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Digital Garden System Using Arduino

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Abstract

Gardening can help with unfavorable weather conditions to provide a sustainable food crop without struggling with the planting season and being pest-free. Creating an artificial atmosphere that can stabilize plant-like lettuce and strawberry is somewhat tricky; however, developing a closed cubicle with an artificial environment consisting of LED grow light, compressor, air pump, and humidifier solve the problem. The device used an Arduino microcontroller to control the growth of Lettuce and Strawberry using the Hydroponics technique. The temperature sensor is used in this device to activate the cooling system of the project. The study focuses on developing the online monitoring application of the garden that displays Humidity, Temperature using a DHT sensor, adjust the light intensity inside the garden using AC light dimmer, and display local video streaming through RTSP connection.

Moreover, the wifi module is used in the project to transmit and receive data over the internet. Furthermore, the digital garden system also has its web-based monitoring application made up of PHP, HTML, and SQL to store and filter data from the DHT sensor. Based on the various tests conducted, the digital garden system has successfully produced a stable environment that successfully grows healthy lettuce and strawberry.

Keywords: Monitoring Application; Digital Garden; Philippines

1. Introduction

1.1 Project context

The quick pace of globalization goaded by Information and Communication Technology developments over the past years. IT specialists are increasingly in great demand in providing software solutions for businesses [12].

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The development of software solutions to enhance the delivery of productivity encompasses the ability to keep up with the hasty stride of change. IT professionals work closely with the clients to modify and customize the existing systems.

Agriculture has been the most crucial part of our country [11]. Many issues affect the agriculture development in this country. However, the vital bottlenecks are the lack of instant information and the farming practices of the farmers. Agriculture is the traditional way of cultivating soil, planting crops, and raising production [14]. Climate change and an unpredictable environment can affect the plant. The farmer is always finding ways to have a sustainable food source to sustain daily life; experts like indoor farming introduce some solutions. However, indoor farming needs to have a controlled environment that can grow the plant, the indoor farm also needed to have a monitoring application that will monitor the environment of the plants, nowadays there is more application specifically designed for specific plants, and it is hard to integrate to our garden. Therefore, agriculture should smartly surmount these issues. Vividly, few talks over the internet, radio, and television on smart climate agriculture can eventually provide sustainable agricultural productivity and income.

The mentioned issues prompted the researcher/ developer to build a mobile application to help agriculture development by providing immediate and actual data. There are many scholarly agricultural mobile applications utilized globally, but the usage is still limited. The enormous opportunities for utilizing intelligent phones as a part of India's agribusiness improvement are vital for rapid growth and easy access to information to Indian agriculturists, farmers, and growers. They emphasized the importance of mobile application in the field of agriculture. It is essential to monitor the condition of the plant, wherein the internet of things platform application necessitates the monitoring of the plant growth in a controlled environment [1]. Humidity and temperature were important in plant growth. Hence, the researcher/developer configured the Blynk Application to display the sensor data via the internet. The created web page also displays and filters the logs obtained from the sensor and saves them into the database. Moreover, the impact of the digital Garden System in agricultural sectors was perfect for it can help agricultural scientists to conduct the study using a simulated environment.

The Digital Garden System provides a controlled environment for the plant using the sensor. The DHT11 humidity and temperature sensor provide data on plant conditions stored in the DGS database. The data transmitted to the Blynk mobile application via the Node MCU ESP8266 WIFI module. Then, the web browser shows the data. The configured mobile application controls the adjustment of LED grow light intensity and displays local video streaming of the plant inside the box garden. The Digital Garden system utilized hydroponics techniques to grow the plant in a controlled environment. So even individuals can plant vegetables like lettuce and strawberry in their own offices or condominium.

1.2 Purpose and Description

This study purposely used Arduino Uno microcontroller or Arduino-based Temperature Controller to regulate the temperature inside the closed cubicle garden.

This project formulated the code for the microcontroller function using Arduino IDE software. The microcontroller loaded with a condition statement that the compressor will power ON if the temperature reaches 23 degrees. While the compressor is ON, the humidifier will be activated to cool down the temperature inside the garden. The LED grow light representing the plant's sunlight will constantly power ON; however, the mobile phone controls the intensity. Thus, the air pump is constantly ON to produce steady oxygenation to the plant root inside the garden.

The Blynk mobile application displays the monitoring of plant condition. The numerical value of humidity and temperature appears in the gauge at the top position of the application. The middle portion of the Blynk displays the video streaming of the plant inside the cubicle via RTSP.

The bottom part of the application displays the slider that can adjust the intensity of the LED grow light through AC dimmer. The nodeMCU esp8266 WIFI module loaded with a code was connected to the AC dimmer. Also, it transmits the logs of the temperature and humidity to the 000webhost SQL database, the logs filtered by date can be accessed through a webpage using PHP and HTML.

1.3 Objectives

The ultimate goal of the proponent was to develop the Digital Garden System with a monitoring application.

1.3.1 General

The project's objective was to develop a simple and accurate algorithm for a Digital Garden System that shows plant status in real-time.

1.3.2 Specific

The following objectives guided the development of the project. The specific development of components, namely:

1.3.2.1 Develop a closed cubicle garden as a planting area using a hydroponics technique.

1.3.2.2 Utilized LED grow light that represents the sunlight of the plant; compressor that cools down the temperature inside the garden; air pump that helps the root oxygenation of the plant.

1.3.2.3 Utilize Arduino IDE software to load codes and to manage Arduino microcontroller.

1.3.2.4 Develop codes for Arduino Uno that controls the temperature and humidity inside the cubicle.

1.3.2.5 Design codes for the Node MCU esp8266 WIFI module send temperature and humidity sensor values to the Blynk application and 000webhost database.

1.3.2.6 Develop codes for Node MCU that control the AC Light Dimmer using the slider button from the Blynk application.

1.3.2.7 Develop SQL database that stores data from Humidity and Temperature Sensor.

1.3.2.8 Develop webpage using HTML and PHP that displays and filters the logs by date from the database.

1.3.2.9 Developed Real-Time Streaming Protocol in Blynk mobile app to display videos of the plants inside the garden using the local network.

1.4 Scope and Limitation of the Study

The scope of this project includes recording and monitoring the condition of the plant inside the box. The user can view real-time online information on plant status using the mobile application. Digital Garden System al has a web-based monitoring application that can view the temperature and humidity, stored the data from the database, and Filter the sensor logs by date. The developer utilized the tools like Arduino microcontroller, compressor air pump, humidifier and LED grow light, DS18B20 waterproof sensor, and DHT11 humidity and temperature sensor, node MCU esp8266 WIFI module, AC light dimmer device.

The application is compatible with IoT and android platform applications. The mobile monitoring system used the blynk application, 000webhost SQL database, PHP, and HTML in the web-based monitoring.

The Digital Garden System needs a consistent current supply to power all the devices that can produce the artificial climate and display the monitoring, power failure within 24 hours can harm the plants inside the garden and lost connection to the monitoring application, the mobile and web-based monitoring application of the garden also needs an internet connection to display the plant status inside the garden, specifically, the mobile application limits only to a single user, the Arduino IDE does not support multi-authentication for many users. If the user needs to transfer from a different user or smartphone for monitoring, replacement of the authentication is necessary.

2. Review of Related System

There were several innovations and studies conducted to help farmers due to farming problems. The following are some of the innovations or studies conducted.

2.1 Herb Box Eco System

The herb box eco system is an automated irrigation system designed specifically for indoor herb plants. It uses Arduino Uno, esp wifi module, and Amazon Alexa Echo Dot to build the device. It also displays humidity monitoring through the web. Amazon Alexa Echo Dot is used in the study to automate irrigation through voice command, the herb box eco system was design to control the plant watering [5].

Compared to the herb box eco system, the proponent used an Arduino microcontroller to control and automate the device attached to the cubicle. In this project, the temperature and humidity sensor triggers the compressor and humidifier; if the sensor receives a high temperature, that can hamper the plant—the esp wifi module to transmit the signal to the monitoring application.

2.2 Smart Garden

The smart garden system is a device that can monitor the plants' environment. The system utilizes the Blynk application and thinkspeak to display the sensor value online. The smart garden system used moisture, temperature, and humidity sensor to automate the watering system, the device can aid the tedious part of manual watering and ensure the plant will grow healthy [6].

About the study, the added features to the Blynk application were the web application that displays and filters the sensor logs in the browser. The web application also has its database to store the temperature and humidity value coming from the sensor inside the garden.

2.3 Arduino Grow Box Controller

The Arduino GrowBox Controller is a compact cubicle device containing an artificial environment. the device is composed of humidity and temperature sensor displayed in the device's LCD. Ethernet shield in this project sends the sensor value to the monitoring application, the ethernet shield is also used in the project for online configuration of the device, as well as for viewing of records and retrieving the logs. EmonCMS is a monitoring application that displays humidity and temperature and the sensor graph, the plant is grown inside the box with soil [7].

The study was patterned to serve as the simulated environment garden of the plant. However, compared to the Arduino Grow Box Controller, this study adds controls in the mobile application to adjust the light intensity inside the garden using AC light dimmer. The LED grow light is attached to the AC light dimmer controlled using Blynk mobile application; the user can manually adjust the led light through the slider.

2.4 Green Box Prototype

The Green Box Prototype is a closed box controlled by Arduino to grow all kinds of plants; the installed esp8266 wifi module for the web interface. The project used temperature, light, and humidity sensors for the prototype of the project. The installed led stripe in the prototype can be upgraded into led grow light for betting lighting of the project, the main goal of the project is to grow a plant in an controlled environment with minimal human intervention [8].

Compared to the Green Box Prototype, the Digital Garden system used an Arduino microcontroller to control and monitor the status of the plants. Also, local streaming of the plant can be viewed in the blynk application using the video widget. The Blynk Application connects to the camera through a real-time streaming protocol.

2.5 Remote Temperature and Humidity Monitoring with ESP8266 and Blynk App

The remote temperature and humidity monitoring with ESP8266 and the Blynk app is a project design to determine the humidity and temperature variations inside the greenhouse using DHT22 sensor. The Blynk mobile application is an IoT flatform that can display variables for monitoring using internet, the device and flatform used is very interesting for the beginners to develop the greenhouse monitoring system [9].

Compare to the Remote Temperature and Humidity Monitoring with ESP8266 and Blynk App, the Digital Garden System also used the Blynk mobile application for monitoring the plant inside the box and the web-based monitoring application that contains the database that stores the sensor value online, the sensor value can view in the web-based monitoring application

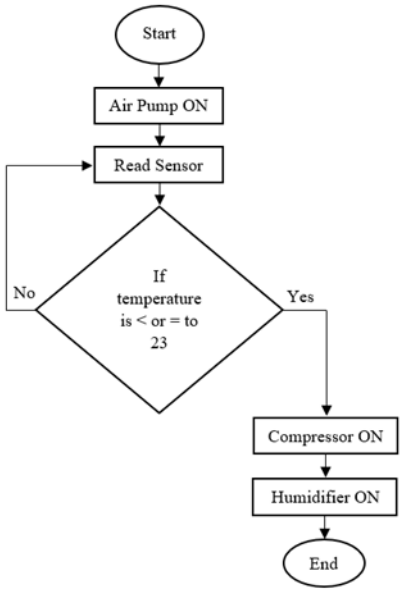

Figure 1: Flow chart of Digital Garden System**.**

In figure 1, the flow chart of the Digital Garden System shows the method to control the temperature. The air pump of the system was steady power ON to have constant plant oxygen in the garden; Then, the compressor will power ON depending on the temperature of the garden; if it is greater than or equal to 23 degrees, the compressor and humidifier will power ON to cool down the garden.

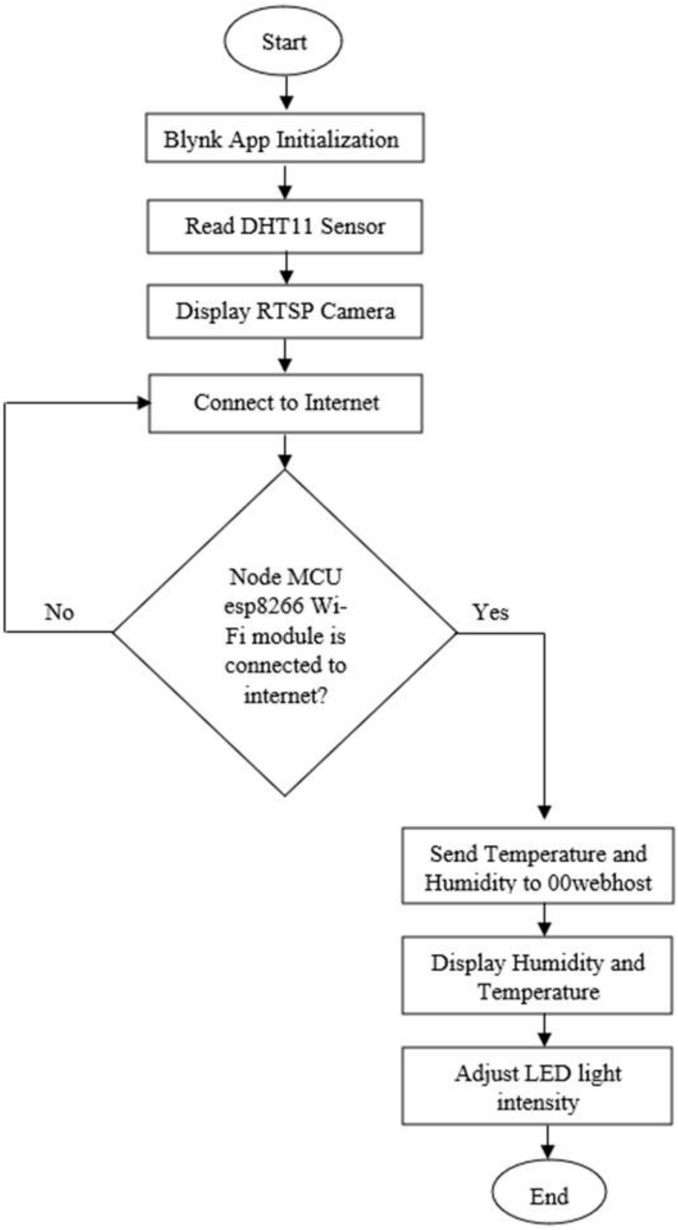

Figure 2: Flow chart of Digital Garden System Monitoring Application.

Figure 2 shows the flow chart of the Digital Garden System Monitoring Application. It displays the environment inside the garden. The numerical value of humidity and temperature appears in the gauge at the top position of the application. The middle portion of the Blynk displays the video streaming of the plant inside the cubicle via RTSP. The bottom part of the application displays the slider that can adjust the intensity of the LED grows light through AC dimmer. The nodeMCU esp8266 WIFI module loaded with a code was connected to the AC dimmer. Also, it transmits the logs of the temperature and humidity to the 000webhost SQL database, the logs filtered by date can be accessed through a webpage using PHP and HTML.

3. Technical Background

This chapter contains the technical background of the project consisting of the development tools used to develop both the hardware and software parts.

3.1 Conceptual Framework

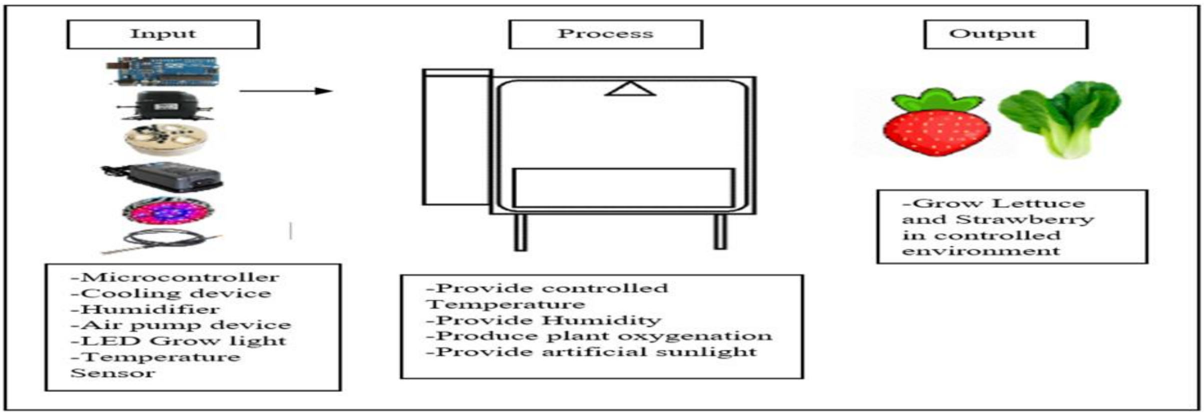

Figure 3: Conceptual Framework of Digital Garden System.

Figure 3 Conceptual Framework of Digital Garden System shows the several devices to build the controlled environment of Digital Garden System. The Arduino Uno microcontroller controls all the devices like compressor, air pump, and humidifier in producing an artificial environment. Simultaneously, the temperature sensor is the basis of the compressor to switch ON and OFF to produce a stable temperature that is good for lettuce and strawberry.

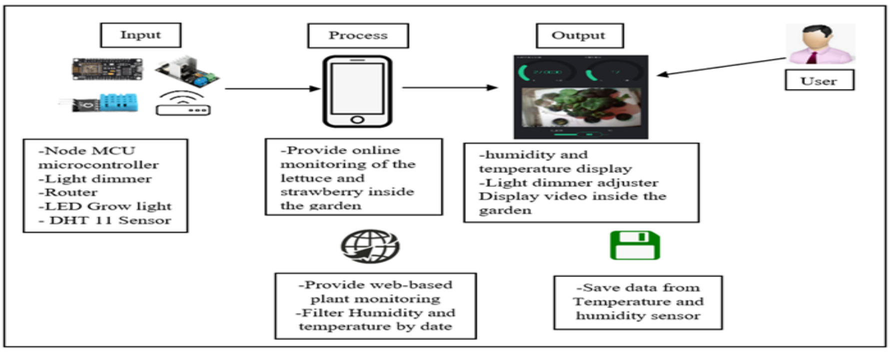

Figure 4: Conceptual Framework of Digital Garden Monitoring Application.

Figure 4 shows the Conceptual Framework of the Digital Garden system monitoring application. The configuration of the mobile monitoring application uses the blynk application, connected to the DHT11 sensor via the node MCU esp 8266 wifi module, that connects the monitoring application to the internet. Additionally, the mobile monitoring application displays the humidity, temperature, and local streaming of the plant within the garden. The adjustment of LED grows light intensity through AC light dimmer. The web-based monitoring application is also a feature of the digital garden system that can display and filter the sensor logs. The SQL database stores all the data coming from the sensor. The web-based monitoring application uses PHP, HTML, and SQL for developing the database.

3.2 Infrastructure Overview Diagram

The infrastructure overview diagram represents the connection of the devices from the Digital Garden System.

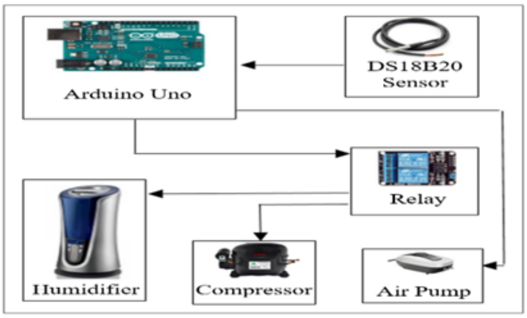

Figure 5: Digital Garden System Infrastructure Overview Diagram.

Figure 5 Digital Garden System Infrastructure overview diagram shows the connection of the different kinds of devices to the microcontroller. The waterproof temperature sensor is connected to the Arduino to analyze the temperature. If it exceeds 23 degrees, it will trigger the relay and switch ON the humidifier and compressor to cool down the garden. The air pump is also connected to provide oxygen to the plant; the pump is steady ON.

3.3 Infrastructure overview diagram of Digital Garden System Monitoring Application

The monitoring application has its hardware that is responsible for the display of the monitoring application.

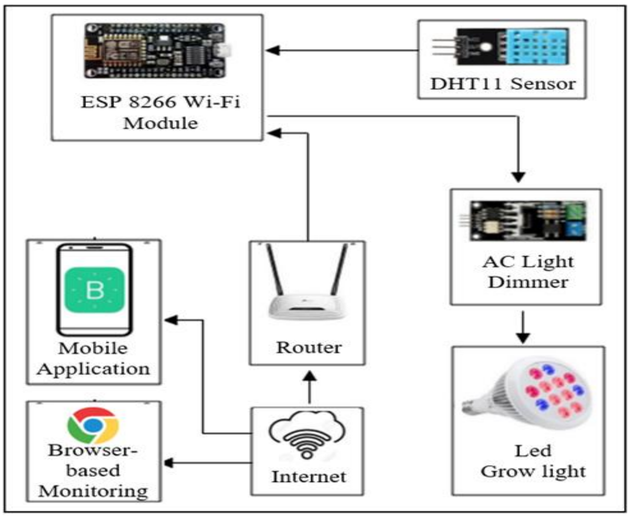

Figure 6: Digital Garden System Monitoring Application Infrastructure overview diagram.

Figure 6 shows the infrastructure Digital Garden System Monitoring Application. The Node MCU esp8266 wifi module is the microcontroller used to send the DHT11 Temperature and Humidity sensor data to the Blynk Application. Then, the Node MCU connects to the router that has an internet connection. The humidity and temperature can be accessed using a web browser. Connecting online is possible through LED-grow light connected to the AC light dimmer.

3.4 Development Tools

The project aimed to grow lettuce and strawberry in a controlled environment garden with a monitoring application; the project used different devices to produce and control the artificial environment. It utilized software development to produce monitoring applications.

3.4.1 Arduino IDE

The Arduino IDE software is the program used to create code for the microcontroller. Arduino IDE is compatible with different kinds of operating systems like Windows 7, 8, and 10. Digital Garden System is a controlled environment device that will automatically power ON the compressor and humidifier if the temperature reaches 23 degrees, the inputs are coming from the sensor that will trigger the microcontroller to switch ON the compressor and humidifier, the code is developed from Arduino IDE and loaded to the microcontroller using the USB cable.

3.4.2 Network Router

The network router is used in the project as the connection of the Node MCU esp8266 wifi module to the internet, the service Set Identifier or SSID and Password of the router is declared into the code of the Node MCU esp8266 wifi module to have an internet connection between the monitoring application and the Digital Garden System.

3.4.3 Mobile Monitoring Application

The developer uses Blynk mobile app to develop the project monitoring application. The humidity and temperature display as the gauge in the upper portion of the application. The humidity is connected to the Node MCU esp8266 using virtual PIN6, and the temperature is in virtual PIN5. The mobile application can also display the video streaming through real-time streaming Protocol or RTSP in local area connection. The Monitoring Application can adjust the light intensity of the LED grow light inside the garden using the slider button from the Blynk Application; the slider button is connected to the Node MCU wifi using virtual PIN 4.

3.4.4 Webhosting Site

The developer creates an account from the 000webhost. It is a free web hosting site that can publish web pages online; the 000webhost is also utilized in the study to create a SQL database that will store the data from the sensor. PHP code is uploaded to the 000webhost to display a web-based monitoring application online.

3.4.5 Database

The project has its online database to store the logs from the sensor. The SQL database stored The Current

Time, Temperature, and humidity from the PHP myadmin panel of the free Webhosting site.

3.4.6 PHP and HTML

The Digital Garden System has its web-based monitoring application made from PHP and HTML; PHP is a scripting language responsible for fetching and filtering the value of the sensor from the SQL database and display it into the browser. HTML is also used in the webpage for the data positioning in the browser.

3.4.7 Web-based Monitoring

The web-based monitoring application displays the current time, humidity, and temperature on the website. Users can access the webpage through a URL. The webpage can filter by the date that the user is setting.

4. Methodology

4.1 Agile Scrum Methodology

The project development used agile scrum methodology. It is composed of sprints series that divides all the parts of the project. Sprints are the specific task that is necessary to the program.

4.2 Requirements Specification

4.2.1 Product Perspective

The Digital Garden system is an innovation of the traditional backyard gardening system. It aims to grow lettuce and strawberry using an artificial and control environment. Hence, it was made for indoor plant growing and useful for those individuals living in a condominium who want to grow vegetables and fruits.

Table 1: Hardware components.

Digital Garden	**Monitoring Application**
Arduino Uno	Node MCU
Ds18b20 temperature sensor	DHT11 Sensor
Relay module	AC light dimmer
Humidifier	LED grow light
Compressor	Router
Air Pump	
Closed cubicle	
Rockwall	
Hydroponic planting box	

The table above shows the hardware components of the project. The digital garden consists of different hardware to control and monitor the plant inside the cubicle.

4.2.2 User documentation

The developer provides the user manual containing instructions to operate the Digital Garden System and Monitoring Application. The manual contains the procedure for manipulating the device.

4.2.3 Hardware Quality Attributes

The Digital Garden System possess the hardware quality attributes:

4.2.3.1 Reliability

The developer ensured that all the devices installed inside the Digital Garden System would work appropriately according to its function. The project underwent several testings to prove its reliability.

4.2.3.2 Efficiency

The Digital Garden System contained devices that monitor the growth of lettuce and strawberry. It would provide efficient data through applications and internet connections affix in the cubicle.

4.2.3.3 Usability

The Digital Garden System tends to innovate the growing process of the lettuce and strawberry using an artificial environment. It can help those individuals who want to grow veggies in condominiums or offices.

4.2.3.4 Software reliability

The developer ensured that the monitoring application, as well as the web-based, will function properly. The monitoring application has undergone several testing to ensure its Reliability.

4.3 Analysis

In this phase, the developer formulated the Digital Garden System's objectives and evaluated whether it is technical and operationally feasible. Digital Garden System is an indoor garden machine that consists of an artificial environment; the compressor and humidifier of the garden will automatically power ON if the sensor detects the temperature exceeding 23 degrees set in the code. The LED grow light is constantly ON in the garden to produce 24 hours photosynthesis to maximize the plant growing process. However, it can be adjustable using a slider in the application, depending on the user. The Digital Garden System is using hydroponic techniques that are manually watered by the user every planting time.

4.3.1 Technical Feasibility

The developer designed a prototype of the Digital Garden System and the monitoring application. The exhibit shows the capability of the device to grow strawberries and lettuce inside the garden under a controlled environment. The Blynk and web-based monitoring applications can control and monitor the environment of the garden. The developer confirmed that the monitoring application works efficiently.

4.3.2 Operational Feasibility

The Digital Garden System was operationally feasible because the device and the monitoring application were user-friendly.

4.4 Design

4.4.1 Use Case Diagram

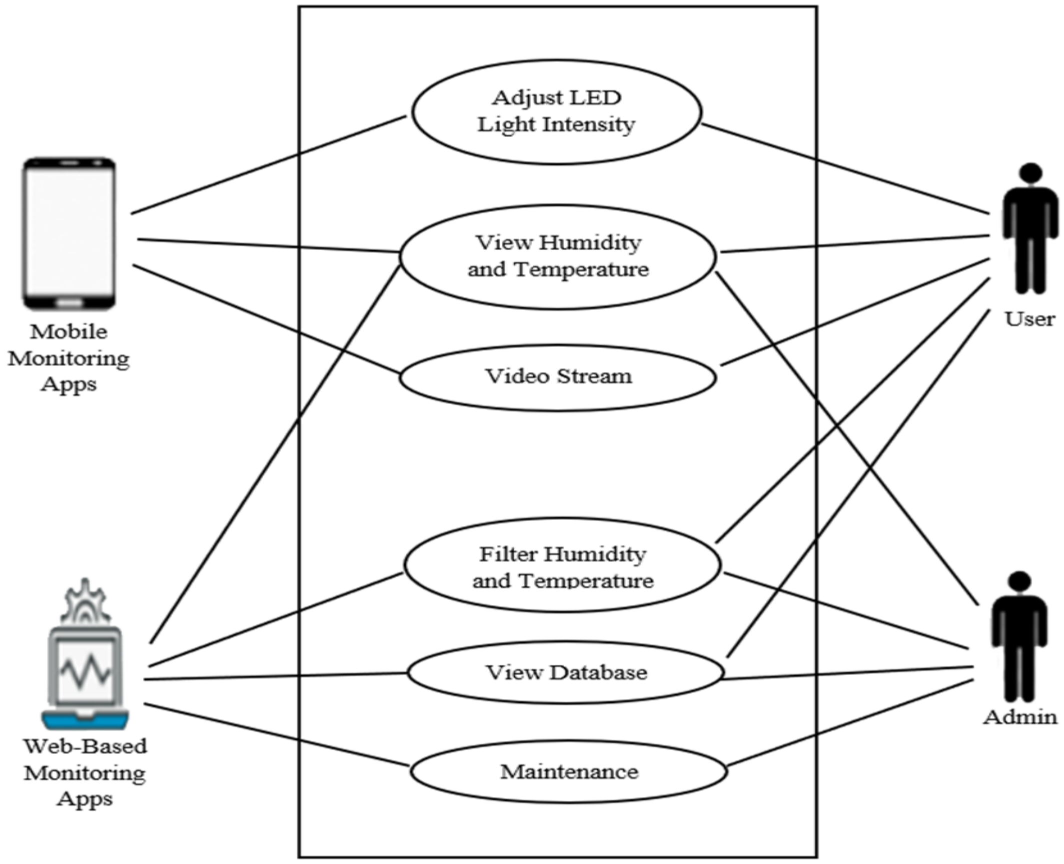

Figure 7: Use Case Diagram.

Figure 7 Use Case Diagram shows the user full access to the mobile and web-based monitoring application, thus adjusting LED light intensity, viewing, and filtering the temperature and humidity from the web application. The mobile application displays a video that the user can view the plant status inside the garden. The system administrator can also view and filter the humidity and temperature of the web-based monitoring application and in charge of the system maintenance.

4.4.2 UML sequence diagram

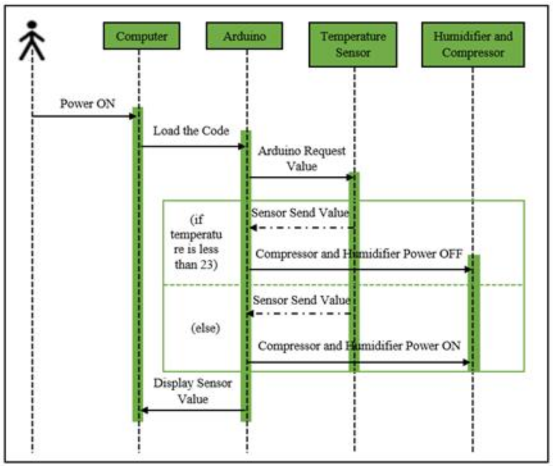

Figure 8: UML sequence diagram of Digital Garden System.

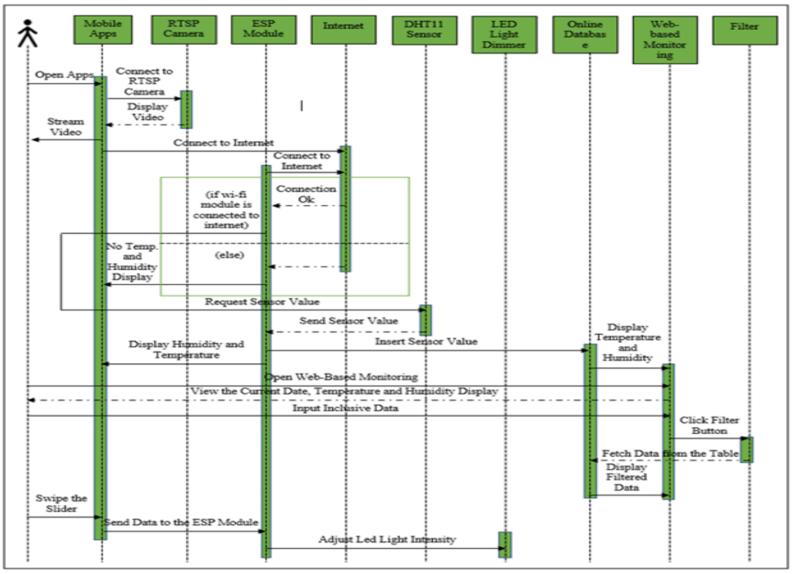

Figure 9: UML diagram of monitoring application.

The UML diagram shows the transaction flow of the application.

4.4.3 Digital Garden System Design

The developer formulated project-specific objectives to derive the design, including the hardware and software specifications.

Figure 10: Digital Garden System growing plants inside.

The device is a closed cubicle that contained the LED grow light, DS18B20 temperature, and DHT11temperature and humidity sensor. Subsequently, inside the garden was the hydroponics planting box that contains strawberry and lettuce plants.

4.4.4 Installed devices

Figure 11: Installed Devices responsible for the artificial environment.

The compressor, humidifier, and air pump were mounted on the box's left side, while the condenser on the cubicle's adjacent side.

4.4.5 Microcontrollers and Circuits

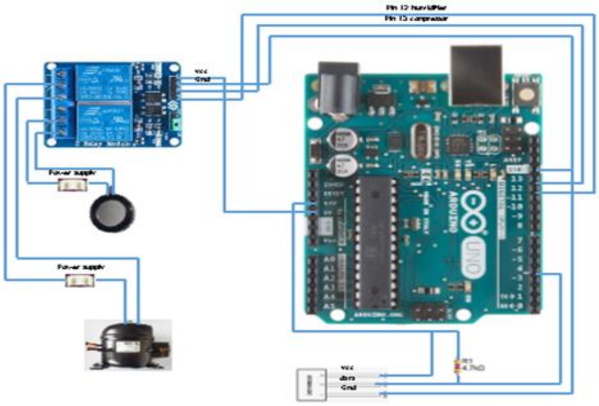

Figure 12: Digital Garden system-controlled temperature schematic diagram.

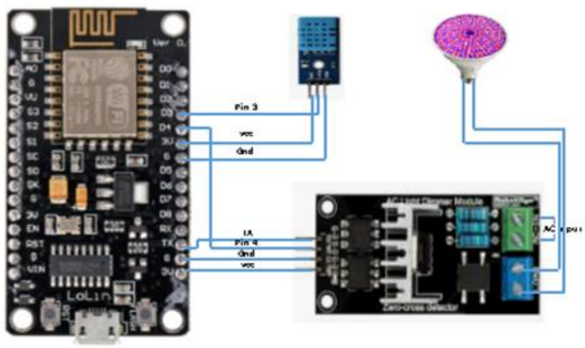

Figure 13: Node MCU wifi module circuit diagram**.**

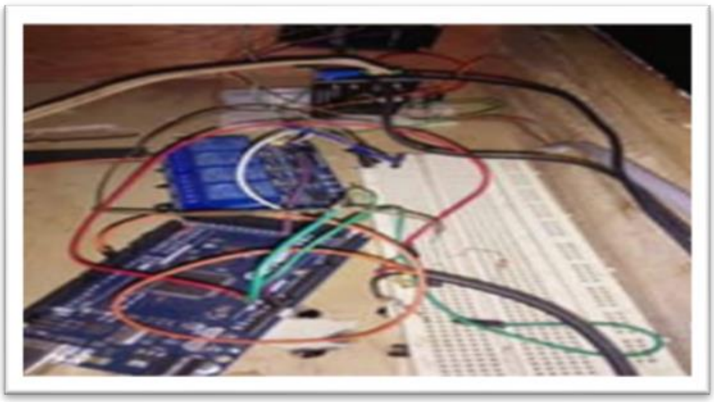

Figure 14: Microcontrollers and circuits.

The circuit of the project installed at the top of the cubicle included the current outlet.

4.4.6 Temperature and Humidity display

Figure 15: Temperature and Humidity Display.

The design of the temperature and humidity was similar. The real value appears in the middle of the gauge.

4.4.7 Video widget

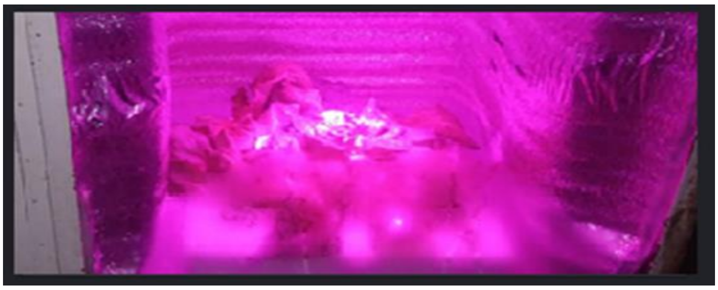

Figure 16: Video widget.

The video from the camera inside the garden appears in the monitoring application using the Video widget from the blynk mobile application.

4.4.8 Slider

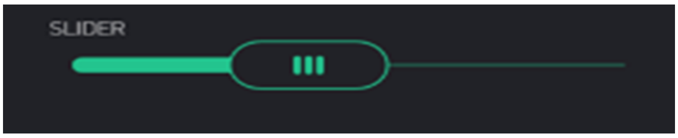

Figure 17: LED Light Intensity Adjust Slider.

The slider from the blynk application used in the project will adjust the LED grow light of the Digital Garden System.

4.4.9 Web-based monitoring Application

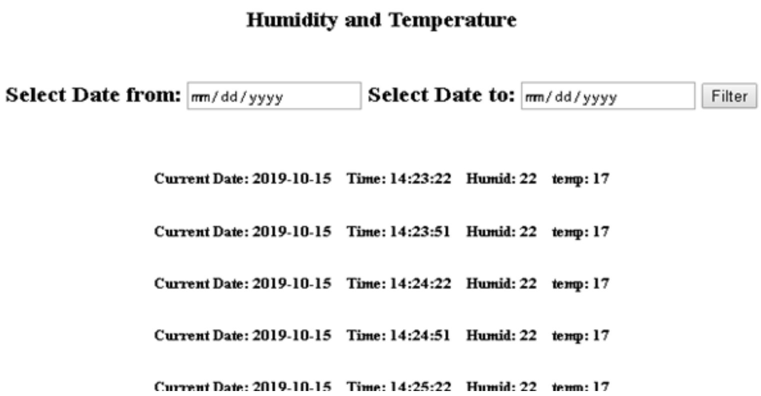

Figure 18: Web-based Monitoring Application.

The web page of the Digital Garden System displays the current time, temperature, and humidity. Also, the filter button was available on the webpage.

4.5 Development and testing

The developer did online research to come up with the project title digital garden system. Growing lettuce in a controlled environment with monitoring application leads the researcher to formulate the specific objectives. The developer used agile scrum methodology for the development of the project.

The study underwent two types of testing to ensure that the project hardware and software parts work correctly. The first testing, alpha testing, was done at the developer site to ensure that all the device and system features were working correctly before proceeding to the second testing. The beta testing concerns the end-user part to ensure the Reliability of the Digital Garden System.

Sprint 1. Development of the digital garden system. The developer prepared the planting area, gathered the hardware requirements like LED grow light, compressor air pump, humidifier, sensors, and microcontroller to create the artificial environment inside the cubicle.

Sprint 2. Installation of the Arduino IDE software to design a code and to be loaded into Arduino microcontroller. This sprint also involves the testing of the DS18B20 temperature sensor and DHT11 humidity and temperature sensor.

Sprint 3. In this phase, the developer developed codes that will control the temperature inside the garden. After that, the developer set up the garden and determined the temperate's stability inside the garden. The plant lettuce and strawberry grew.

Sprint 4. The developer utilized the Node MCU esp8266 wifi module to transmit the data from the DHT11 sensor to the blynk application. In this development phase, the developer also utilized AC light dimmer to dim the LED light inside the garden using the Blynk app.

Sprint 5. The developer utilized the Blynk application to display the humidity and temperature using a gauge design located in the upper portion of the blynk application to monitor the garden. The developer used a video streaming widget for video live stream of the garden. Then, slider for the adjustment of the LED light intensity.

Sprint 6. The researcher developed the webpage using the 000webhosting site to store, display and filter data from the DHT11 sensor. In this phase, the developer uses PHP and HTML scripting language.

Sprint 7. Finalization of the project, the developer repaired all the errors of the hardware and software part of the Digital Garden System. The researcher/ developer made sure that the full-blown project works correctly.

4.5.1 Implementation and Unit Testing

4.5.1.1 White box testing

The developer used white-box testing to verify the reliability of the code running on the Arduino Uno microcontroller, the node MCU, and the PHP scripts that comprise the web-based monitoring program.

4.5.1.1.1 Arduino Uno white box testing

Table 2: Test Case 1.

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Pass/fail
DS18B20 functionality	Check data logs displaying in serial monitor	Arduino IDE must be installed	Step 1. Launch Arduino IDE Step 2. connect the microcontroller Step 3. load the code requesting the temperature from the sensor		Temperature display successfully	Temperature display successfully	pass

Table 3: Test Case 2**.**

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Pass/fail
Condition statement	Check response	Arduino IDE must be installed	Step 1. Launch Arduino IDE	temp = 22	Compressor and Humidifier power OFF	Compressor and Humidifier power OFF	pass
			Step 2. connect the microcontroller	temp = 23	Compressor and Humidifier power ON	Compressor and Humidifier power ON	
			Step 3. load the code requesting the temperature from the sensor and the conditional statement	temp = 24	Compressor and Humidifier power ON	Compressor and Humidifier power ON	

The table above shows the white box testing of the Arduino Uno microcontroller responsible for controlling the temperature inside the garden. Test case 1 involves the functionality testing of the DS18B20 temperature sensor code that successfully senses the temperature and display in the serial monitor of the Arduino Uno Microcontroller. Test case 2 involves the condition statement that will turn ON the relay module for the compressor and humidifier when the temperature reaches 23 degrees and above.

4.5.1.1.2 node MCU white box testing

Table 4: Test Case 3.

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Pass/fail
Node MCU functionality integrated to blynk mobile application	Sending temperature and humidity from DHT11 sensor to blynk application	Arduino IDE must be installed, the node MCU is connected to the internet, the tester is registered in blynk application	Step 1. Configure blynk application Step 2. Copy the AuthN from the gmail account and paste into the code Step 3. load the code		Humidity and temperature display in blynk applecation	Humidity and temperature successfully display in blynk application	pass

Table 5: Test Case 4.

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expecte d result	Actual results	Pass/fail
AC light dimmer functional ity	Check light intensity adjuster	Arduino IDE must be installed, the node MCU is connected to the internet, the tester is registered in blynk application	Step 1. Configure blynk application Step 2. Copy the AuthN from the gmail account and paste into the code Step 3. load the code	Swipe the slider button	Light intensity adjusted	Light intensity successfully adjusted	pass

Table 6: Test Case 5.

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Pass/fail
Local video streaming	Check video streaming in blynk application	RTSP camera is installed in the smartphone used for video streaming	Step 1. Start RTSP camera Step 2. Connect blynk video widget to RTSP camera		Display Video from RTSP camera	Successfully display Video from mobile application	pass

The table above shows the white box testing from the Node MCU microcontroller; the node MCU is a wifi module integrated into the blynk application for monitoring the digital garden system. Test case 3 sends temperature and humidity data to the blynk application using void sensSensor loop. The blynk application shows the temperature and humidity. Test case 4 was to examine the code for the light intensity adjuster by swiping the slider to increase or decrease the light intensity of the LED grow light. Test case 5 involves the local video streaming that successfully meets the expected result to view the real-time streaming of the plant inside the garden.

4.5.1.1.3 Web-based monitoring white box testing

Table 7: Test Case 6.

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Pass/fail
DHT11 sensor functionality sending temperature and humidity logs to website home page	Check temperature and humidity logs using insert php script	The tester should access the webhost and the arduino IDE containing the node MCU code	Step 1. Access the webhost Step 2. Open the file containing the script	Run the insert.php code into the URL	Real time temperature and humidity logs	Real time temperature and humidity logs successfully	pass

Table 8: Test Case 7.

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Pass/fail
Database connection	Check temperature and humidity saved in the database	The tester should have access to the database in the admin panel of the webhost	Step 1. Log in to the webhosting site Step 2. Open the database Step 2. Open the insert.php code	Temperature and humidity data from the sensor	Stored humidity and temperature to the database	Successfully stored humidity and temperature to the database of the website	pass

Table 9: Test Case 8.

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Pass/fail
Filter button functionality on	Check the filter button	The tester should open the homepage of the web-based monitoring application	Step 1. Connect to the internet Step 2. Input the URL of the web-based monitoring	September - October 2019	September - October 2019 temperature and humidity data display	Successfully display of filtered data of temperature and humidity	pass

The table above shows the white box testing from the web-based monitoring application. Test case 6 inspects the website's homepage that successfully displays the temperature and humidity from the DGT 11 sensor. Test case 7 involves testing the database connection from the insert PHP script to the website's database that successfully stored the data. Test case 8 inspects the filter button to successfully display the date, time, temperature, and humidity from the website's database.

4.5.1.2 Black box testing

The Digital Garden System underwent black box testing to ensure that all the features of the monitoring application are fully functional.

4.5.1.2.1 Mobile monitoring application Black box testing

Table 10: Test Case 1.

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Functional/ not functional
mobile monitoring application functionality	Checking temperature display	the user should have gmail account and registered in blynk application	Step 1 open arduino IDE from the computer		temperature display	successfully temperature display	Functional
	Checking humidity display		step 2 copy the authentication code from the g mail account and paste into the node MCU code		humidity display	successfully humidity display	Functional
	Checking video streaming display		step 3 load the code to the node MCU microcontroller		video streaming of the plant inside the garden	video streaming of the plant inside the garden successfully displayed	Functional
	Checking light intensity slider response		step 4 start RTSP camera	the user swiped the slider	light intensity adjusted	light intensity adjusted successfully	Functional

The above table displays the mobile monitoring application's functional testing. The monitoring application's features show the application's temperature and humidity levels. The video of the plants in the garden was also seen success during the local streaming. The slider button functions virtually.

Table 11: Test Case 2**.**

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Functional/ not functional
web-based monitoring functionality	Checking temperature display	the user should have access with the admin page of the webhost and the database of the web-based monitoring.	Step 1 access the url of the web-based monitoring , step 2 access the admin panel of the webhost, step 3 access the web-based monitoring database		temperature display	successfully temperature display	Functional
	Checking humidity display				humidity display	successfully humidity display	Functional
	Checking filter button			September - october 2019	September - october 2019 temperature and humidity data logs	September - october 2019 temperature and humidity data logs successfully display	Functional
	Checking database				Date, time, temperature and humidity logs	Date, time, temperature and humidity logs successfully display	Functional

Table 12: Test Case 3**.**

Test scenario	Test case	Pre-conditions	Test steps	Test data	Expected result	Actual results	Functional/ not functional
controlled temperature functionality	Checking condition statement	the user should access the arduino uno code from the arduino IDE	Step1. open arduino UNO microcontroller code Step2. open arduino serial monitor	temeperature = 22	compressor and humidifier power OFF	compressor and humidifier successfully power OFF	Functional
				temeperature = 23	compressor and humidifier power ON	compressor and humidifier successfully power ON	Functional
				temeperature = 24	compressor and humidifier power ON	compressor and humidifier successfully power ON	Functional

The table above shows the functional testing of the Arduino Uno microcontroller that controls the temperature of the plants inside the garden, the condition statement was tested working successfully after the temperature sensor sends different value such as temperature equal or lower than 22 that the compressor and humidifier is in the low state or power OFF or temperature equal or higher than 23 will power ON the compressor and humidifier as being set in the code.

4.5.1.3 Alpha Testing

Table 13**:** Digital Garden System Alpha Testing Result**.**

The University of Mindanao

Alpha Testing Criteria (Adviser)

Thesis /Capstone Title: **DIGITAL GARDEN SYSTEM**

Group Members:

Product Quality	**Weight (100%)**	**Score**
a) Reliability, proper functioning as specified and expected.	10%	8%
b) Robustness, acceptable response to unusual inputs, loads and conditions.	10%	7%
Functional testing: execute each use case, use case flow, or function, using valid and invalid data with an objective to verify that:		
1) The expected results occur when valid data is used.	10%	8%
2) The appropriate error / warning message are displayed when invalid data is used.	10%	8%
Functionality ▪ Suitability ▪ Accuracy ▪ Interoperability ▪ Compliance ▪ security	10%	9%
Reliability ▪ Maturity ▪ Fault-tolerance ▪ Recoverability	10%	8%
Usability ▪ Understandability ▪ Learnability ▪ operability	10%	9%
Efficiency ▪ Time behavior ▪ Resource behavior	10%	8%
Maintainability A set of attributes that bear on the effort needed to make a specified modified modification.	10%	9%
Portability A set of attributes that bear on the ability of software to be transferred from one environment to another.	10%	8%
Total		82%

The table above shows the alpha testing conducted from the project developer, adviser, and skilled tester's perspective. The developer installed and configured the monitoring application in blynk software. The mobile application can handle and run the monitoring application smoothly because it is multiplatform. Moreover, Digital Garden System has web-based monitoring apps tested in the browser to ensure its workability.

The developer tested every device connected to the Digital Garden System to guarantee its performance in producing an artificial environment for the plants inside the garden. Also, the testing of the monitoring application to ensure that all features of the application were operational. The product quality composed of Reliability rated 8% out of 10% total Weight and robustness that obtain 7% out of 10%, which means that the Digital Garden System quality. Furthermore, the functional testing is breakdown into different factors like the accuracy response of the web-based and mobile monitoring applications. The mobile application can display an error message when inappropriate data is input, which both obtains 8% out of 10% total weight, moreover, the functionality, usability, and maintainability are scored 9% out of 10%, the Reliability, Efficiency, and portability are rated 8% out of 10% total weight. The alpha testing resulted in a weighted mean of 82%, which means that the Digital Garden System is Functional.

4.5.1.4 Beta Testing

Table 14**:** Digital Garden System Beta Testing Result**.**

The University of Mindanao

Beta Testing Criteria (Clients)

Thesis /Capstone Title: DIGITAL GARDEN SYSTEM

Group Members:

Product Quality	Weight (100%)	Score
a) Reliability, proper functioning as specified and expected.	5%	4%
b) Robustness, acceptable response to unusual inputs, loads and conditions.	5%	4%
c) Efficiency of use by frequent users.	5%	4%
d) Easy to used even for the frequent users.	5%	4.2%
Functional testing: execute each use case, use case flow, or function, using valid and invalid data with an objective to verify that:		
1) The expected results occur when valid data is used.	10%	8.9%
2) The appropriate error / warning message are displayed when invalid data is used.	10%	8.6%
Functionality ▪ Suitability ▪ Accuracy ▪ Interoperability ▪ Compliance ▪ security	10%	8.4%
Reliability ▪ Maturity ▪ Fault-tolerance ▪ Recoverability	10%	9.8%
Usability ▪ Understandability ▪ Learnability ▪ operability	10%	9.6%
Efficiency ▪ Time behavior ▪ Resource behavior	10%	8.4%
Maintainability A set of attributes that bear on the effort needed to make a specified modified modification.	10%	9.8%
Portability A set of attributes that bear on the ability of software to be transferred from one environment to another.	10%	9.6%
Total		89.3%

The Beta Testing comes from the client's point of view to prove that the plant can grow inside the controlled environment. The developer performs beta testing during the deployment of the application to the College of Agriculture in CFCST. The developer administered the questionnaires to the eleven agriculture students, teachers, and agriculture experts from the LGU, which resulted in relatively higher compare to alpha testing. The beta testing questionnaire is almost related to the alpha testing, consisting of product quality and functional testing factors. Thus, examining the product quality improved the efficiency and easy-to-use elements. Moreover, the reliability, robustness, and efficiency associated with the web-based monitoring application obtain 4% from the total weight of 5%. The easy-to-use elements associated with web-based monitoring applications obtain 4.2% out of 5% total.

Furthermore, the encoded data accuracy resulted in a web-based scored of 8.9%. The mobile monitoring application displays an error message when invalid data is detected, which obtain 8.6% out of 10% total weight.

The functionality and efficiency of the Digital Garden System both obtain 8.4% out of 10% total weight, the Reliability and maintainability both scored 9.8% out of 10% total weight, lastly, the usability and portability both obtain 9.6% out of 10% total weight. The beta testing total score obtains 89.3% out of eleven respondents, which means that the Digital Garden and monitoring application is functional.

4.5.2 Deployment

The Digital Garden System Provides an experimental study of plant growth characteristics under a controlled environment from the College of agriculture. The prototype can help the College of agriculture to determine the difference between traditional outdoor gardening and indoor gardening using artificially controlled climate with lettuce and strawberry plants through research.

4.5.2.1 Project Presentation

The project successfully underwent a different testing process to ensure it is fully functional. The developer conducts a project presentation from the College of Agriculture, which is the primary client of the project. The faculty and dean of the College approved and verified the project's reliability.

4.5.2.2 Letter approval

The project already introduces to the client, which is the College of agriculture. The College is interested and prepares to adopt the project for future study purposes. The developer prepared and forwarded the letter address to the dean of agriculture for the proper project deployment.

4.5.2.3 Information drive

The developer introduced the Digital Garden System to the client. The developer presented all the specific devices and their function to produce and control the artificial environment. Moreover, the developer also introduces the mobile and web-based monitoring application to monitor the plants' status and environment inside the garden. All the features are introduced to the clients to understand every function of the application.

4.5.2.4 Project turnover

The developer planted a strawberry and lettuce inside the garden and formally deployed the project at the College faculty office after the letter's approval.

4.5.3 Results and discussion

The Digital Garden System undergone successfully four testing process, the white box, black box, alpha and beta testing

The controlled temperature and artificial climate have been long used in the dry country to grow plants inside the greenhouses, this technique is used to avoid the pest to penetrate into the plants and control the heat of the sunlight. The Digital Garden System is portable device that can grow plants like strawberry and lettuce with artificial climate, the device can be placed inside the house, office or condominium, the device is perfectly suited to the people who wanted to grow their own vegies.

4.5.3.1 White Box Testing Result

the white box testing was conducted from the programmer's perspective to examine and ensure that the code is free from bugs. All the codes are operational from the process to display the monitoring application from the mobile phone web-based monitoring of the Digital Garden system. The developer invited programmers and IT experts to examine every block of code from the Arduino Uno, node MCU and PHP scripts that display the web-based monitoring.

The Arduino Uno underwent white box testing to examine every block of codes that are fully functional to produce controlled temperature inside the garden. The tester opens Arduino IDE to check the code inside the microcontroller that can display the actual temperature to the serial monitor from the BDS18B20 temperature sensor. The condition statement also tested functional after the sensor sense higher than 23 degrees and the compressor power. After the sensor sensed the garden's environment, the condition statement is successful below 22 degrees, the compressor power off. The Arduino Uno obtain a passing rating after the code.

Moreover, the node MCU is functional after it was tested to ensure code integration to the blynk application. The tester opens Arduino IDE software and checks the code that sends the temperature and humidity from the DHT11 sensor to the blynk application. The code that controls AC light dimmer device is also tested and obtains a passing rating from the tester. Furthermore, the tester also tested the website script that displays the temperature and humidity from the DHT11 sensor. The tester examined the website's homepage that successfully shows the temperature and humidity through insert scrip that gets the data from the DHT sensor from the node MCU. The filter button code was also tested after the tester input date and time from the website and displayed the filtered temperature and humidity. The mobile and web-based monitoring successfully passed the test.

4.5.3.2 Black Box Testing Result

The black box testing ensures all the system feature is appropriately working from the sensors to the data displayed in the mobile and web-based monitoring application.

The black box testing was conducted from the user's point of view. The developer invites selected participants from the College of Agriculture to test the mobile and web-based application. The black box testing contains the functionality testing of all the mobile and web-based monitoring application features. The user of the digital garden system monitoring application is from the College of Agriculture faculty. The user checks all the features of the monitoring application, including the temperature and humidity display, the video display of the application from the garden, and the light intensity adjuster. The tester finds out all the mobile monitoring application is fully functional. Moreover, the web-based monitoring application humidity and temperature on the homepage are displayed accurately. The web page that can save the temperature and humidity to the database is functional. The filter button that shows the filtered data from the database is working. Furthermore, the Arduino UNO microcontroller that controls the temperature inside the garden functions well.

4.5.3.3 Alpha Testing Result

The Digital Garden System successfully passed the alpha testing that is conducted from the developers' perspectives, all the device and monitoring application of the project is working properly to produce controlled temperature and view the plant status from the mobile and web-based monitoring application.

4.5.3.4 Beta Testing Result

The Digital Garden System was tested and successfully passed from the users' point of view, the user finds that the project is working and successfully grow the plants like lettuce and the strawberry inside the device with controlled climate, the user also can view the plant status from the mobile and web-based monitoring application

4.5.3.3 Plant Growth

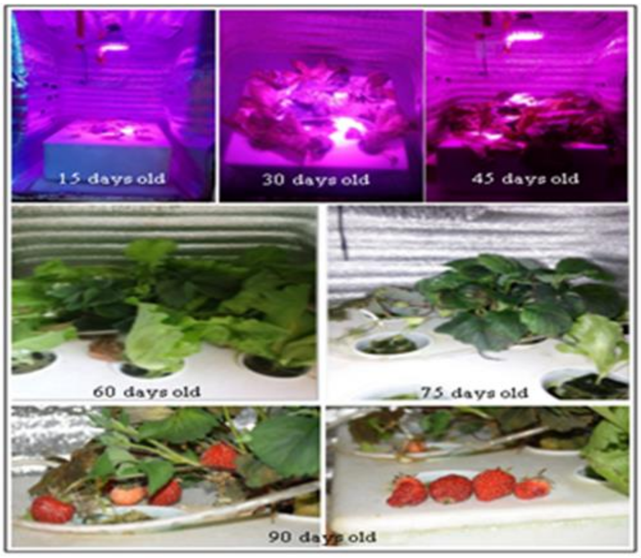

Figure 19: Hydroponics Plant progress.

The figure shows the plant progress inside the Digital Garden system. It shows that the plant is successfully growing with the use of an artificial environment. The lettuce harvesting period is at 45 days old. The strawberry started flowering in 60 days and harvested within 90 days. The Digital Garden System alpha testing obtain a total score of 82% out of 100% total weight, which means that the device passed the diagnostic on quality and functionality. Therefore, the software is reliable, and all the features are working accurately. The software and the device are also reliable, efficient, easy to use and maintain. Additionally, beta testing at the College of Agriculture, the experiment site, was successfully administered by the developer. The beta testing resulted in a weighted mean of 82.9%, which means that the project is appropriately working to grow lettuce and strawberry inside the garden system. The mobile and web-based monitoring applications are reliable, functioning, and responsive. The monitoring application displays and stores data accurately and secured. The mobile application is also compatible with different android versions. The mobile and web-based monitoring applications are very user-friendly for the user from the College of agriculture.

5. Conclusion and Recommendation

5.1 Conclusion

Based on the testing/s conducted, the project developer concluded that the Digital Garden System produces a proper environment that successfully grown lettuce and strawberry. All the device connected to the project is working correctly. The mobile and web-based monitoring application successfully displayed the plant status inside the garden. During the beta testing, the recipient of the project, which is the College of Agriculture, the user conveniently monitors the plant status inside the garden online through mobile and web-based monitoring applications. The developer concluded that a Digital Garden system is beneficial for growing lettuce and strawberry plants indoors utilizing closed cubicle as planting area using hydroponics technique. The LED grow light representing the plant's sunlight is needed to be installed inside the garden for the plant to grow. In conclusion, the garden has an excellent temperature using the compressor and air pump for the oxygenation. The humidifier device can also enhance plant growth inside the garden. The developer concludes that the microcontroller helps manage all the devices connected to control the garden environment and monitoring application. The AC light dimmer device that adjusts the light intensity can be helpful to control the light based on the plant needed. The HTML and PHP development tools are also suitable to display and stored data on the web. The filter button from the web-based can conveniently display to trace the stored humidity and temperature data from the SQL.

5.2 Recommendation

According to the agriculture experts who are the clients of this project, the digital garden system must be energy-saving to reduce costs. It is also highly recommended that the Digital Garden system must be used for plats cloning. Therefore, this project is ready for commercialization.

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