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Developing and Implementing a Smart Greenhouse for AI Education: Effects on High School Students' Attitudes toward Artificial Intelligence

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Abstract

The integration of smart greenhouse technology into educational contexts offers an opportunity to enhance students' understanding of artificial intelligence (AI) and its applications. This study investigates the on students' attitudes toward AI technology. The smart greenhouse system utilizes microcontrollers, sensors, and Fuzzy Logic algorithms to and control environmental factors, particularly water and lighting systems, based on temperature detection through sensors. The system includes real-time data visualization via the Node-RED dashboard, enabling students to analyze and interpret the collected data effectively. This research was conducted with high school students who participated in project-based learning (PBL) activities centered on the smart greenhouse system. Post-learning surveys were administered to evaluate students' attitudes toward AI technology. The findings highlight the potential of incorporating smart greenhouse systems into educational settings to enhance AI literacy and inspire innovation among students. Furthermore, the study emphasizes the importance of hands-on learning experiences in fostering critical thinking and problem-solving skills, which are essential for future technological advancements. Additionally, the attitude assessment showed that 85.1% of students agreed or strongly agreed they understood DHT sensor principles, 88.8% acknowledged improved understanding of fuzzy logic, and 81.5% responded positively to using the Node-RED dashboard. The project also enhanced creativity (92.6%), problem-solving skills (85.2%), and technological proficiency (96.3%).

Keywords: Smart greenhouse, fuzzy logic, high school education, project-based learning

Introduction

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The integration of smart greenhouse technologies into educational contexts has become a novel approach to enhancing students' skills in technology and innovation, especially in an era where the Internet of Things (IoT) and Artificial Intelligence (AI) play crucial roles in various aspects of daily life. The use of smart greenhouses in education not only helps students understand technology but also fosters critical thinking, problem-solving skills, and the ability to apply knowledge effectively (Vishwakarma et al., 2020; Farooq et al., 2022). Smart greenhouse systems that utilize IoT and sensor technologies allow precise and efficient control of the greenhouse environment, such as temperature, humidity, and irrigation. These systems employ sensors to monitor key factors that affect plant growth, including soil moisture, temperature, and light levels in the growing area (Guo et al., 2015; Singh et al., 2024). The data collected from these sensors is transmitted to microcontrollers, which in turn control various devices within the greenhouse, such as irrigation and lighting systems (Vishwakarma et al., 2020). This integration of technology not only helps students learn theoretical concepts but also promotes hands-on learning, which is crucial for developing critical thinking and problem-solving abilities. This is particularly evident in project-based learning activities that emphasize real-world applications (Jackson et al., 2022; Huang et al., 2023). Such learning experiences not only enhance technology and science skills but also provide a deeper understanding of agriculture and resource management (Tawfeek et al., 2022). Previous studies have shown the positive impact of using smart greenhouses in education, particularly in the application of IoT technologies, which not only improve agricultural productivity but also expose students to the process of system design and development (Achour et al., 2021; Tawfeek et al., 2022). Research has demonstrated that smart greenhouses can be valuable tools for educating students about technologies related to smart agriculture (Rubanga et al., 2019)., with applications such as temperature control, humidity regulation, irrigation, and environmental monitoring (Farooq et al., 2022). The ability to develop smart greenhouse systems that autonomously regulate the environment within the greenhouse enables more effective learning. These systems facilitate structured and flexible learning, which can be adapted to various educational contexts, particularly in activities related to agriculture and science (Huynh et al., 2023; Singh et al., 2024). In virtual learning environments, the development of smart greenhouses that simulate scenarios through virtual reality (VR) technology has become a key tool for providing students with immersive learning experiences that help them understand complex systems (Huang et al., 2023). This is particularly true in STEAM (Science, Technology, Engineering, Art, and Mathematics) curricula, which integrate science and technology to foster analytical and creative thinking among students (Huang et al., 2023). Studies on the use of smart greenhouse technologies in education have also inspired innovation, as students can apply the knowledge they have gained to solve real-world problems (Ali et al., 2024). This is particularly relevant in the context of sustainable agriculture, which emphasizes the efficient use of resources and the reduction of unsustainable natural resource consumption (Tawfeek et al., 2022; Farooq et al., 2022). Numerous studies have highlighted the potential of smart greenhouses to advance agricultural technologies, such as irrigation control systems and plant disease monitoring using deep learning for disease prediction, which can be applied in educational settings through case studies or simulations (Guo et al., 2015; Singh et al., 2024). Furthermore, smart greenhouses provide students with opportunities to design and develop systems within these environments (Farooq et al., 2022). Thus, integrating smart greenhouses into high school education not only enhances students' knowledge in technology and agriculture but also develops critical thinking and problem-solving skills, which will have long-term implications for the development of technology and innovation across various professional fields (Rubanga et al., 2019; Huynh et al., 2023). In addition to developing technical skills, fostering a positive attitude toward Artificial Intelligence (AI) is essential in educational settings. As AI becomes increasingly embedded in everyday life, helping students understand both its potential and its limitations can demystify the technology and reduce apprehension (Long & Magerko, 2020; Katsantonis & Katsantonis, 2024). When students are introduced to AI through meaningful, hands-on applications such as smart greenhouse systems. They are more likely to view AI as a beneficial and empowering tool rather than as a threat. This can cultivate curiosity, ethical awareness, and a readiness to innovate, equipping students to responsibly engage with AI technologies in the future (Tuomi, 2018; Holmes et al., 2023). Moreover, fostering such attitudes toward AI can significantly enhance students' engagement with intelligent systems and broaden their perspectives on technology's role in society. When students interact with AI-driven smart greenhouses particularly those incorporating fuzzy logic, automated control, and real-time monitoring through tools like Node-RED dashboards. They are exposed to the real-world applicability of AI in solving complex agricultural problems (Farooq et al., 2022; Singh et al., 2023). These experiences not only strengthen their conceptual understanding but also build confidence and motivation to pursue innovation in AI-integrated environments. Cultivating these attitudes early helps prepare students to critically evaluate and ethically apply AI in future academic and professional contexts (Zawacki-Richter et al., 2019; Holmes et al., 2023).

However, despite the wealth of research on smart greenhouses, no studies have yet explored the integration of fuzzy logic conditions in smart greenhouse technology, particularly with the use of Node-RED dashboards to promote high school students' attitudes toward AI technology.

This study, therefore, proposes the design of an automatic irrigation and lighting control system using fuzzy logic principles, with real-time data displayed on a Node-RED dashboard. This system aims to enhance smart agricultural practices and teach high school students how to apply AI technologies, fostering a positive attitude toward AI while engaging them in hands-on learning. The integration of fuzzy logic and Node-RED into smart greenhouse systems can help improve agricultural efficiency and provide students with valuable insights into the practical applications of AI in modern technology.

■ Research Methodology

System Components

The system depicted in the image and code is designed to create an automated system using the DHT11 sensor to measure temperature and humidity in the environment. The data is processed by an Arduino microcontroller using a Fuzzy Logic algorithm to control devices such as a water pump, and a light bulb, and display real-time data on a Node-RED Dashboard. This system can be applied in various contexts, such as Smart Agriculture or Smart Home systems. The system consists of three main components: Input, Process, and Output, as shown in Figure 1 which are described below:

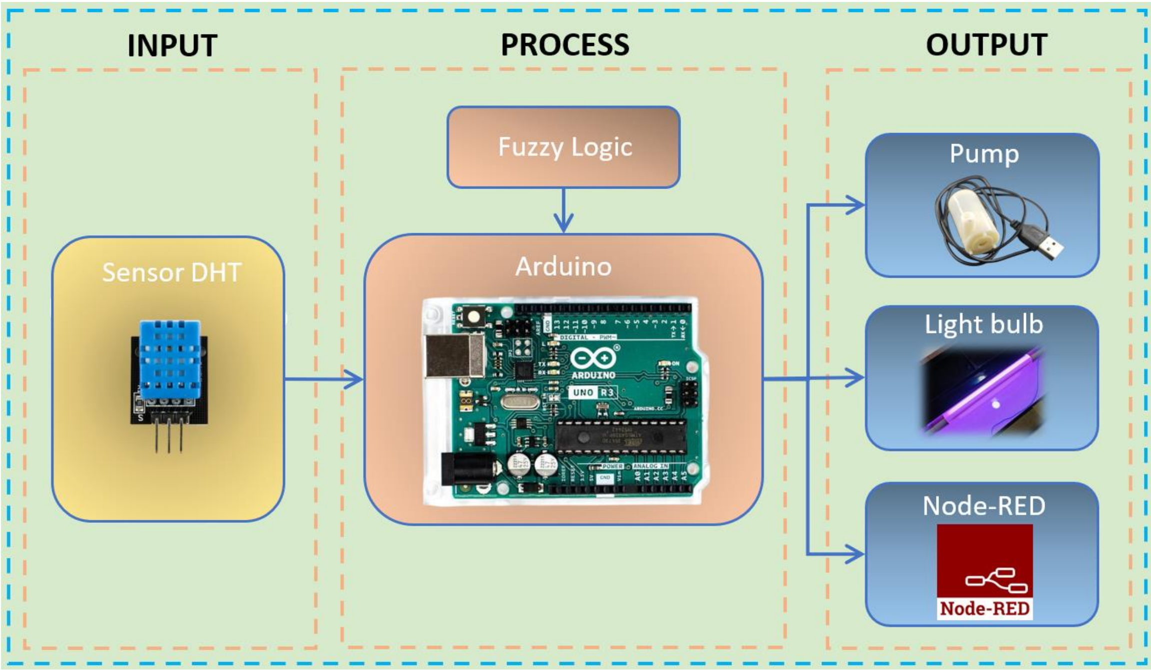

Figure *1.* System Components of Smart Greenhouse

Input: The input component uses the DHT11 sensor, which is capable of measuring temperature and humidity. The data collected is sent to the Arduino microcontroller for further processing.

Process: The Arduino Uno microcontroller processes the temperature and humidity data received from the DHT11 sensor. The Fuzzy Logic algorithm is employed to evaluate the environmental conditions and determine the appropriate control signals for the output devices.

Output: The output component controls two devices

Water Pump: The operation of the water pump is controlled based on the specified temperature range.

Light Bulb: The light bulb operates in response to predefined temperature conditions.

Additionally, the data collected by the sensors and the results of the processing are displayed on a Node-RED Dashboard, enabling users to monitor the system's status in real-time. In the context of a smart greenhouse system, the Arduino code functions as the core logic responsible for environmental monitoring and automated device control. The system begins by configuring specific digital pins to serve as output controls for a water pump and a light bulb, while simultaneously initializing communication with a DHT11 sensor connected to the microcontroller. This sensor is tasked with measuring temperature and humidity within the greenhouse environment. Serial communication is also established at a baud rate of 9600, allowing real-time data monitoring via a serial interface. Within the main loop of the program, the system collects humidity and temperature data at two-second intervals. If the sensor fails to return valid numerical values, the program alerts the user via the serial monitor and halts further processing for that cycle to ensure the reliability of subsequent actions. Upon successful data acquisition, a conditional decision-making structure is executed to control the water pump and lighting based on the measured temperature. Specifically, if the temperature falls below 24°C, the system activates the light while keeping the water pump off, simulating early-morning or cooler conditions that may require supplemental heat. For temperatures between 24°C and 30°C, both devices are activated, maintaining optimal growing conditions. When the temperature exceeds 31°C, the water pump remains on to mitigate overheating, while the light is turned off to prevent additional thermal stress on the plants as shown in Figure 2. This logic enables the system to respond dynamically to environmental fluctuations, ensuring that internal conditions remain conducive to plant growth. The integration of real-time sensing, data validation, and automated control in this manner reflects a practical application of embedded systems in agriculture, promoting precision, efficiency, and sustainability in greenhouse management.

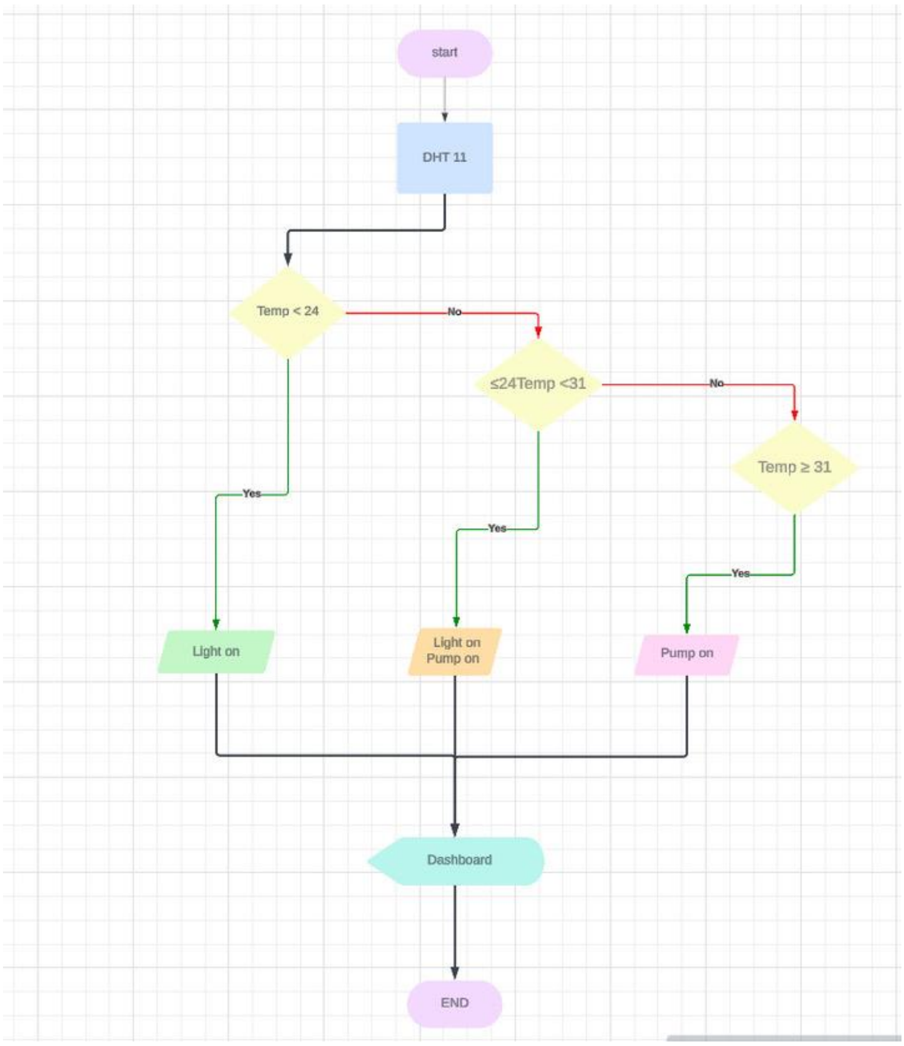

Figure *2.* Flowchart of Smart Greenhouse

Arduino Code for Smart Greenhouse

```
#include "DHT.h"
```

```
#define DHTPIN 2     // Digital pin connected to the DHT sensor
#define DHTTYPE DHT11   // DHT 11
DHT dht(DHTPIN, DHTTYPE);
void setup() {
  Serial.begin(9600);
  pinMode(5,OUTPUT);
  pinMode(6,OUTPUT);
  Serial.println(F("DHTxx test!"));
  dht.begin();
}
void loop() {
  delay(2000);
  // Reading temperature or humidity takes about 250 milliseconds!
  float h = dht.readHumidity();
  // Read temperature as Celsius (the default)
  float t = dht.readTemperature();
  // Read temperature as Fahrenheit (isFahrenheit = true)
  float f = dht.readTemperature(true);
  // Check if any reads failed and exit early (to try again).
  if (isnan(h) || isnan(t) || isnan(f)) {
    Serial.println(F("Failed to read from DHT sensor!"));
    return; }
  // Compute heat index in Fahrenheit (the default)
  float hif = dht.computeHeatIndex(f, h);
  // Compute heat index in Celsius (isFahreheit = false)
  float hic = dht.computeHeatIndex(t, h, false);
if(t < 24 ){
  digitalWrite(5,LOW);
  digitalWrite(6,HIGH);
}else if (t >= 24 && t <= 30){
  digitalWrite(5,HIGH);
  digitalWrite(6,HIGH);
}else if(t > 31){
  digitalWrite(5,HIGH);
  digitalWrite(6,LOW);
}
//  Serial.print(F("Humidity: "));
//  Serial.print(h);
```

```
// Serial.print(F("% Temperature: "));
 Serial.println(t);
// Serial.print(F("°C "));
// Serial.print(f);
// Serial.print(F("°F Heat index: "));
// Serial.print(hic);
// Serial.print(F("°C "));
// Serial.print(hif);
// Serial.println(F("°F"));
}
```

In the setup() function, the code configures pins *5* and *6* as output pins to control the water pump and light bulb, respectively. It also initializes the Serial Monitor with a baud rate of *9600* to display the values read from the sensor. In the loop() function, the system reads humidity and temperature values from the DHT*11* sensor using the functions dht.readHumidity() and dht.readTemperature(). If the values read are NaN (Not a Number), the system alerts the user via the Serial Monitor. The operation of the water pump and light bulb is controlled using conditional statements in the form of an if-else structure, which determines their functionality based on the temperature values read by the sensor. This approach ensures that the system responds dynamically to environmental conditions, providing a basis for automation in applications such as smart greenhouses or smart homes.

Implementation Phase

In this phase, students will work in groups, emphasizing Project-Based Learning (PBL), to create a prototype of a smart greenhouse capable of being controlled through IoT and AI technologies. Students will be assigned a challenging task to design a system with fundamental functions, such as monitoring temperature and humidity and controlling lighting within the greenhouse. This activity aims to demonstrate their understanding of the underlying principles of technology and their ability to address issues encountered during the prototype development process, as shown in Figure 3 and Figure 4.

Once the prototype is completed, each group will present their project to the class. During the presentation, students will explain their design process, system functionality, and project outcomes in an engaging manner. Classmates will have the opportunity to ask questions, provide feedback, or suggest potential improvements to the projects, promoting collaborative learning and fostering critical thinking. This process not only enhances communication skills but also develops analytical abilities and teamwork among students.

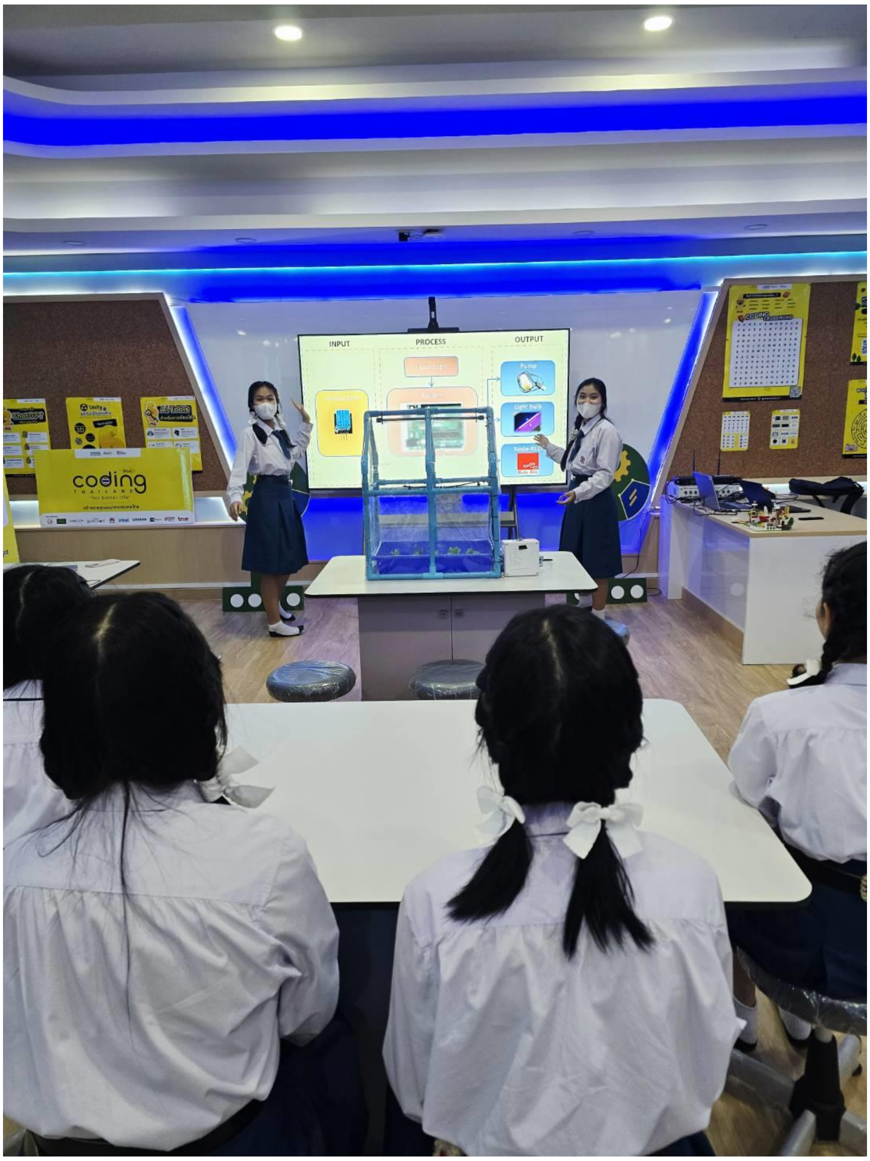

Figure *3.* Presentation of Project Example

After the presentations, a questionnaire will be distributed to collect data regarding students' attitudes toward AI technology. The questionnaire will assess aspects such as interest, confidence, and perspectives on using AI to solve real-world problems. The collected data will then be analyzed to evaluate how the project influences students' attitudes toward technology and whether it has the potential for further implementation or scalability in future educational activities.

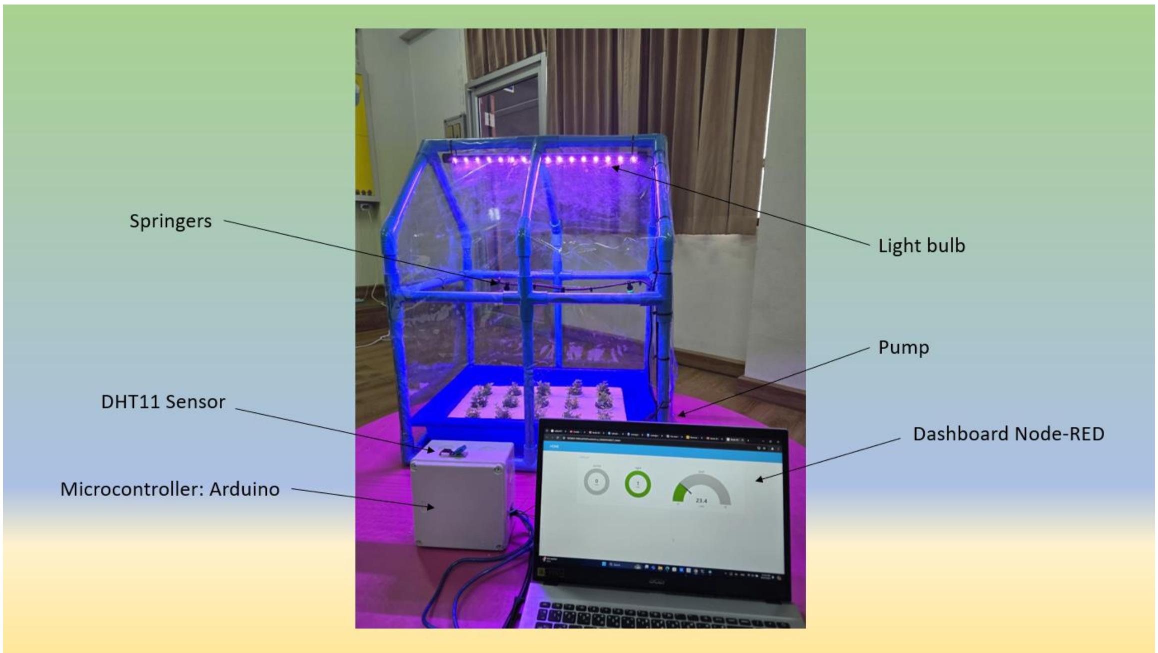

Figure *4.* Prototype of IoT Smart Greenhouse

Results

Basic Smart Greenhouse Control Testing

Testing the basic functionalities of a smart greenhouse control system is a crucial step to evaluate its ability to perform as designed. The following tests focus on assessing the system's core features.

Light Control: Test the operation of LED lighting within the greenhouse by turning it on and off via the control panel (Node-RED Dashboard or connected application). Verify that the system responds to commands immediately and that the lighting operates stably.

Temperature and Humidity Monitoring: Sensors such as DHT11 are used to measure the temperature and humidity inside the greenhouse. Ensure the data displayed on the control panel or dashboard is accurate and updated in real-time.

Water Pump Control: Test the operation of the water pump, such as automatic activation or deactivation based on predefined humidity levels. Check the precision and reliability of the sensors and water pump in maintaining the desired conditions.

IoT Connectivity and Responsiveness: Test the connectivity between the IoT system and control devices, such as the Node-RED Dashboard or MQTT Broker. Ensure the communication between hardware and software is fast, reliable, and accurate.

System Stability Test: Conduct long-term testing to ensure the system operates continuously and that all components function without issues over time. These tests are essential to confirm that the smart greenhouse system is fully functional, reliable, and capable of meeting user requirements effectively.

Table 1.

Fuzzy Logic Control Rules for Smart Greenhouse Operations

Fuzzy	Pump	LED light	Status
t < 24	Off	On	Maintaining warmth
t >= 24 && t <= 30	On	On	Optimal conditions
t > 31	On	Off	Cooling the system

Maintaining warmth: When the temperature is below 24°C, the LED light is turned on to provide warmth, while the water pump remains off.

Optimal environmental conditions: Within the ideal temperature range of 24–30°C, both the LED light and the water pump are activated to maintain optimal conditions for the greenhouse.

Cooling the system: If the temperature exceeds 31°C, the water pump is activated to cool the system, and the LED light is turned off to prevent additional heat. According to Table 1, the application of fuzzy logic rules for controlling a smart greenhouse contributes to enhancing students' learning context by engaging them in the process of formulating fuzzy rules to solve real-world problems involving ambiguity and uncertainty.

Students' Attitudes toward AI Technology

This project will help students gain a better understanding of the operational principles of temperature sensors (DHT), leading to an enhanced comprehension of control systems using Fuzzy Logic. It also strengthens the ability to easily and effectively read and interpret data from the Node-RED dashboard. Additionally, the project fosters a greater desire for self-directed learning, encourages creativity, and develops a wide range of problem-solving skills. Moreover, students will be able to recognize the practical applications of knowledge in real-world situations and improve their proficiency in utilizing new technologies, as shown in Figure 5. The assessment content is as follows:

This project enhances understanding of the operating principles of temperature sensors (DHT).

This project improves comprehension of control principles using Fuzzy Logic systems.

This project enables students to read and interpret data from the Node-RED dashboard easily and effectively.

This project fosters a greater desire for self-directed learning.

This project promotes the development of creativity.

This project enhances problem-solving skills.

This project helps students recognize the practical applications of knowledge in real-life scenarios.

This project improves proficiency in using new technologies.

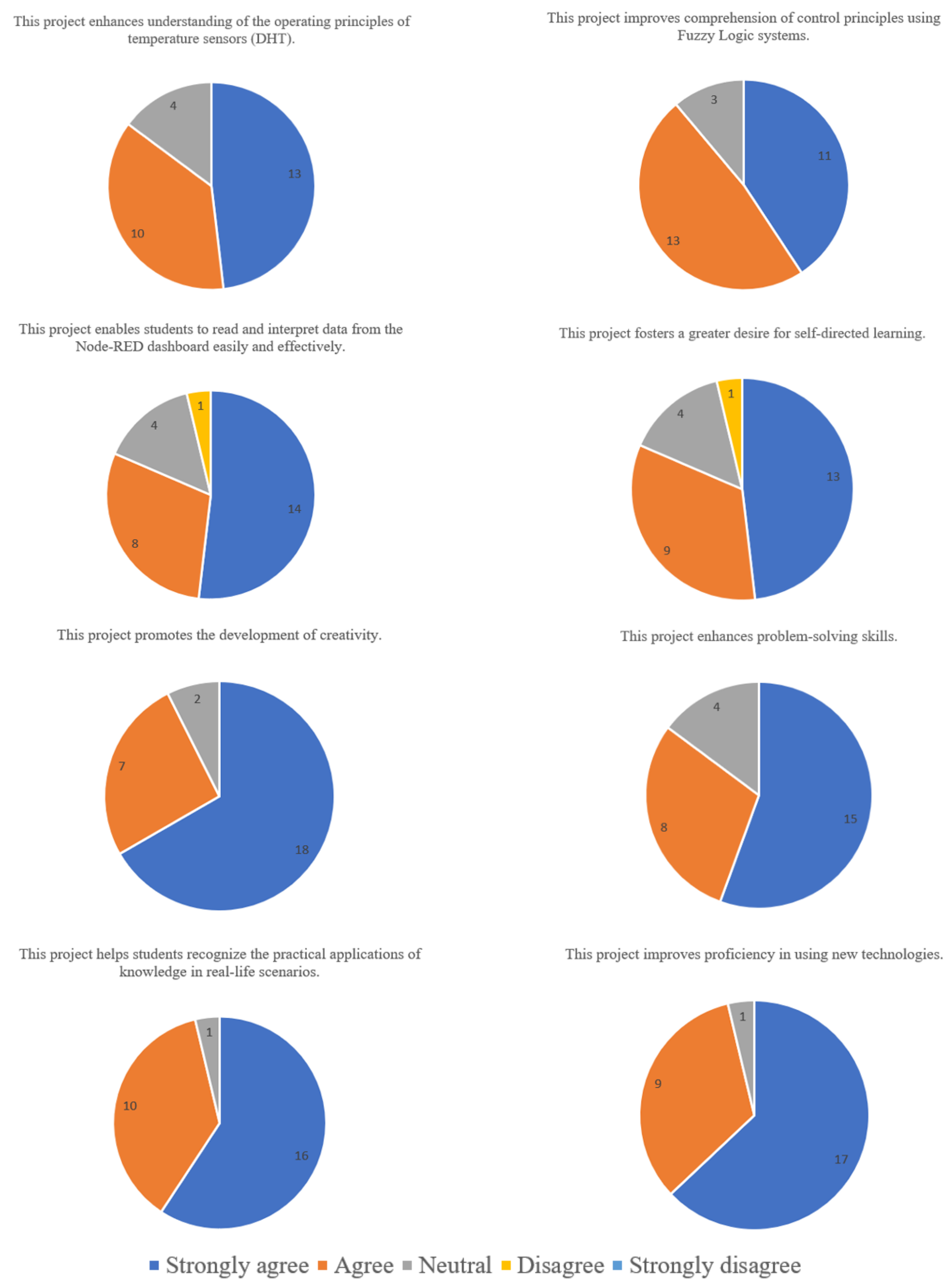

Figure *5.* Evaluation of Students' Attitudes towards AI Technology

Conclusion

This study evaluated students' attitudes toward a learning project involving AI technology, focusing on DHT sensors, fuzzy logic systems, and the Node-RED Dashboard to create an automated control model. Data were collected from 27 female students aged 15–16, with 25.9% aged 15 and 74.1% aged 16. The findings demonstrated positive attitudes toward the project across several aspects. Regarding understanding the principles of DHT sensors, 48.1% of students strongly agreed, and 37.0% agreed, totaling 85.1%. Similarly, 88.8% of students either strongly agreed or agreed that the application of fuzzy logic improved their understanding of complex control principles. The use of the Node-RED Dashboard also received favorable responses, with 51.9% strongly agreeing and 29.6% agreeing that it enabled effective data interpretation. In terms of skill development, 66.7% of students strongly agreed, and 25.9% agreed that the project fostered creativity. Additionally, 55.6% strongly agreed, and 29.6% agreed that the project enhanced problem-solving skills. Real-life applicability was highlighted, with 59.3% strongly agreeing and 37.0% agreeing that the project helped connect knowledge to practical scenarios. Technological proficiency also improved, as 63.0% of students strongly agreed, and 33.3% agreed that the project enhanced their ability to use new technologies.

This research highlights the effectiveness of integrating AIoT in education, emphasizing its role in fostering creativity, problem-solving, and technological proficiency. The project demonstrated the potential of hands-on, practical approaches in bridging theoretical concepts with real-world applications, aligning well with the needs of digital-age learning. However, this study had certain limitations. The research period was relatively short, suggesting that future studies should extend the duration of data collection to better assess long-term outcomes. Additionally, the sample size was small and lacked diversity. Subsequent research could involve a larger and more diverse population to enhance the generalizability of the findings. Integrating the Smart Greenhouse project into interdisciplinary learning contexts such as environmental science, computer science, and data analysis may also increase the real-world relevance and deepen students' learning experiences.

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