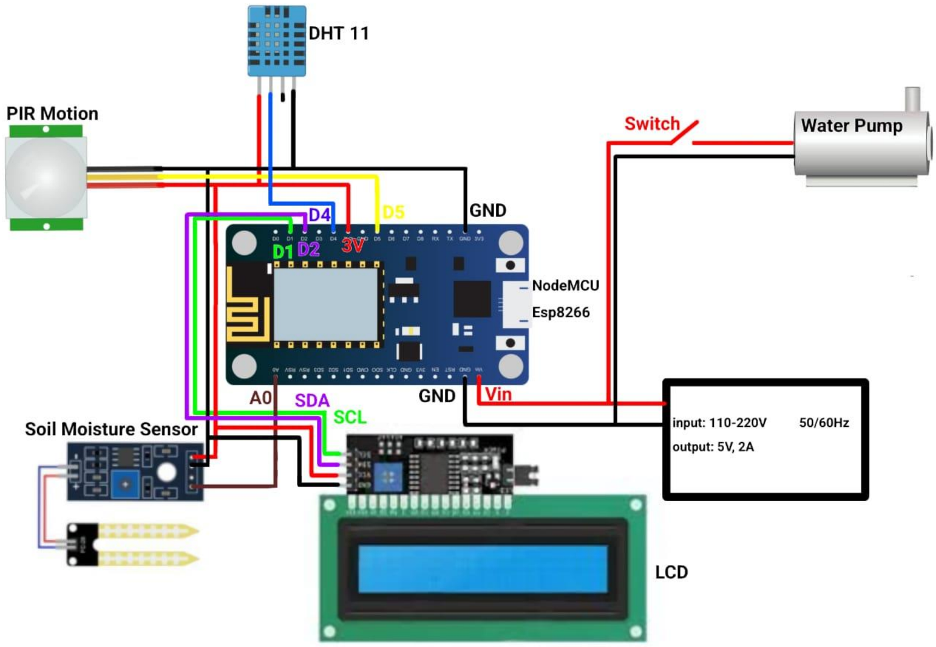

Figure 3: IoT-based Plant *Monitoring* Tool Design

monitoring tool uses a 5V 2A input voltage that can be output by the adapter. This voltage is the energy source to turn on the water pump with an input voltage of 3-5V and also becomes the energy source for the NodeMCU Esp8266 which is the brain in the sensors used. The positive cable on the adapter is connected to the Vin pin on the NodeMCU and is also branched to the switch that connects the positive DC water pump. The negative cable is connected to GND and branched to the negative part of the DC water pump.

NodeMCU Esp8266 works as the brain of the sensor, therefore all sensors will be connected to NodeMCU. The DHT 11 sensor is connected to the Digital (D) 4 pin on the NodeMCU. The PIR *Motion sensor* is connected to the D5 pin on the NodeMCU. The Soil Moisture sensor is connected to the Analog (A) 0 pin on the Node MCU. The SCL and SDA pins on the LCD are connected to the D1 and D2 pins on the NodeMCU. Finally, to flow the voltage to all sensors, the input pins of all sensors and the LCD are connected to the 3V output on the Node MCU and all sensors are connected to GND. After all the physical devices are arranged properly, the next step is to enter the coding stage which can be seen in Figure 4.

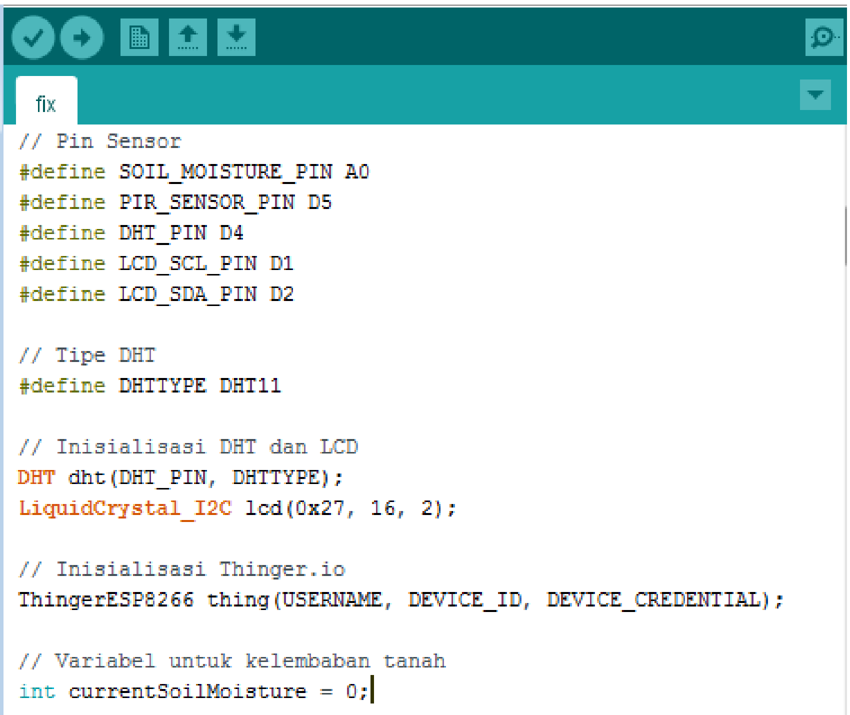

Figure 4: Stage *Coding* and Using Arduino 1.8.13 Applications

The next step is to create a code to run the command we want. The coding input is fully using the Arduino 1.8.13 application which of course uses additional *libraries* such as LCD, Thinger.Io, and NodeMCU Esp8266 Board. Most of the coding created is so that the tool can read sensors with good calibration, and with the right function.

The function of each component created in NodeMCU is:

a. DHT11 Sensor

The DHT11 sensor is used to measure the temperature and humidity of the air in the plant. Physically, this sensor is attached in the same room as the plant. In this study, the DHT 11 sensor is used to read the temperature in Celsius (C) and Air Humidity in percent. It should be noted that air humidity is the amount of water content in the air.

b. Soil Moisture Sensor

Soil moisture sensor is used to measure the level of soil moisture. This sensor is placed in a plant pot which functions to see the percentage of water content in the planting medium. The unit of this sensor in the developed tool is in percent (%).

c. PIR (*Passive Infrared) Sensor*

PIR sensors are used to detect human or animal movement around the device. The function of this sensor in the study is to automatically turn on the LCD when movement is detected near the device. On the LCD itself, the number 1 will be displayed if there is movement and 0 if there is no movement. When there is no movement within a period of 60 seconds, the LCD will automatically turn off.

d. *Liquid Crystal Display* (LCD)

The LCD functions to display all the reading results of the sensors that have been used. On the LCD, coding is given which refers to the position of the letter, the lighting of the letter and is also integrated with the coding of the sensor.

e. Iot System on Thinger.Io

Almost similar to the LCD function, the IoT system on thinger.io functions to *monitor* sensor reading results but remotely. By linking the features on thinger.io with the signals on NodeMCU, the system can be *monitored* properly. Please note that NodeMCU and Thinger.Io can be run with an SSID or WIFI connection located near the NodeMCU.

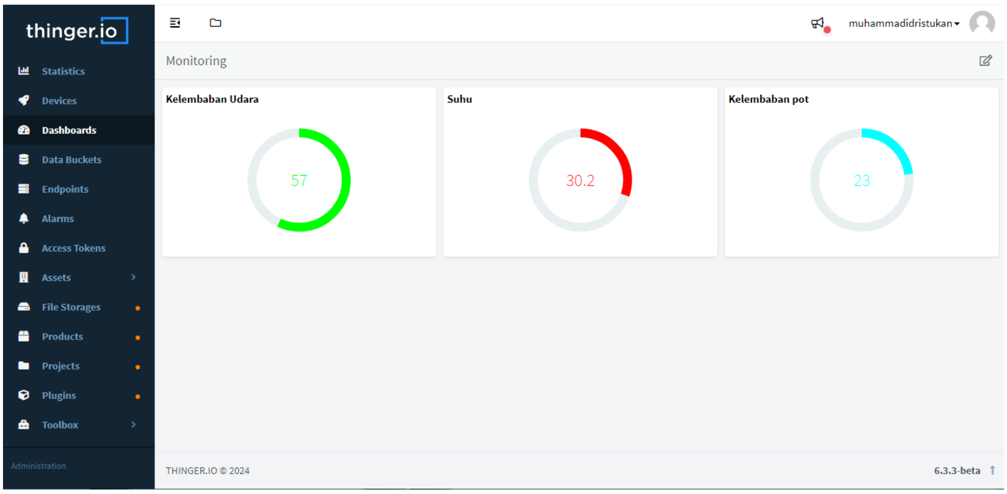

Figure 5: Thinger.Io *monitoring* display design

Figure 5 shows plant *monitoring* on the thinger.io wrb. There are quite a lot of features that can be used for free on the thinger.io web. In this study, researchers integrated the reading of air humidity, temperature, and pot humidity. To link thinger.io with the tool, it is necessary to have a special identity recognition that is entered into the coding, namely the thinger.io username, SSID and wifi password, and the definition of the right sensor.

3.4 *Implement* (Implementation)

The implementation stage of this IoT-based plant *monitoring tool* focuses on testing each sensor. There are three variables that will be seen for their success accuracy by comparing them with the android application and also the literature. On the DHT11 sensor there are 2 variables, namely temperature and air humidity. The results of the accuracy test on the DHT 11 sensor can be seen in Table 2 and Table 3.

Table 2: Results of air humidity sensor accuracy testing

Air humidity sensor (%)	Standard Module (%)	Success (%)	Error (%)
76	80	94.8	5.2
76	80	94.8	5.2
77	80	96.1	3.9
75	80	93.3	6.7

Table 2 shows the results of the humidity sensor (DHT 11) accuracy test by comparing the sensor reading values to the standard module (android). The sensor was tested at several humidity values and showed a high success rate, ranging from 93.3-96.1%. The resulting error rate is relatively small with a range of 3.9-6.7%. This shows that the IoT-based plant *monitoring tool* has quite good performance in reading temperature values.

Table 3: Temperature sensor accuracy test results

Temperature Sensor (C)	Standard Module	Success (%)	Error (%)
30.2	30	99.4	0.6
30.8	30	97.4	2.6
30.8	30	97.4	2.6
30.5	30	98.4	1.6

Table 3 contains the results of the temperature sensor accuracy test which shows that the success rate is very high, ranging from 97.4-99.4%. The resulting error value is relatively small, with a range of 0.6-2.6%.

The sensor successfully approached the standard module value (temperature read on Android) very well, indicating the optimal ability of the plant *monitoring tool* in detecting temperature. Both in the air humidity and temperature tests there were error values. The reason for the error in the sensor reading could be due to the difference in the tools used (Sugianto et al., 2020)

Table 4: Results of soil moisture sensor accuracy testing

Soil moisture sensor (%)	Standard Module (%)	Success (%)	Error (%)
21	21	95	5
21	21	95	5
22	22	95.1	4.9
22	22	100	0

Table 4 presents the results of the soil moisture sensor accuracy test by comparing the sensor reading values to the standard module. The standard module was taken from Fauziah's research (2022) with a percentage of 13-14% indicating dry conditions and a percentage of 21-22% indicating wet soil conditions. In the coa test with humidity values varying between 21% -22%, the sensor showed a success rate of 95-100% with an error rate of 0-5%. This shows that the *monitoring tool* has a fairly good ability to read soil moisture. The error percentage can be caused by sensor readings that have a delay time (Yuandari et al., 2021).

3.5 ***Evaluate*** (Evaluation)

There are weaknesses that must be considered in IoT-based plant *monitoring tools* that implement multisensors, namely noise. Noise is a disturbance that causes errors in sensor readings (Novianto et al., 2022). Therefore, further research is expected to solve the problem of noise in multisensors. In addition, it is a good idea to use a special SSID for the tool so that it can be used at any time without having to turn on the portable hotspot first.

4 Conclusion

monitoring tool using the ADDIE model produces a system capable of monitoring temperature, air humidity, and soil moisture with high accuracy, as well as detecting movement around the tool. This system utilizes the NodeMCU ESP8266 microcontroller to integrate data from various sensors, which are then visualized through the Thinger.IO platform. The trial results show that this tool has a high success rate in measuring environmental parameters, with a minimal error rate in each test. The implementation of this system allows for real-time and remote monitoring of plant conditions, providing a modern solution to support technology-based agriculture.

However, there are some limitations that need to be considered, such as the need for a stable internet connection for optimal operation and the potential for noise interference on the multisensor. To improve the performance of this tool, further research is needed to overcome these obstacles and test its effectiveness on a larger scale. Thus, this tool is expected to contribute to increasing the productivity of modern agriculture in Indonesia.

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