INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue I January 2026

Automated Greenhouse Climate Control Using DHT11 Sensor for Small Scale Plant Growth

Hania R. Ali, Jhenycis Matthew L. Buenafe, Carlo B. Cortezano, Joshua Miguel F. Gannaban, Meshelle N. Fabro

24 Kindful St. Sitio Veterans Brgy Bagong Silangan Quezon City

DOI: https://doi.org/10.47772/IJRISS.2026.10100174

Received: 12 January 2026; Accepted: 15 January 2026; Published: 29 January 2026

ABSTRACT

This study presents the design, development, and evaluation of an automated greenhouse climate control system using a DHT11 temperature and humidity sensor integrated with an ESP32 microcontroller. The system addresses the limitations of manual environmental monitoring in small-scale greenhouse applications by providing continuous, real-time sensing and automated regulation of critical environmental parameters. Temperature and humidity significantly influence plant growth, and unstabl vbce conditions may result in plant stress, reduced growth efficiency, and lower yields.

The proposed system continuously monitors greenhouse temperature and humidity and automatically activates a cooling fan, mist humidifier, and buzzer when predefined environmental threshold values are exceeded. The ESP32 processes sensor data and executes control decisions through a relay module, allowing timely adjustment of the greenhouse microclimate. The system was tested under multiple operational scenarios to evaluate sensor accuracy, actuator responsiveness, system reliability, and overall performance.

Environmental results demonstrated that the system responded consistently according to programmed conditions, with accurate detection of environmental changes and reliable activation of control devices. Data collected over a two-week observation period showed that the automated system successfully maintained temperature and humidity within plant-optimal ranges, Correspondingly, plant growth indicators, including leaf count and leaf length, exhibited a steady increase throughout the monitoring period.

The findings confirm that the DHT11-based automated greenhouse climate control system is effective in stabilizing environmental conditions, reducing the need for constant human intervention, and supporting healthy plants growth. The integration of low-cost components and simple control logic highlights the system's practicality and suitability for small-scale greenhouse applications, educational use, and resource-limited environments.

Keywords: Automated greenhouse, climate control system, DHT11 sensor, ESP32 microcontroller, temperature and humidity monitoring. small-scale agriculture

INTRODUCTION

Globally, an estimated 30–40% of greenhouse crops are affected by suboptimal temperature and humidity, resulting in reduced yields and wasted resources (Heryanto, Kusuma, & Hidayat, 2024). In a world where climate conditions are increasingly unpredictable, maintaining the ideal environment for plant growth has become a critical challenge for small-scale farmers. Greenhouses offer a controlled setting that can mitigate these obstacles, but sustaining optimal temperature and humidity levels is essential. Even minor fluctuations can stress plants, lower yields, and compromise crop quality. Traditional manual monitoring is labor-intensive, inconsistent, and often unreliable, underscoring the need for automated systems capable of maintaining stable and efficient greenhouse conditions.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue I January 2026

Recent advancements in sensor and microcontroller technologies have unlocked new possibilities for precision agriculture. Automated systems that continuously monitor environmental conditions and respond in real time have been shown to enhance plant growth, conserve resources, and reduce human error. Among these technologies, the DHT11 sensor is widely recognized for its accuracy in measuring temperature and humidity, making it highly suitable for greenhouse applications. Studies have demonstrated that automated climate control systems can stabilize internal conditions, optimize plant performance, and improve overall efficiency (Heryanto, Kusuma, & Hidayat, 2024; Tembhurne, Bhatkar, & Ikhe, 2022).

Inspired by these developments, this study introduces an Automated Greenhouse Climate Control System using a DHT11 sensor and an ESP32 microcontroller, designed for small-scale plant cultivation. The system continuously monitors temperature and humidity and automatically activates devices such as fans and humidifiers whenever the environmental thresholds are exceeded. By combining low-cost, real-time sensors with intelligent control logic, the system provides a practical, efficient, and accessible solution for students, hobbyists, and smallholder farmers.

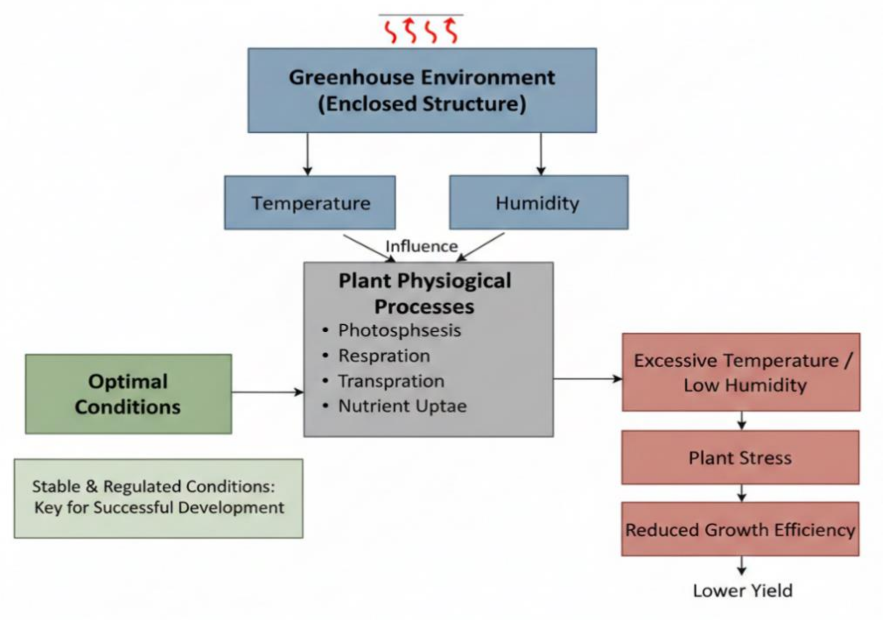
Through this prototype, the study contributes to the field of precision agriculture, demonstrating how affordable technology can support optimal greenhouse conditions, reduce labor requirements, and promote sustainable plant growth. The findings highlight the potential for sensor-based automation to revolutionize small-scale greenhouse cultivation, making advanced climate control achievable for a broader range of growers.

REVIEW OF RELEVANT THEORY, STUDIES, AND LITERATURE

This section presents the theoretical foundations and related studies that support the development and evaluation of the automated greenhouse climate control system. It discusses fundamental concepts in greenhouse climate regulation, temperature and humidity sensing, sensor-based automation, and prior technological and experimental research relevant to small-scale greenhouse applications.

Related Theories

Figure 1. Theory Of Greenhouse Climate and Plant Growth



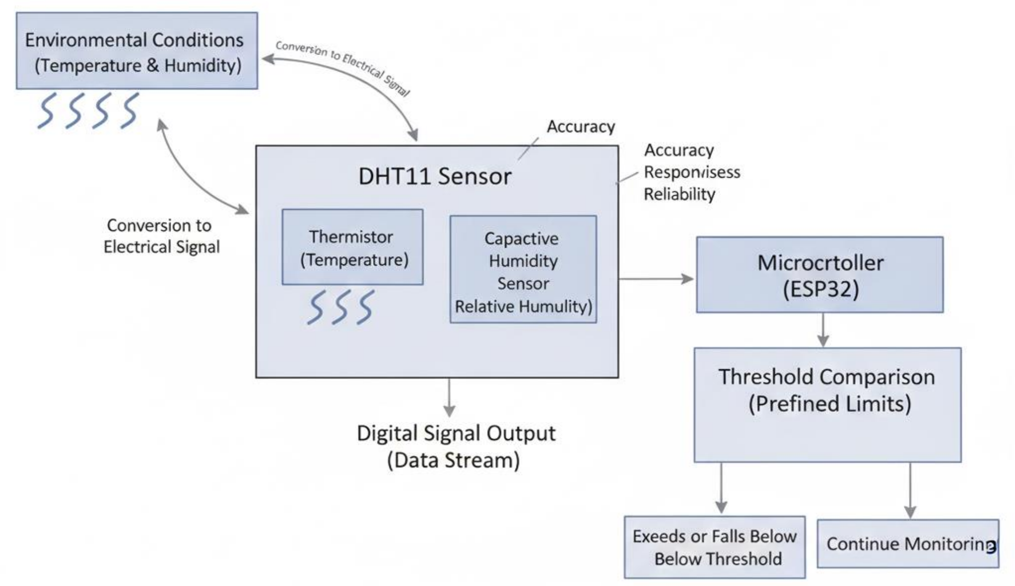
Greenhouse climate theory explains how controlled environmental conditions, particularly temperature and humidity, directly influence plant physiological processes such as photosynthesis, respiration, transpiration, and nutrient uptake. An enclosed greenhouse structure traps heat through the greenhouse effect, creating a microclimate suitable for plant growth. However, excessive temperature or insufficient humidity can lead to plant stress, reduced growth efficiency, and lower yields. According to plant physiology theory, maintaining

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue I January 2026

stable environmental conditions within optimal ranges is essential for healthy plant development, especially during early growth stages.

This theory supports the study's emphasis on continuous monitoring and regulation of temperature and humidity to maintain a stable microclimate conducive to small-scale plant growth.

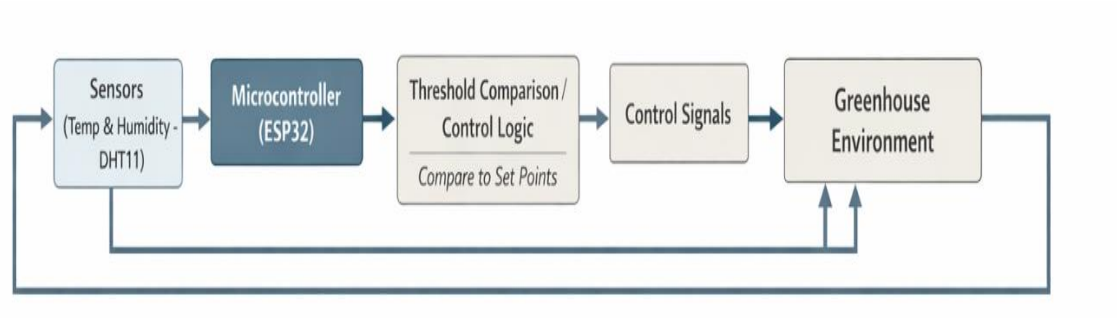
Figure 2. Temperature And Humidity Sensing Theory



Temperature and humidity sensing theory describes how environmental sensors detect physical changes and convert them into electrical signals that can be processed by a microcontroller. The DHT11 sensor operates using a thermistor for temperature measurement and a capacitive humidity sensor for relative humidity detection. Changes in environmental conditions alter the sensor's electrical characteristics, which are translated into digital values.

Threshold-based detection theory explains that predefined temperature and humidity limits are set to determine when corrective actions should occur. When sensor readings exceed or fall below these thresholds, the system triggers appropriate control devices. This theory underpins the evaluation of sensor accuracy, responsiveness, and reliability in monitoring greenhouse conditions.

Figure 3. Automated Climate Control And Feedback Theory



Automated control theory involves the use of feedback loops to maintain system stability. In greenhouse automation, real-time sensor data serve as input to the control system. The microcontroller compares these inputs with preset environmental thresholds and generates control signals to actuators such as fans and humidifiers.

This feedback mechanism ensures that deviations from optimal conditions are corrected automatically without continuous human intervention. The theory supports the system's design logic, demonstrating how real-time monitoring combined with automated actuation can stabilize greenhouse climate conditions efficiently.

Related Studies

Several studies support the effectiveness of automated greenhouse climate control systems. Heryanto, Kusuma, and Hidayat (2025) demonstrated that automated temperature and humidity control using sensor-based systems significantly improved environmental stability and crop productivity compared to manual monitoring. Their findings validate the importance of automation in mitigating environmental fluctuations inside greenhouses.

Tembhurne, Bhatkar, and Ikhe (2022) developed an automatic greenhouse monitoring system and reported improved plant growth and reduced labor requirements through real-time environmental control. Their work supports the use of microcontroller-based systems for efficient greenhouse management.

Mas et al. (2022) evaluated the accuracy of low-cost sensors in agricultural applications and found that the DHT11 sensor provided reliable temperature and humidity measurements suitable for small-scale greenhouse systems. This study supports the sensor selection used in the present research.

Duobiene et al. (2022) highlighted the role of IoT-based environmental monitoring systems in precision agriculture, emphasizing how real-time data collection and automated responses improve efficiency and sustainability. Their findings reinforce the integration of wireless data logging and automation in greenhouse systems.

Haller (2024) discussed the practicality of the DHT11 sensor in embedded applications, noting its affordability and ease of integration for educational and small-scale projects. While more advanced sensors exist, the study emphasized that the DHT11 remains suitable for applications where simplicity and cost-effectiveness are priorities.

Synthesis Of Literature

The reviewed theories and studies collectively emphasize that stable temperature and humidity are critical factors in successful greenhouse cultivation. Literature consistently shows that automated, sensor-based climate control systems outperform manual monitoring by providing consistent environmental regulation, reducing human error, and improving plant growth outcomes. Previous research confirms that low-cost sensors and microcontroller platforms can effectively support small-scale greenhouse automation when properly designed and calibrated.

However, many existing studies focus on larger or more complex systems, leaving a gap in affordable, educational, and small-scale greenhouse solutions. This study addresses that gap by evaluating a simple, low-cost automated greenhouse climate control system suitable for students, urban gardeners, and small-scale growers.

Theoretical Framework

The theoretical framework of this study is anchored on **Greenhouse Climate Theory**, **Temperature and Humidity Sensing Theory**, and **Automated Control and Feedback Theory**. These theories collectively explain how environmental conditions affect plant growth, how sensors detect temperature and humidity changes, and how automated systems regulate greenhouse climate.

In the framework, environmental conditions such as temperature and humidity serve as the independent variables. These are measured by the DHT11 sensor, which converts physical changes into digital signals. The ESP32 microcontroller processes these signals using predefined threshold values and control logic. When conditions exceed or fall below optimal levels, the system activates output devices such as the cooling fan, humidifier, and buzzer to restore suitable conditions.

The dependent variables of the study include environmental stability, sensor accuracy, system responsiveness, and plant growth indicators such as leaf count and leaf length. Environmental factors such as external temperature, airflow, and greenhouse size act as moderating variables that may influence system performance.

This framework guides the system design, experimentation, and analysis by illustrating the interaction between sensor inputs, control processing, and automated outputs. It provides a logical basis for evaluating whether the automated greenhouse climate control system can function as an effective, affordable, and practical solution for small-scale plant.

Importance And Relevance

The use of the DHT11 humidity and temperature sensor is highly relevant in greenhouse automation due to its accuracy, affordability, and adaptability to embedded systems. Maintaining environmental conditions within optimal ranges is crucial for plant health, affecting germination rates, nutrient absorption, transpiration, and overall growth. In small-scale and low-budget greenhouse setups, manual monitoring is often inconsistent and unreliable. “The DHT11 sensor is a fundamental component in the realm of sensor technology, offering a simple yet effective solution for measuring temperature and humidity” Haller, M. (2024). The integration of the DHT11 sensor enables continuous, real-time environmental measurement, ensuring that climate conditions remain stable and favorable for plant development.

The sensor’s application demonstrates the practical value of embedded systems in addressing real-world agricultural challenges. Its implementation supports sustainable farming practices by reducing energy and resource wastage while ensuring higher productivity. The relevance of this sensor extends to small communities, urban agriculture, and educational environments, where low-cost but effective automation is needed to optimize plant growth and promote technological innovation in agriculture.

Problem Statement

Small-scale greenhouse operators, students, and urban gardeners often face difficulties in maintaining stable temperature and humidity levels, which are critical environmental factors influencing seed germination, nutrient uptake, and overall plant development. Manual monitoring and regulation of these parameters are labor-intensive, inconsistent, and prone to human error, frequently resulting in fluctuating greenhouse conditions that lead to plant stress, reduced growth efficiency, and lower yields. According to Nassar et al. (2018), effective monitoring of localized environmental conditions plays a significant role in improving plant survival and productivity. Despite the availability of low-cost sensors and automation technologies, many small-scale users lack the technical knowledge and resources required to implement automated greenhouse control systems. This gap highlights the need for a simple and affordable solution capable of continuously monitoring environmental conditions and automatically regulating greenhouse climate to maintain plant-optimal levels.

1. How accurate is the DHT11 sensor in measuring and monitoring temperature and humidity inside the greenhouse environment?

2. How effective is the automated control system in regulating greenhouse climate through the activation of fans and humidifiers based on real-time sensor data?

3. To what extent does the implemented system maintain stable and optimal environmental conditions over time as reflected in the collected greenhouse data

General And Specific Objectives

This study aims to design, develop, and evaluate an automated greenhouse climate control system that utilizes a DHT11 sensor to maintain optimal temperature and humidity conditions for plant growth. The system continuously measures and monitors the internal greenhouse environment by collecting real-time temperature and humidity data through the DHT11 sensor. Based on these sensor readings, a control mechanism is designed and implemented to automatically activate climate-regulating devices, such as a fan or a humidifier, whenever the measured values deviate from the predefined optimal thresholds. Furthermore, environmental data gathered during system operation are collected and analyzed to evaluate the effectiveness of the automated control system in maintaining stable and suitable greenhouse climate conditions.

Scope And Limitations

The scope of this study encompasses the design and implementation of an automated climate control system intended to regulate humidity and temperature within a small-scale greenhouse environment. The system incorporates a DHT11 sensor, an ESP32 microcontroller, and basic actuators such as a cooling fan and humidifier to sustain the desired environmental conditions. Data on humidity and temperature will be collected over a defined monitoring period to assess the system's accuracy, stability, and responsiveness. The study further includes a comparative evaluation of plant growth between the automated system and a manually regulated setup, using key growth indicators to determine relative effectiveness.

This research will not extend to the advanced factors. It is restricted to monitoring and controlling humidity and temperature alone, excluding other variables such as soil moisture, light intensity, and nutrient availability. The use of a small-scale greenhouse limits the generalizability of the results to larger or commercial greenhouse systems and not comparing a non-automated greenhouse environment. The system's performance is also constrained by the accuracy, calibration, and response characteristics of the DHT11 sensor and the operational capabilities of the ESP32 microcontroller. The project is intended for short-term observation of leafy vegetable growth under controlled conditions. However, the study is limited by the accuracy and sensing range of the DHT11 sensor, which provides lower precision compared to more advanced sensors. Additionally, the system does not include nutrient monitoring, nor does it implement advanced control algorithms such as PID. Furthermore, external weather conditions and other uncontrollable environmental factors may influence internal greenhouse conditions despite automation. Finally, the evaluation of plant growth is limited to a one-month duration, allowing only short-term observations rather than long-term developmental analysis.

METHODOLOGY

This study employed a prototype-based experimental approach to develop an automated greenhouse climate control system that maintains optimal temperature and humidity for small-scale plant growth. The system integrates environmental monitoring with automated device control, allowing real-time adjustments to maintain stable greenhouse conditions.

The prototype was built around an ESP32 microcontroller, which serves as the main controller. A DHT11 sensor continuously measured temperature and humidity inside the greenhouse. Controlled devices, including a fan, air humidifier, and buzzer, were connected through a relay module and programmed to activate when predefined temperature and humidity thresholds were met. Specifically, the controlled load would activate when the temperature reached 30 °C and the humidity dropped below 60%. Components were linked using male-to-female jumper wires, and the system was powered by a regulated 5V supply.

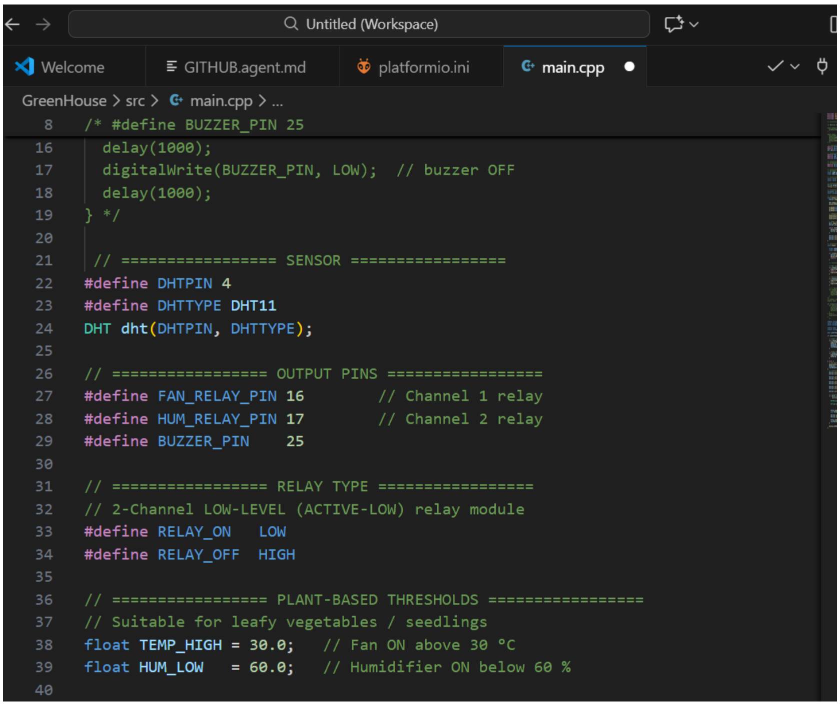
Programming of the ESP32 was done using PlatformIO. The program continuously monitored sensor readings and compared them with the programmed thresholds. Once these conditions were satisfied, the ESP32 triggered the relay module to operate the corresponding devices, adjusting the greenhouse environment to maintain suitable conditions for plant growth. Prior to full-scale testing, the system was trialed in a controlled environment to verify correct operation.

The system was evaluated under ten different scenarios, including startup, normal operation, activation of temperature and humidity controls, simultaneous operation of multiple devices, and system reset. Each scenario was repeated three times to ensure consistent performance. Performance was assessed based on accurate sensor readings, proper activation of controlled devices, and absence of false triggers.

All tests were conducted internally without external participants. Observations included sensor readings, device activation in response to programmed conditions, and resulting environmental changes, such as the stabilization of temperature and humidity within the greenhouse.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue I January 2026

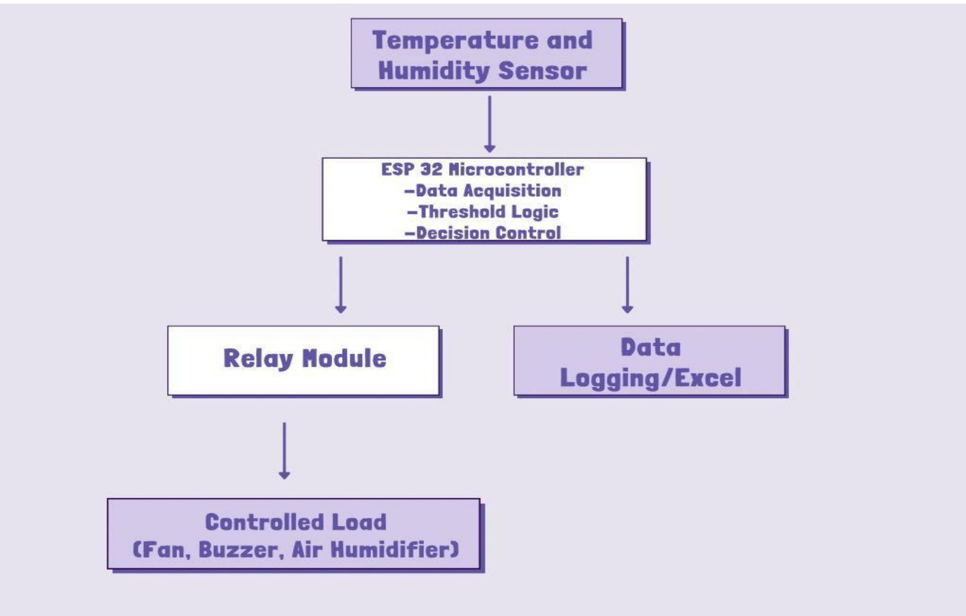
Figure 4. ESP 32 Source Code



```
/* #define BUZZER_PIN 25
  delay(1000);
  digitalWrite(BUZZER_PIN, LOW);  // buzzer OFF
  delay(1000);
} */

 // ================ SENSOR ================
#define DHTPIN 4
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

// ================ OUTPUT PINS ================
#define FAN_RELAY_PIN 16        // Channel 1 relay
#define HUM_RELAY_PIN 17        // Channel 2 relay
#define BUZZER_PIN    25

// ================ RELAY TYPE ================
// 2-Channel LOW-LEVEL (ACTIVE-LOW) relay module
#define RELAY_ON   LOW
#define RELAY_OFF  HIGH

// ================ PLANT-BASED THRESHOLDS ================
// Suitable for leafy vegetables / seedlings
float TEMP_HIGH = 30.0;   // Fan ON above 30 °C
float HUM_LOW   = 60.0;   // Humidifier ON below 60 %
```

It presents the ESP32 source code used in the implementation of the automated greenhouse climate control system. The program is responsible for acquiring temperature and humidity data from the DHT11 sensor, processing the measured environmental parameters, and comparing them with predefined plant-based threshold values. When the temperature reaches or exceeds the set limit, the ESP32 generates a digital control signal to activate the relay module that drives the cooling fan, thereby reducing the greenhouse temperature. Similarly, when the humidity level falls below the specified threshold, the controller activates the relay connected to the mist humidifier to increase moisture in the environment. In addition, the program triggers an audible alert through an active buzzer whenever abnormal temperature or humidity conditions are detected, providing real-time warning to the user. The code also establishes a WiFi connection and periodically transmits the measured data to Google Sheets for remote monitoring and logging. Overall, the program demonstrates how sensor-based analog data are converted into digital control actions, highlighting the ESP32's capability for real-time environmental monitoring, automated decision-making, and cloud-integrated control.

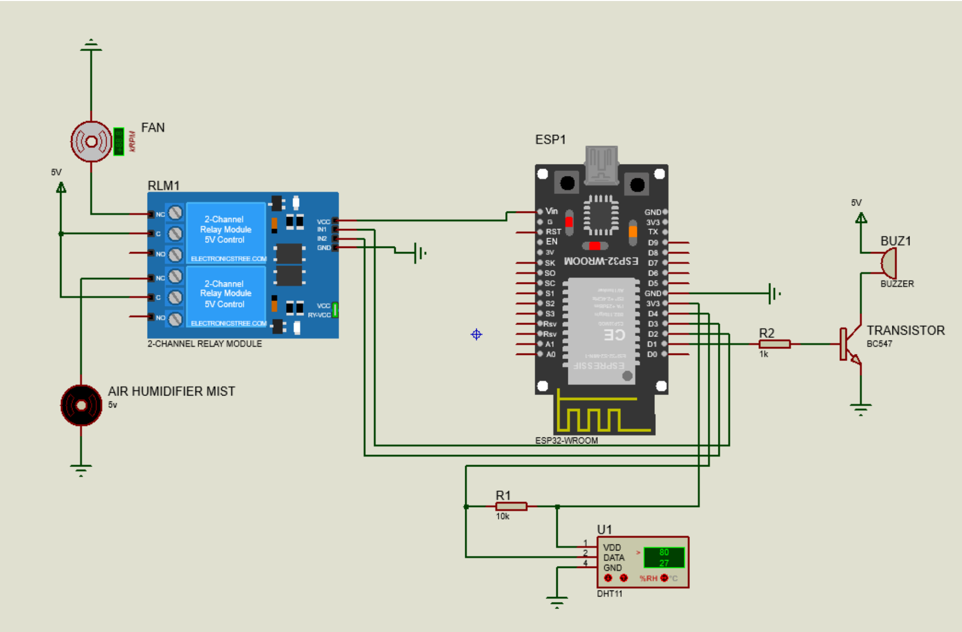
Figure 5. Block Diagram of Automated Greenhouse



ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue I January 2026

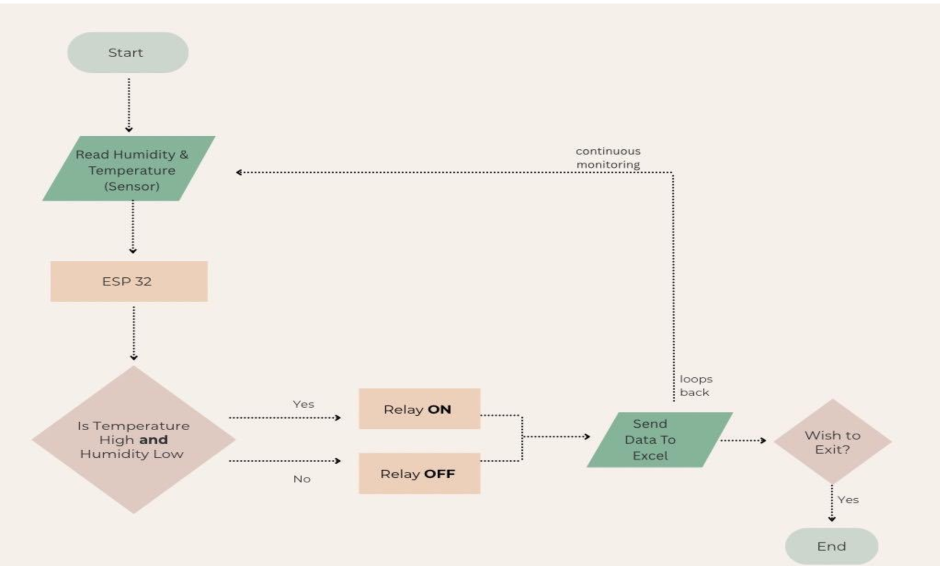
The block diagram illustrates the overall system architecture. The temperature and humidity sensor measures environmental conditions and sends the data to the ESP32 microcontroller. The ESP32 performs data acquisition, applies threshold logic, and makes control decisions. Based on the decision, the relay module controls the connected load such as a fan, buzzer, or air humidifier. At the same time, the processed data are sent to Excel for logging and analysis.

Figure 6. Schematic Diagram of Automated Greenhouse



It shows the schematic diagram of the greenhouse monitoring and control system designed using Proteus Professional. The system uses an ESP32-WROOM microcontroller as the main control unit. A DHT11 temperature and humidity sensor is connected to the ESP32 to monitor the environmental conditions inside the greenhouse. The microcontroller processes the sensor readings and compares them with the set temperature and humidity limits. A 2-channel 5V relay module is used to control the fan and the air humidifier mist. When the temperature becomes too high, the fan is activated, and when the humidity level becomes too low, the humidifier is turned on. A buzzer circuit with a transistor is added to provide an audible alert whenever the temperature or humidity goes beyond the normal range. The schematic also shows the proper connection of components and power supply to ensure safe and reliable system operation.

Figure 7. Flowchart and System Operation



The flowchart shows how the system works step by step. The process begins by measuring the temperature and humidity using a sensor. These values are then sent to the ESP32 microcontroller, which analyzes the data and checks whether the temperature is high and the humidity is low. Based on this condition, the system decides whether to turn the relay ON or OFF. After the decision is made, the sensor readings and the relay status are sent to Excel for monitoring and record-keeping. The system then repeats the same process to continuously monitor the environment, unless the user chooses to exit the system.

Tools & Software Used

The development and implementation of the automated greenhouse climate control system required the use of specific software tools and hardware resources to support system design, programming, simulation, and testing. PlatformIO was utilized for program development, compilation, and uploading of the control algorithm to the microcontroller. These environments provide reliable libraries for sensor integration and facilitate efficient debugging and validation of embedded system applications.

An ESP32 development board served as the central processing unit of the system. This platform was selected due to its compatibility with the DHT11 sensor, relay modules, and peripheral devices, as well as its suitability for real-time environmental monitoring and control applications. The board enabled continuous acquisition of temperature and humidity data and execution of control logic based on predefined threshold values.

Proteus simulation software was optionally employed to model and verify the circuit design before physical implementation. The use of simulation allowed for early detection of potential wiring and logic errors, reducing hardware risks and improving system reliability. The Serial Monitor was used during testing and evaluation to observe real-time sensor readings and system responses, enabling verification of correct data acquisition and control behavior.

A USB cable was used to establish communication between the microcontroller and the development workstation for program uploading and serial data transmission. Additionally, basic hand tools, such as screwdrivers and cutters, were utilized during the assembly and modification of hardware components to ensure proper physical connections and secure mounting.

Lastly, SolidWorks was employed for mechanical design and visualization of the greenhouse structure and component placement. This software facilitated the creation of accurate three-dimensional models, enabling assessment of spatial layout, airflow considerations, and enclosure design before physical construction. The integration of SolidWorks supported a systematic and well-documented design process, enhancing the overall quality and reproducibility of the research.

Components and Their Functions

Table 1. Variables and Conditions of Automated Greenhouse Climate Control

Component	**Function**
ESP32 Microcontroller	Serves as the central processing unit of the system. It reads sensor data, executes control logic, activates actuators, and transmits data wirelessly.
DHT11 Temperature and Humidity Sensor	Measures real-time temperature and humidity inside the greenhouse and provides stable digital output for monitoring and control.
Humidifier / Mini Fogger	Automatically activates when humidity falls below the set threshold to increase air moisture and maintain optimal plant growth conditions.
Cooling Fan	Activates when temperature or humidity exceeds predefined upper limits to reduce heat buildup and excess moisture within the greenhouse.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue I January 2026

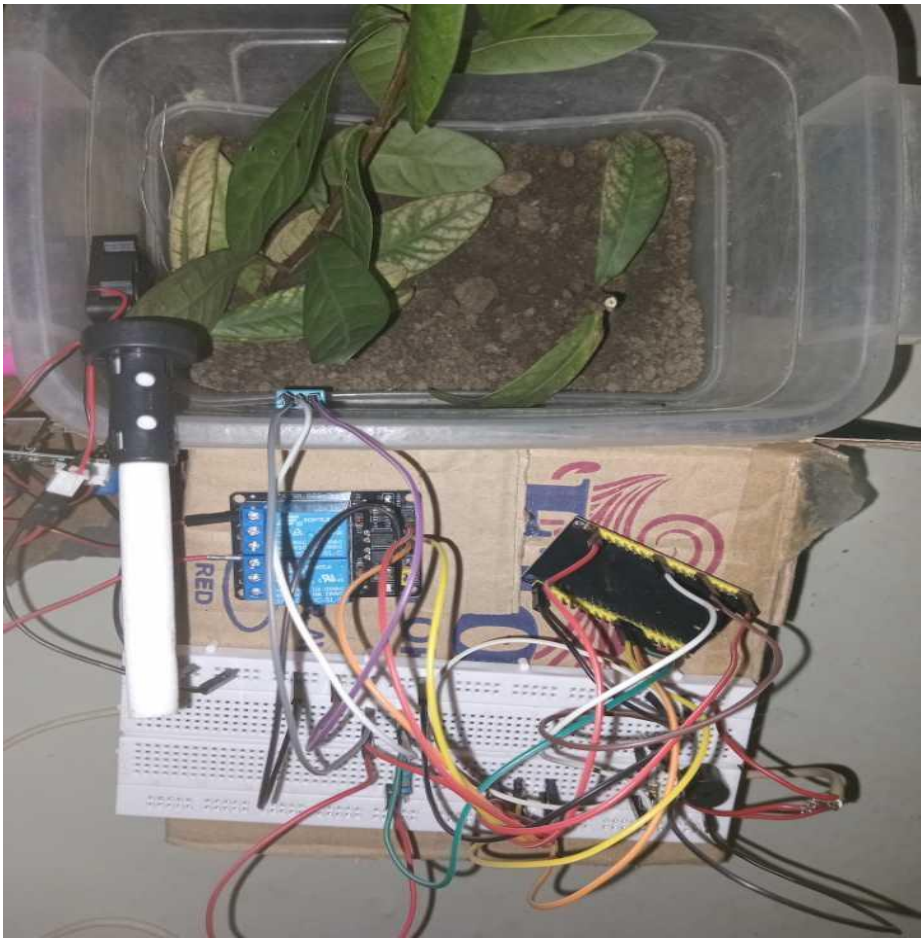
Relay Modules (1–2 Channels)	Provide electrical isolation and safely switch high-current devices such as the fan and humidifier, controlled by ESP32 GPIO pins.
Wires, Jumper Cables, Breadboard / PCB	Enable electrical connections and proper circuit integration among all system components.
Greenhouse Prototype (Acrylic/Plastic Enclosure)	Encloses the plants and creates a controlled microclimate for effective environmental regulation.

Development & Implementation Steps

The development and implementation of the automated greenhouse climate control system were conducted following a structured research methodology. Initially, system requirements were analyzed to determine the appropriate hardware and software components necessary for monitoring and controlling greenhouse environmental conditions. The DHT11 sensor was selected for temperature and humidity measurement due to its cost-effectiveness and availability. A microcontroller was then configured to process sensor data and execute control decisions based on predefined environmental thresholds. The sensor and actuators were interfaced through relay modules to enable automatic activation of cooling and humidifying devices.

Subsequently, the system software was developed to acquire environmental data continuously, compare sensor readings against threshold values, and trigger corresponding control actions. The program logic was validated through iterative testing to ensure accurate sensor readings and reliable actuator responses. After successful validation, the system was deployed in a small-scale greenhouse setup under controlled conditions. Data collection was conducted over a defined observation period to assess system performance and stability. The implementation process emphasized repeatability and reliability to support systematic evaluation of the automated climate control system's effectiveness in maintaining suitable conditions for small-scale plant growth.

Figure 8. Actual Picture of the Automated Greenhouse



SolidWorks was used to design the physical structure of the automated greenhouse system. The software provided a clear visual representation of the actual device, including the arrangement and placement of the microcontroller, sensor module, relay unit, and other components. This design served as a reference for the physical assembly of the system.

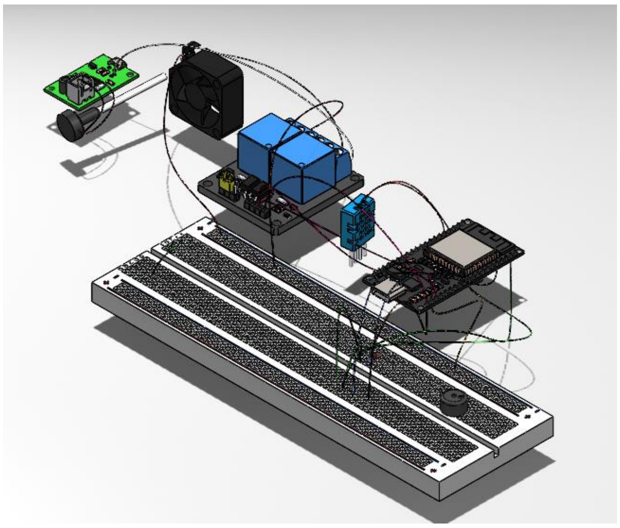


Figure 9. SOLIDWORKS Assembly

RESULTS & DISCUSSION

The automated greenhouse climate control system was evaluated through a series of structured experimental tests designed to assess its functional accuracy, operational reliability, and response behavior under varying environmental conditions. The testing procedures were conducted by subjecting the system to controlled temperature and humidity variations representative of typical greenhouse environments. Particular emphasis was placed on verifying the performance of the DHT11 sensor, the effectiveness of the actuator control mechanisms, and the reliability of the alert system. The results of these evaluations were systematically recorded and organized into tabular form to enable objective comparison between expected system behavior and observed outputs. The observed system performance and plant growth trends are consistent with findings from previous studies on automated greenhouse climate control, which reported improved environmental stability and enhanced plant development through sensor-based automation (Heryanto et al., 2025; Tembhurne et al., 2022).

Table 2. Sensor, Actuator, and Alert System of the Automated Greenhouse Climate Control

Test #	Input Condition	Observed Output	Expected Output	Pass/Fail	Remarks Explanation
1	System power ON	Stable sensor readings displayed	Sensor initializes correctly	Pass	Slightly delayed to proceed in sheets
2	Continuous operation (1 hr)	No false triggering observed	Stable system behavior	Pass	Provide a much better power bank
3	Humidity above 70 %	Mister OFF, buzzer OFF	Mister and buzzer OFF	Pass	System correctly detected high humidity and disabled mister and buzzer as programmed
4	Humidity between 60–70 %	Mister OFF, buzzer OFF	Mister OFF, buzzer OFF	Pass	System maintained safe state by keeping mister and buzzer OFF within the acceptable humidity range

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue I January 2026

5	Humidity ≤ 60 %	Mister and buzzer ON	Mister ON, buzzer activated	Pass	Low humidity was accurately detected, activating the mister and buzzer as intended
6	Temperature below 30 °C	Fan and buzzer OFF	Fan OFF, buzzer OFF	Pass	System correctly identified normal temperature and kept fan and buzzer OFF to conserve power
7	Temperature ≥ 30 °C	Fan and buzzer ON	Fan ON, buzzer activated	Pass	High temperature condition was detected, activating the fan and buzzer for cooling and alert
8	Both conditions reach the threshold	All outputs ON	Fan, mister, buzzer ON	Pass	System successfully handled simultaneous conditions by activating all required outputs
9	Normal conditions restored	All outputs OFF	Fan, mister, buzzer OFF	Pass	Outputs were properly deactivated once environmental conditions returned to normal levels
10	Power reset	Safe system restart	System restarted normally	Pass	System rebooted successfully and resumed normal operation without data loss or errors

Table 4. Variable and conditions of the Automated Greenhouse Climate Control System

Variable / Component	Type (Input / Output)	Parameter Measured / Controlled	Condition or Range	System Response / Action
DHT11 Sensor	Input	Measures temperature and humidity	Temperature: 20–35 °C; Humidity: 20–80 %	Sends temperature and humidity to microcontroller
Microcontroller (ESP 32)	Controller	Processes sensor data and executes control logic	Operates at 5V / 3.3V logic; continuous loop	Reads sensor values, compares thresholds, controls outputs
Air Humidifier Mist	Output	Controls humidity level	ON when humidity ≤ 60 %; OFF when > 60 %	Increases air moisture inside greenhouse
Fan	Output	Controls air circulation and temperature	ON when temperature ≥ 30 °C; OFF when < 30 °C	Reduces greenhouse temperature
Buzzer	Output	Audible alert indicator	Activated when temperature or humidity exceeds threshold	Alerts user of abnormal conditions
Relay Module	Output	Switches high-power	HIGH / LOW digital	Activates fan, and air

	Interface	devices	signal	mister
Power Supply	Power Source	Supplies power to system components	5 Volts	Ensures stable operation of sensors and actuators
Variable / Component	Type (Input / Output)	Parameter Measured / Controlled	Condition or Range	System Response / Action

The experimental evaluation results indicate that the automated greenhouse climate control system consistently performed in accordance with its design specifications. The temperature and humidity control mechanisms responded appropriately to environmental changes, while the alert system reliably provided notification during critical conditions. The observed outputs closely aligned with the expected responses across all test scenarios, demonstrating stable and dependable system operation. These findings validate the effectiveness of the implemented control strategy for maintaining suitable greenhouse conditions for small-scale plant growth and confirm the system's suitability for low-cost agricultural automation applications.

Table 5. Two-Week Average Greenhouse Conditions and Observed Plant Growth

Days	Average Humidity	Average Temperature	Leaves Count	Leaves Length
1	68.8	29.22	2	2.1
2	74.38	29.15	2	2.4
3	60.1	30.35	2	2.8
4	59.7	29.3	3	3.3
5	57.6	30.12	3	3.7
6	57.45	30.10	4	4.2
7	65.06	29.09	4	4.5
8	66.55	28.42	5	4.9
9	65.8	29.46	5	5.4
10	66.5	28.5	5	5.8
11	71	29.21	5	6.2
12	73.75	29.3	6	6.7
13	70.35	30.38	6	7.3
14	71.9	29.3	7	7.9

The temperature and humidity values presented in Table 3 represent the daily average environmental conditions recorded inside the greenhouse, while plant growth was evaluated using leaf count and average leaf length measurement

Analysis and Interpretation

The experimental results indicate that the automated greenhouse climate control system performed reliably and consistently across all test scenarios. Sensor readings from the DHT11 were stable and closely aligned with expected environmental values, allowing accurate detection of temperature and humidity changes. The system successfully activated the fan, humidifier, and buzzer based on predefined threshold conditions, demonstrating effective decision-making by the ESP32 microcontroller.

Based on the 14-day monitoring period, the automated greenhouse climate control system maintained environmental conditions within the defined operational ranges. Average temperature values remained between approximately 28.4 °C and 30.4 °C, while average humidity ranged from 57.4 % to 74.4 %. These values align with the working range of the DHT11 sensor and the programmed plant-based thresholds implemented in the ESP32 microcontroller.

Plant growth data showed a consistent upward trend. Leaf count increased steadily from 2 leaves on Day 1 to 7 leaves by Day 14, while leaf length increased from 2.1 cm to 7.9 cm. This gradual and continuous growth suggests that the controlled temperature and humidity environment provided favorable growing conditions.

The two-week environmental data showed that temperature and humidity were maintained within optimal ranges for leafy vegetable growth. Correspondingly, plant growth indicators such as leaf count and leaf length increased steadily throughout the observation period. These results suggest that maintaining stable environmental conditions through automation positively influences plant development. Overall, the system proved effective in minimizing environmental fluctuations and supporting healthy plant growth in a small-scale greenhouse setting.

Problems Encountered & Solutions

Several technical issues were encountered during system implementation and testing. Initial sensor instability caused repeated DHT11 read errors, particularly during startup. This was addressed by adding a sensor initialization delay and ensuring stable power delivery.

Another issue involved power inconsistencies when using a low-capacity power bank. During long operation, slight delays were observed in data transmission to Google Sheets. Replacing the power source with a higher-capacity power bank improved system stability, as reflected in the continuous operation test.

Relay logic issues were also encountered due to the use of a low-level (active-LOW) relay module. This was resolved by explicitly defining relay states in the code. Additionally, buzzer activation issues were corrected by ensuring the buzzer was triggered only when temperature or humidity thresholds were exceeded.

CONCLUSION

The automated greenhouse climate control system successfully monitored environmental conditions and responded appropriately to changes in temperature and humidity. Results from the 14-day plant growth data, system variable analysis and functional testing confirm that the ESP32-based control logic effectively regulated the greenhouse environment. Results confirm that the system accurately monitors temperature and humidity and effectively regulates greenhouse conditions through automated control of fans and humidifiers. According to Widiono, S., & Tu, I. (2023). “Misting of plants in a greenhouse has an important role in maintaining the environmental humidity that plants need”. Using a DHT11 sensor to automatically regulate a fan and misting system in a greenhouse, temperature and humidity are reliably stabilized at crop-appropriate set points. The system reduced reliance on manual monitoring and supported consistent plant growth. Therefore, the proposed system is a practical, low-cost, and efficient solution for small-scale greenhouse automation.

This study evaluated an ESP32-based automated greenhouse system using environmental monitoring, actuator control, and alert mechanisms. Data collected over a two-week period showed stable temperature and humidity conditions, accompanied by consistent plant growth. Functional testing verified correct system behavior across multiple operating scenarios, including continuous operation and simultaneous threshold conditions.

RECOMMENDATIONS

Future improvements may include upgrading the DHT11 sensor to a more accurate alternative, namely the DHT22 or BME280. Implementing real-time data visualization and long-term cloud storage could enhance monitoring and analysis. Additional sensors, such as soil moisture and light intensity sensors, may further optimize plant growth. Future studies may include a comparative analysis between automated and non-automated greenhouse systems to strengthen both technical evaluation and educational outcomes. Conducting parallel observations of plant growth, environmental stability, and maintenance effort in automated versus manually controlled greenhouses would allow students to directly examine the advantages and limitations of automation. Testing the system across different plant species and extended growth periods is also recommended for broader validation.

ACKNOWLEDGEMENT

The researchers would like to express their sincere appreciation to Engr. Meshelle Fabro, PCpE, for her invaluable mentorship, professional guidance, and expert supervision throughout the completion of this study. Her academic insight, constructive feedback, and unwavering encouragement greatly contributed to the successful development and refinement of this research.

The researchers also extend their profound gratitude to Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST), particularly the Department of Computer Engineering, and the faculty members who provided the academic foundation, technical resources, and institutional support necessary for the realization of this project. The institution's continued commitment to research, innovation, and quality education played a crucial role in the advancement of this study.

Heartfelt appreciation is given to the families and friends of the researchers for their patience, emotional support, and constant motivation. Their encouragement and understanding served as a source of strength during challenging phases of the research process.

The researchers likewise acknowledge the contribution of modern digital and artificial intelligence tools, including ChatGPT, GitHub, and Consensus, which were utilized to support literature exploration, code development, version control, and research clarification. These tools enhanced productivity, improved organization, and supported informed decision-making throughout the study.

Above all, the researchers offer their deepest gratitude to the Almighty God for the wisdom, guidance, strength, and perseverance granted throughout this endeavor. This work is humbly dedicated to His glory, as every achievement made possible was through His divine grace.

REFERENCES

1. **British Geological Survey.** (2023, April 5). The greenhouse effect. British Geological Survey. https://www.bgs.ac.uk/discovering-geology/climate-change/how-does-the-greenhouse-effect-work/
2. **Duobiene, S., Ratautas, K., Trusovas, R., Ragulis, P., Šlekas, G., Simniškis, R., & Račiukaitis, G.** (2022). Development of wireless sensor network for environment monitoring and its implementation using SSAIL technology. Sensors, 22(14), 5343. https://doi.org/10.3390/s22145343
3. **Fabro, B. C., Caoile, A. D., & Gatdula, M. M. V.** (2025). Smart water dispenser: A safety system for preventing motor dry-run in water dispensing applications. International Journal of Research and Innovation in Social Science, 9(11), 3827–3838. https://doi.org/10.47772/ijriss.2025.91100298
4. **Haller, M.** (2024). DHT11 sensor: A comprehensive study on temperature and humidity sensor. International Journal of Scientific Research in Engineering and Management. https://doi.org/10.55041/ijsrem29310
5. **Heryanto, I., Kusuma, S. A., & Hidayat, M. N.** (2025). Sistem otomasi suhu dan kelembaban pada greenhouse berbasis sensor DHT22 dan mikrokontroler. Elprosys: Jurnal Sistem Kelistrikan, 12(2). https://doi.org/10.33795/elposys.v12i2.7521
6. **Jamaluddin, T. A. A., Nur, F. S., Tahir, S. M., Achmad, A. D., & Reskyanto, A.** (2025). Temperature and humidity control in a small-scale greenhouse in a tropical climate. Salaga, 6–10. https://doi.org/10.70124/salaga.v3i1.1815

7. **Mas, F., Suciyati, S., Pauzi, G., & Junaidi, J.** (2022). Smart greenhouse monitoring with soil temperature and humidity control on Internet of Things (IoT) based orchid plants. Journal of Energy, Material, and Instrumentation Technology. https://doi.org/10.23960/jemit.v3i3.111
8. **Nassar, J. M., Khan, S. M., Villalva, D. R., Nour, M. M., Almuslem, A. S., & Hussain, M. M.** (2018). Compliant plant wearables for localized microclimate and plant growth monitoring. NPJ Flexible Electronics, 2(1). https://doi.org/10.1038/s41528-018-0039-8
9. **Tembhurne, V., Bhatkar, M., & Ikhe, Y.** (2022). Automatic greenhouse environment monitoring and controlling system. International Journal of Research in Engineering, Science and Management, 5(12). https://journal.ijresm.com/index.php/ijresm/article/view/2472
10. **Widiono, S., & Tu, I.** (2023). Fuzzy logic implementation in Internet of Things technology for fogging greenhouse plants. International Journal of Engineering Technology and Natural Sciences. https://doi.org/10.46923/ijets.v5i1.205

ABOUT THE AUTHORS

Jhenycis Matthew L. Buenafe is a third-year Bachelor of Science in Computer Engineering student at Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST) – Manila. He is committed to understanding the dynamic evolution of modern technology and to developing a strong foundation in both hardware and software systems. This research represents an important milestone in his academic training and contributes to his continued professional growth in the field of computer engineering.

Hania R. Ali is an aspiring Computer Engineer currently pursuing a Bachelor of Science in Computer Engineering at Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST) – Manila. With a strong passion for innovation, she is particularly interested in SolidWorks modeling and circuit design and aspires to contribute to technological advancement through continuous learning and technical excellence.

Carlo B. Cortezano is an aspiring Computer Engineering student at Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST) – Manila. He has a keen interest in programming and software development and is driven to enhance his technical competencies through continuous learning and hands-on project experience. His involvement in this study reflects his dedication to applying theoretical knowledge to practical engineering challenges.

Joshua Miguel F. Gannaban is a third-year Bachelor of Science in Computer Engineering student at Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST) – Manila, Philippines. His academic interests focus on microcontroller-based systems and electronic circuit design. This study was conducted as part of his engineering coursework and reflects his growing expertise in embedded system applications.

Engr. Meshelle N. Fabro is a Professional Computer Engineer with extensive academic and industry experience. She has worked with leading technology companies such as Hewlett-Packard (HP) and IBM, where she specialized in systems and enterprise solutions. She currently serves as a Part-time Instructor in the Computer Engineering Department of the Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST), where she is actively involved in training and mentoring future engineers. Her professional interests include computer systems, VLSI design, artificial intelligence, and emerging technologies in computing.