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Development of Learning Media for Hydroponic Systems Based on the Internet of Things

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Abstract

Advances in information and communication technology have changed the paradigm in the agricultural sector, especially in the application of the Internet of Things (IoT). An IoT-based monitoring system is an innovative step as there is an increasing need for technology in the agricultural sector and the development of the world of education. SMK Negeri 3 Salatiga, majoring in agribusiness, has great potential in hydroponic agriculture of lettuce plants, but there is no use of IoT technology in it. Hydroponic learning activities at SMK Negeri 3 Salatiga still use manual hydroponic learning media, which results in the competence possessed by teachers and students not being competent in IoT technology, especially its application to hydroponics. Meanwhile, if adjusted to learning outcomes, students should be able to fertilize plants in a modern way. The purpose of this study is to develop and implement hydroponic monitoring learning media based on Internet of Things technology. The application of learning media aims to improve the understanding or competence of teachers and students at SMK Negeri 3 Salatiga. The research methods used are Research and Development with the ADDIE development model, as well as one group pre-test and post-test design research design with 31 samples as a competency improvement test. This study resulted in 26 participants out of 31 participants experiencing an increase in competency in the results of the post-exam exam. So, it can be concluded that there is an increase in the competence of using hydroponic IoT by 83% among teachers and students.

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INTRODUCTION

The development of technological advancements, especially in the field of information and communication technology, is currently very rapid. Humans can create various kinds of devices as tools used to facilitate human life activities. One example of such a technology application is the "Smart Garden," where this agricultural system can combine the application of technology and crop cultivation by applying the Internet of Things (IoT). "Smart Garden" is also known as the application of a plant care control and monitoring system that utilizes smart technology. This is because the "Smart Garden" can use a computerized system to regulate factors such as pH and plant nutrients. "Smart Garden" can be used for a variety of plants. One of the agricultural commodities that are quite large in the Semarang district is lettuce (Danuri, 2019) (Darmanto & Chrism, 2019), (Fauzan & Fahlefie, 2022), (Darmawan et al., 2022).

In addition to being the main commodity of cultivated plants in partners, lettuce is also a vegetable plant with very high economic value, fresh taste, and nutritional content, making this plant have the potential to continue to be cultivated. Based on the increasing need for technology in the agricultural sector and the latest developments in the world of education, especially in the fields of Agribusiness, Food Crops, and Horticulture, it has proven that integrating IoT in monitoring systems can be an innovative solution. Transformation towards smart agriculture has become a necessity, such as in the Semarang Regency area, which has huge agricultural potential (Meriaty et al., 2021), (Dhamayanti, 2023).

In the hydroponic system of lettuce plants, the pH of water is one of the key variables that help plant fertility. The pH of water will affect the effectiveness of nutrient absorption from plants (Gude et al., 2024). The nutrient content of plants must also be considered because it will greatly affect plant fertility (Kurniawan et al., 2023).

One of the schools in Semarang Regency that has a significant role in supporting the development of expertise in the field of Agribusiness is SMK Negeri 3 Salatiga. This school has a vision to prepare its students to become experts in the cultivation of food crops, ornamental plants, and annual plants with a focus on quality, cost efficiency, and punctuality. SMK Negeri 3 Salatiga has a huge potential for lettuce farming; in addition to being supported by natural conditions, learning is also focused on improving students' skills so that they can manage lettuce plantations well.

However, the cultivation of lettuce plants at SMK Negeri 3 Salatiga, which is carried out manually, is considered to take longer than cultivation using technology. Applying "Smart Garden" technology will provide great benefits, such as monitoring plant conditions in real-time, optimizing the use of resources such as water and fertilizer, and increasing the productivity of agricultural products (Ramu et al., 2024)

The application of IoT "Smart Garden" technology will provide great benefits, such as monitoring plant conditions in real-time, optimizing the use of resources such as water and fertilizer, and increasing the productivity of agricultural products. This is because plant monitoring, which was previously done manually, can now be done automatically and sophisticatedly so that it can be efficient for workers in terms of time, effort, and cost. The following is an overview of the comparison of lettuce plant growth between ordinary hydroponics and IoT-based hydroponics. (Saputra, 2023), (Andrianto & Suryaningsih, 2023).

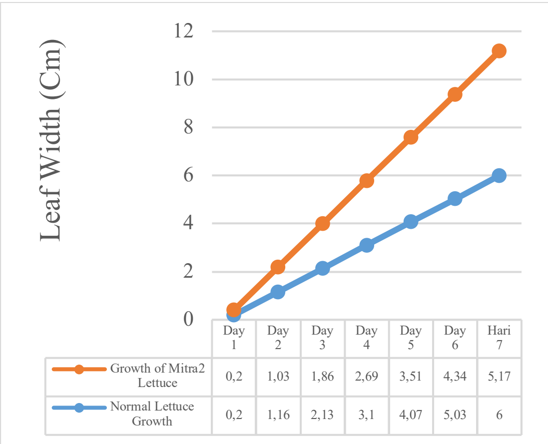

Figure 1. Graph of problems in the cultivation time of partner lettuce plants

The learning process in SMK Negeri 3 Semarang must be adjusted so that students and teachers have skills or competencies regarding the application of IoT in agriculture. In order to achieve educational success, three main pillars are needed: students, teachers, and materials (Abdullah R, 2016). In accordance with the phase F fertilization lesson module, there are learning outcomes where students must be able to fertilize using organic fertilizers in a modern way. Therefore, it is necessary to learn by utilizing IoT-based hydroponic learning media.

Learning media is an instrument that can be used as a tool to convey information or learning materials. Learning media should be able to convey information and improve student understanding. Meanwhile, the learning process that is currently implemented has not utilized IoT hydroponic learning media, which still uses manual hydroponic practicum learning media. This impacts the lack of skills of teachers and students in utilizing IoT technology in hydroponics. As a result, teachers and students are still not ready to apply IoT technology in the hydroponics of lettuce plants.

Based on these problems, it is necessary to develop learning media and apply learning media for the hydroponic system based on IoT technology "Smart Garden" in learning, where the hydroponic learning media can control the pH of water, control hydroponic plant nutrients and monitor both in (Atin et al., 2023) real-time through smartphones using Blynk. In addition, this tool can also monitor pH content and hydroponic nutrients in real time through a smartphone using the Blynk application.

Therefore, this study aims to develop an IoT-based hydroponic learning media as a learning medium to improve the competence of teachers and students in applying IoT in hydroponics at SMK N 3 Salatiga. In addition, this study also aims to see the improvement of the ability of teachers and students regarding the application of IoT in hydroponics based on pre-test and post-test experiments, where data will be tested using t-tests and analysis of student knowledge improvement.

This learning media was made by utilizing pH and TDS sensors that were controlled using Arduino R3. The real-time monitoring system can be done using mobile apps made with Blynk. The Blynk platform is a website or application that can be connected to a microcontroller through IoT communication so that it can be used to control electronic components with the help of a microcontroller (Setiawan & Vidyastari, 2023).

RESEARCH METHODS

The research model used in this research uses the Research and Development (R&D) method. Research method Research & Development is a research method used to make products and test the effectiveness of the product (Sugiyono, 2015). The learning media development carried out in this study uses ADDIE's research design. ADDIE Design is an acronym for the stages of research, namely Analysis, Design, Development, Implementation, and Evaluation (Sugiyono, 2015). This method is used to create IoT-based hydroponic prototype learning media "Smart Garden", which will be used in the learning process. In addition, at the implementation stage, an experimental method will be used, where both will be given a pre-test and a post-test; the difference lies in the treatment that is only applied to the experimental group (Sugiyono, 2015).

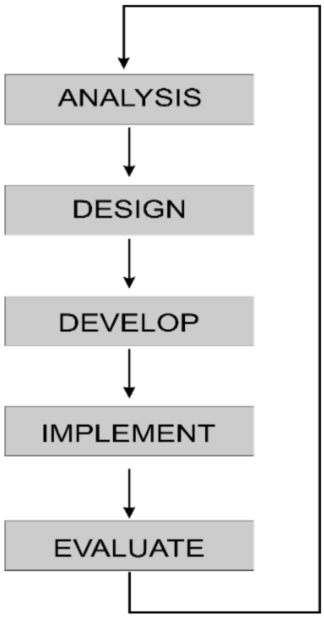

Figure 2. Research and development procedure flow

A. Analysis

The analysis stage is a stage in research conducted by researchers to find out the problems that occur in the field. This stage aims to determine solutions that can be applied to overcome these problems. The analysis was conducted at SMK Negeri 3 Salatiga through interviews and field observations.

B. Design

After analyzing the problem, the researcher can formulate a solution that can be applied; at the design stage, the researcher will design or design predetermined solutions. The design carried out in this study involves making hardware designs from hydroponic prototypes, designing software, and using blink applications to control and monitor hydroponics remotely in real-time using smartphones.

C. Development

In the development stage, the researcher will realize the prototype design of a hydroponic system for pH, nutrient control, and real-time monitoring based on IoT with the Blynk application. After the prototype is completed, the next step is to test the tool to see its function, especially the accuracy of the sensor in reading the pH and nutrient content of hydroponic water.

In addition, a trial of the Blynk application will also be carried out to monitor and control the pH and nutrients of hydroponic water in real-time using a smartphone.

D. Implementation

At the implementation stage, sampling will be carried out using the Non-Probability Sampling technique with the type of Purposive Sampling, which is a sample determination technique based on the consideration of researchers, namely students and teachers who have participated in agribusiness learning technology. The number of teachers and students sampled in this study was 31, comprising 22 students with nine teachers. Therefore, the subject of this study is students and teachers from the agribusiness department of SMK Negeri 3 Salatiga, which has a total of 31 samples.

After the sampling, the stage will be carried out to collect data using a one-group pre-test and post-test research design. The initial stage will be a pre-test to determine the participant's level of skill regarding the use of IoT technology in hydroponics. After the pre-test test, treatment will be carried out in the form of training on the use of IoT in hydroponics. This activity aims to increase teachers' and students' understanding of the use of IoT in hydroponics.

After the treatment is carried out, the last step is to conduct a post-test where the post-test test is carried out to find out if there is a change in the improvement of the participant's ability to understand the use of IoT in hydroponics. The design of the experiment can be seen in Table 1 (Sugiyono, 2015).

Table 1. Research Experiment Design

Subject	***Pre-test***	**Treatment**	***Post-test***
Group	01	X1	02

E. Evaluation

After the implementation of the learning media, the researcher then evaluated or analyzed the data to see the influence of training using IoT-based hydroponic prototypes that had been applied to the experimental group at the implementation stage. The data analysis used at the evaluation stage includes:

1. Normality Test

In educational research, data normality tests are needed to find out whether the empirical data obtained is in accordance with the normal distribution or not (Sugiyono, 2015). The normality test used in this study is the Shapiro-Wilk test because it has a sample number of < 100.

2. T-test

A paired sample t-test was carried out because sample data is interrelated between pre-test and post-test data. This test was carried out to see whether there was a significant difference between the results of the pre-test and post-test exams. If the P value or Sig value < 0.05, then it can be concluded that there is a significant difference between the values of the pre-test and the post-test.

RESULT AND DISCUSSION

A. Analysis

In the first stage of the research, observations will be carried out to analyze the problems found in SMK Negeri 3 Salatiga. After observations and interviews, the researcher formulated several issues, namely (1) Inadequate hydroponic learning media, where the existing learning media still uses manual hydroponics, not connected to IoT (2) Lack of skills or competencies of students and teachers in utilizing IoT in hydroponics of lettuce plants.

Based on the problems found at SMK Negeri 3 Salatiga, the researcher formulated several solutions to overcome these problems. Solutions that can be done include (1) The need to develop IoT-based hydroponic learning media. (2) There is a need to use IoT-based hydroponic learning media in learning to improve the competence of teachers and students in applying IoT to lettuce hydroponics.

B. Design

After analyzing the problem and formulating the solution, the next step is to design or design an IoT-based hydroponic prototype using an Arduino R3 microcontroller, a pH sensor, and a TDS sensor. The flowchart of the working system of the prototype can be seen in Figure 3.

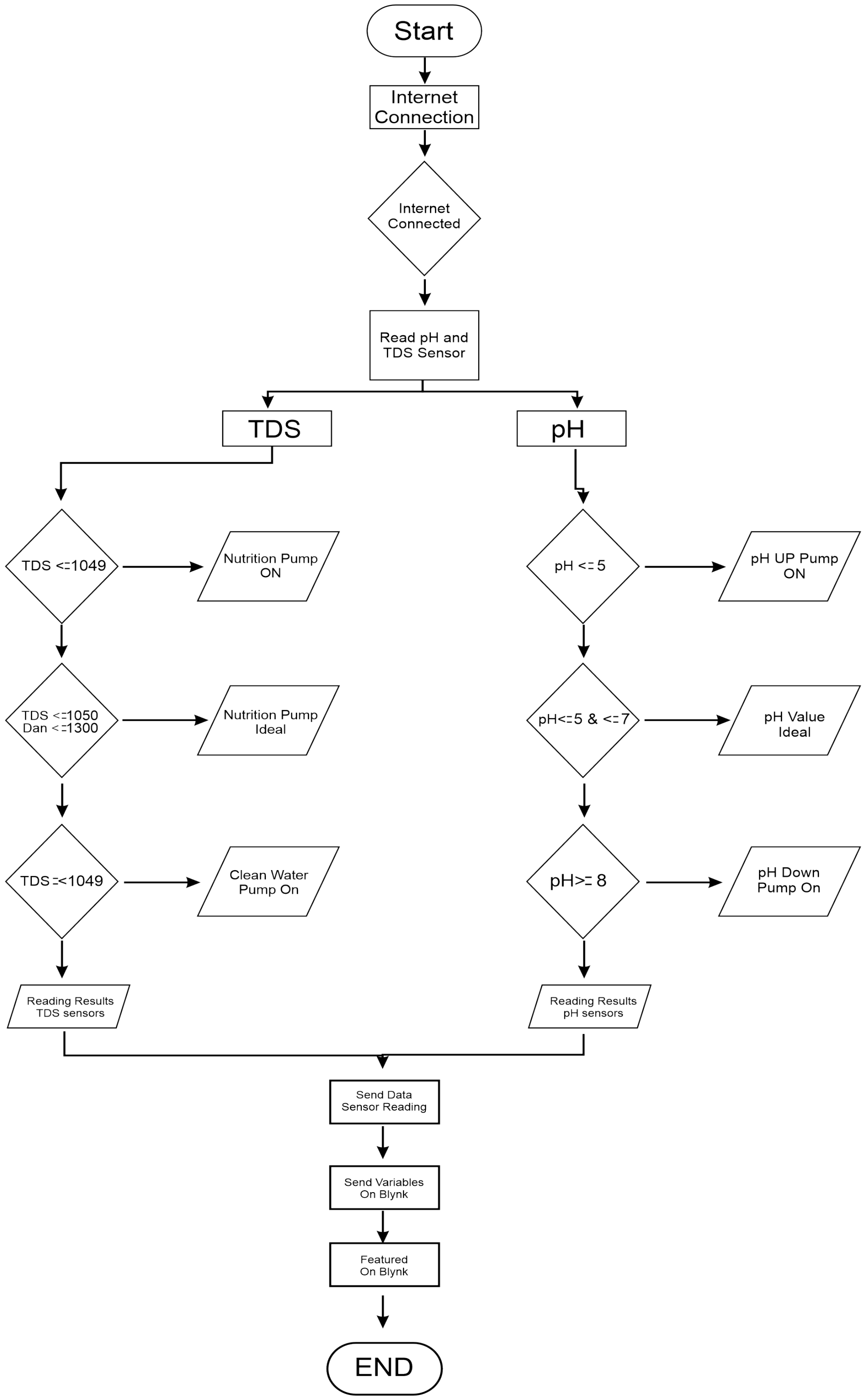

Figure 3. IoT-Based Hydroponic Flowchart

Flowchart is based on the concept of an IoT-based "Smart Garden" monitoring system to monitor and control the hydroponic plant environment in real time. The system includes sensors that measure pH and nutrients. The system also includes a control system to adjust the pH level and nutrient levels based on measured values. The flowchart illustrates the steps to monitor and control the pH and nutrients of hydroponic plants in real time using a smartphone. The schematic of the circuit for connecting each component to the Arduino UNO R3 microcontroller board according to its function is shown in Figure 4.

The need for tools and materials used in this study is shown in Table 2.

Table 2. Components of Tools and Materials

Hardware Components	Software Components
- Arduino UNO R3	- Arduino IDE
- Wemos D1 Mini ESP8266	- Blynk
- Sensor PH	- ISIS Proteus
- Sensor TDS	- Arduino System
- LCD 20X4 I2C	
- DC Pump	
- Relay 4 Channel	
- Smartphone	

C. Development

After the design in the previous stage, development will be carried out, namely the realization of making IoT-based hydroponic prototypes. There are two main parts of this prototype, namely the water box, which is the primary place to control the pH content and plant nutrients. In this box, pH, temperature, and TDS sensors will be installed and controlled through a pre-programmed ESP 32 microcontroller. This water box is also equipped with a panel as a container for electronic components, and an LCD is installed to monitor pH and nutrient content in real-time. The results of the prototype realization can be seen in Figure 5.

The second part is the Internet of Things mobile apps that are used as remote controllers of pH and nutrient content using cell phones. Users can control and monitor in real-time using a cellphone remotely, making it easier for their hydroponic farming. The UI/UX appearance of the Blynk application can be seen in Figure 6.

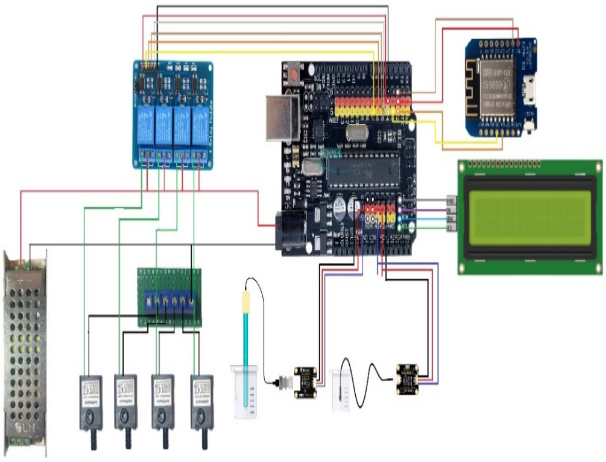

Figure 4. Network scheme "smart garden"

Figure 5. *Hydroponic* prototype

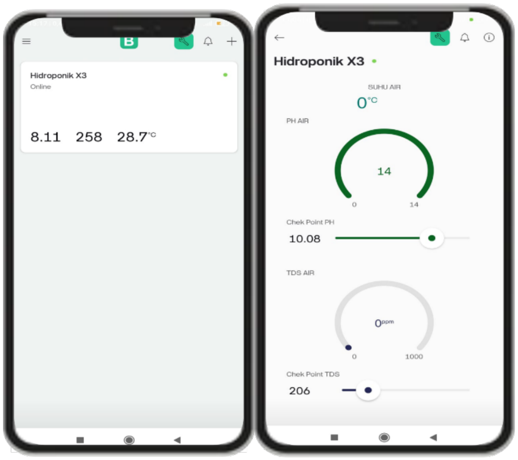

Figure 6. Blynk UI/UX display

D. Implementation

In the implementation stage, an experiment will be carried out using a research design of one group pre-test and post-test design. There will be training on the use of IoT in hydroponics using a prototype that was made previously. In this training, a pre-test will be carried out to determine the initial competencies or skills of each participant; after the pre-test test is carried out, the next is the provision of treatment or training to participants starting from the introduction of IoT to its use in the hydroponic power of lettuce plants. After the training, the next is a post-test to see whether there is a change in IoT utilization skills in the participants.

E. Evaluation

After implementation, an evaluation will be carried out, namely an analysis of the data that has been obtained previously; the analysis is carried out with the aim of seeing the difference between the pre-test and the post-test and seeing the improvement of the skills of the participants regarding the use of IoT in hydroponics. The stages of the evaluation include:

1. Normality Test

The Normality Test was carried out to find out whether the data obtained was normally distributed or not. The normality test was carried out using SPSS software. The type of normality test used is Shapiro Wilk because the data has < 100. The data will be said to be normal if the significance level value is > 0.05 (Sugiyono, 2015). The results of the normality test of pre-test and post-test data can be seen in Table 5.

Table 5. Normality Test Results

Variable	Statistics	Df	Sig.
Pretest & Postest	0.966	31	0.421

From the test results, the value of Sig is 0.421, meaning that the value is > 0.05, so it can be concluded that the distribution of pre-test and post-test data is normally distributed and can be used for the next parametric test.

2. T-test

The data testing process using the Paired Sample T-test was carried out with the aim of seeing whether there was a significant difference between the results of the pre-test and post-test exams. If the value of P value or. Sig < 0.05, so it can be concluded that there is a significant difference between the values of the pre-test and post-test. The results of the Paired Sample T-test can be seen in Table 6.

Table 6. T-test results

	Mean	t	Df	Sig. (2tailed)
Pretest-Postest	-22.161	-6.5	31	0.000

From the results of the test, it can be seen that the average difference in the increase in trainees' knowledge regarding the application of IoT in hydroponics is -22,161. Meanwhile, for the P-Value or Sig. Value, which is 0.000, which means < 0.05. So, it can be concluded that there is a significant difference between the results of the pre-test and post-test tests after the training.

3. Knowledge Improvement Evaluation

Based on the results of the pre-test and post-test exams that have been carried out previously, the researcher analyzed the percentage of participants who experienced an increase in scores. The results of the analysis can be seen in Figure 7.

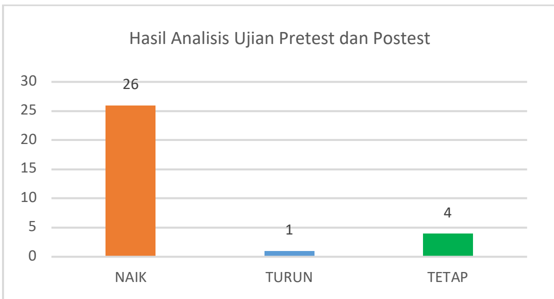

Figure 7. Graph Analysis of pre-test and postest exam results

Based on the graph above, the number of trainees who experienced an increase in knowledge about the use of IoT in agriculture amounted to 26 participants, participants who did not experience an increase and decrease of 4 participants, while participants who experienced a reduction of 1 participant. This means that the number of trainees who experienced an increase in knowledge was 83% of the 31 sample.

CONCLUSION

Based on the results of the research on the use of IoT-based hydroponic learning media in training to improve the skills and competencies of teachers and students at SMK Negeri 3 Salatiga, the conclusions were obtained as follows:

1. The IoT-based hydroponic learning media "Smart Garden" is able to monitor and control pH and nutrients in real-time remotely by utilizing the Blynk application.
2. Based on the pre-test and post-test tests that were carried out in training on the use of IoT in hydroponics on 31 participants it resulted in an increase in the knowledge of teachers and students regarding the use of IoT in hydroponics by 83%, which as many as 26 participants experienced an increase in score, 4 participants remained, and 1 participant decreased.

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