

West Visayas State University
COLLEGE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY
La Paz, Iloilo City

INTERNET-OF-THINGS INVENTORY MANAGEMENT SYSTEM FOR
ULTRA-LOW BIOFREEZER IN MQTT FRAMEWORK

An Undergraduate Thesis
Presented to the Faculty of the
College of Information and Communications Technology
West Visayas State University
La Paz, Iloilo City

In Partial Fulfillment
of the Requirements for the Degree
Bachelor of Science in Information Technology

by
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Paul Adrian D. Soncio
Jose Mari C. Wong

June 2022

West Visayas State University
COLLEGE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY
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Approval Sheet

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June 2022

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Acknowledgment

This research paper will not be possible without the guidance of various people who never failed to support the researchers in every endeavor especially during the conduct of the study.

Their parents and guardians, Mr. Loijie Amio, Mrs. Edelyn Amio, and Mrs. Rosemarie Amio Aclaro, Mrs. Mary Ann D. Castro, Mrs. Georgina C. Sevilla, Mrs. Jacqueline Wong, and Mr. Benedict Wong, Mrs. Lolita D. Soncio, and Mr. Ronnie G. Soncio, for the financial, emotional and moral support that they had offered since the day of their research study;

Dr. Evans B. Sansolis, thesis adviser, for all the help, guidance, and patience;

Mr. Shem Durst Elijah Sandig and Mr. Ralph Voltaire Dayot, for the help, advice, and valuable ideas they gave.

Dr. Ma. Beth Concepcion and Mr. Cyreneo Dofitas Jr. and the rest of the faculty and staff of College of Information and Communications Technology, for their helping hand and limitless support;

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┌
That friend, for the help, knowledge, support, time,
accommodation to his home, and encouragement he gave to
the group;

BSIT 4A, for their emotional and financial support;

The West Visayas State University, for allowing them
to experience IT Training and for molding them to become
responsible citizens of the society;

All these things will never be possible without the
guidance of the Almighty God. To God be the Glory!

To all of them, this humble work is heartily
dedicated.

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Amio, Ayrra Jane R.; Castro, Mc Kelly D.; Sevilla, Winston C.; Soncio, Paul Adrian D.; Wong, Jose Mari C.: "Internet-of-Things Inventory Management System for Ultra-Low Biofreezer in MQTT Framework". Unpublished Undergraduate Thesis, Bachelor of Science in Information Technology, West Visayas State University, Iloilo City, Philippines, June 2022.

Abstract

With the increasing number of specimens being stored inside Ultra-Low Biofreezers, the Biological and Physical Sciences Department of the West Visayas State University needs a systematic and reliable way of monitoring inventory and the fluctuation of the temperature inside the biofreezer. Thus, this study aimed to develop an Internet-of-Things Inventory Management System to manage the biospecimen materials in Ultra-Low Biofreezers. The system is composed of an ESP8266 NodeMCU microcontroller and a K-type thermocouple sensor with a MAX6675 module. The researchers utilized a QR Code - integrated Inventory Management Mobile Application with the Cayenne MQTT Service for user notification via email and SMS in case of sudden temperature fluctuations. The system can monitor temperature and record data logs inside the biofreezers.

┌┐
It can also generate a record of inventory load in and load
outs, fluctuations and manifesto reports.

The system was implemented, tested, and evaluated based on usability and effectiveness using the ISO/IEC 25010:2011 Systems and Software Quality Requirements. The Biological and Physical Sciences Department should use the system to assist laboratory personnel to show efficiency in the department's monitoring process for compliance with good laboratory practice.

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CHAPTER 1 INTRODUCTION TO THE STUDY

Background of the Study and Theoretical Framework

Researchers rely on cold equipment such as Ultra-low Biofreezers to maintain the quality of biospecimens. In most laboratory assessments, biospecimens are preserved in ultra-low freezers where temperatures can drop to -80°C . Nonetheless, the quality of these specimens can be disturbed and influenced by the fluctuation in the temperature within these Ultra-low storage units (Powell et al., 2019). The Ultra-low Biofreezer is one of the most important tools used in the laboratory. The biofreezer protects the biological sample by keeping it at a very low temperature. The failure of it not only results in significant financial loss, but can also endanger samples that disrupt critical research.

With the increasing number of biospecimens being stored and monitored inside these Ultra-low storage units, there will be a higher need for a reliable and systematic way to handle these stored specimens (Shukran et al., 2017). In addition to this, an IoT Inventory Management System based on emerging technology to manage the biospecimen in an Ultra-low Biofreezer will be included in the development of the

study. It will also prevent frequent manual handling of biospecimens, as they require biofreezers to be opened temporarily, risking the integrity of biospecimen quality (Powell et al., 2019).

In this research, the main idea is to develop a functional IoT inventory management system for the Biological and Physical Sciences Laboratory of West Visayas State University, to manage the biospecimens in Ultra-low Biofreezers. Figure 1 shows the conceptual framework of the said study. The study is composed of inputs, processes and outputs. The system starts as the thermocouple sensor device installed in the biofreezer sends temperature data to the database and the Cayenne MQTT Service Broker through the IoT gateway. As for the temperature monitoring and inventory management inside the biofreezer, a mobile application is developed by the researchers in order to output the data stored in the database. A Standalone Web System was also made for the Registration, Adding of Item Inventory and QR Generation. The data from the sensor is processed on the Cayenne Service Broker. If fluctuation is detected, it will send an SMS alert or email notification to the admin. The admin will be the Laboratory Head while the users will be the

Research Facilitators of the Biological and Physical Sciences

Department of West Visayas State University.

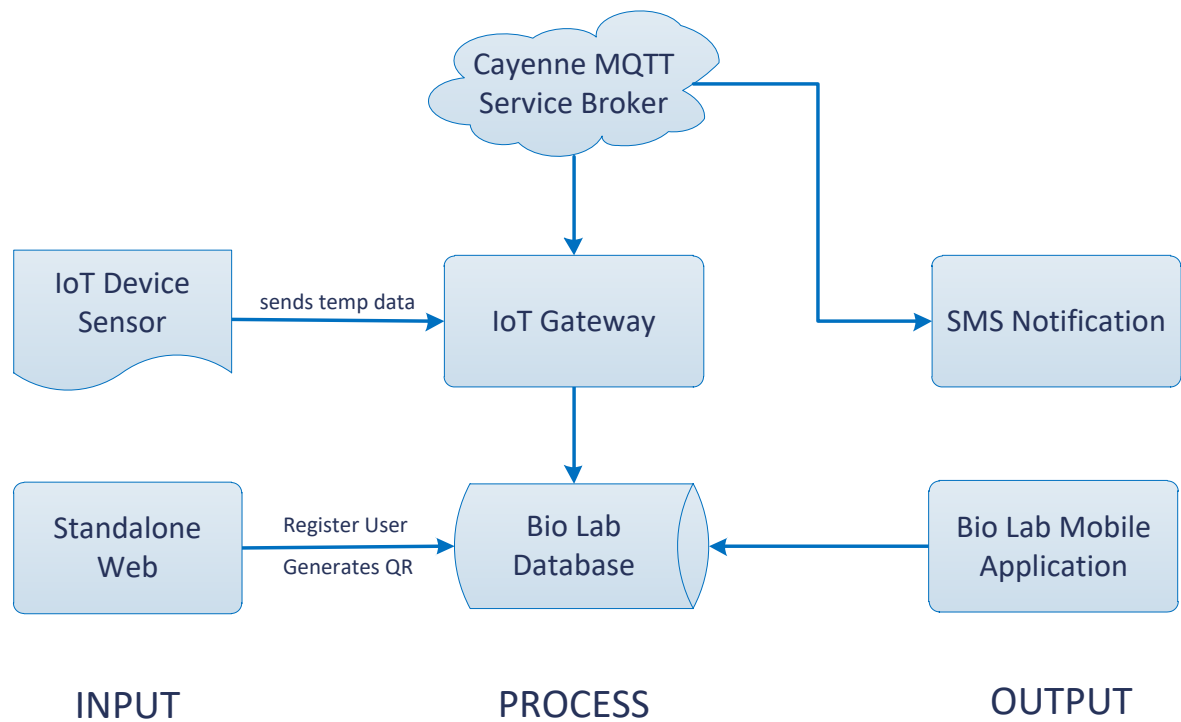


Figure 1. Conceptual Framework

Objectives of the Study

This study generally aims to develop an IoT Inventory Management System based on emerging technology to manage the biospecimen in an Ultra-low Biofreezer.

Specifically, it aims to:

1. Develop a Biospecimens Inventory Management Mobile Application integrated with QR code Technology for an inventory of biospecimens inside Ultra-Low Biofreezers and real-time temperature monitoring.
2. Develop an IoT device using ESP8266 Node MCU that will be able to continuously send temperature data to Biospecimens Inventory Management Mobile Application.
3. Integrate a User Notification System using MQTT Framework and SMS Technology for user notification in an event of sudden temperature fluctuations in Ultra-Low Biofreezers.
4. Implement and test the IoT Inventory Management System, and finally evaluate based on usability and effectiveness using ISO-standard Usability Evaluation Tools.

Significance of the Study

The results of this study will be beneficial to the following:

Biological and Physical Sciences Department of West Visayas State University. Temperature data given will provide efficiency in the department's monitoring process to gather data for compliance for good laboratory practice.

Faculty Researchers and Laboratory Head. The development of the device in the study will help them in managing inventory and monitoring the temperature inside the biofreezer without going to the lab physically. It will also provide efficiency in the department's monitoring process to gather data for compliance for a good laboratory practice.

College of Information and Communications Technology. This study will improve the college in the development of Information Communications Technology education. This study will foster new ways of enhancing knowledge and skills in ICT, thus preparing globally competitive technology students in the future.

Future Researchers. This study will encourage students to apply the knowledge and skills they have obtained in both

┌ areas of hardware and software. This study will contribute to
└ areas where temperature monitoring is required.

Definition of Terms

For better understanding, the following terms were defined conceptually and operationally:

Arduino Integrated Development Environment (IDE) -- is a text editor for writing code and contains a message area, a text console, a toolbar with buttons for common functions, and a series of menus. (Arduino Integrated Development Environment, 2021).

In this study, "Arduino Integrated Development Environment (IDE)" refers to the text editor used for the code construction on the microprocessor.

Biospecimen -- is any natural material from a living organic body, such as tissue, blood, and urine (University of California, 2021).

In this study, "Biospecimen" refers to the samples inside the biofreezer.

┌┐
Cayenne MQTT -- MQTT is the preferred transport and API for sending data to the Cayenne Cloud, or for devices that receive commands from Cayenne (Del C., 2021).

In this study, Cayenne MQTT acts as a broker, managing the various sensor and actuator client devices that wish to send and receive data using the Cayenne Cloud.

I2C LCD Adapter -- A typical I2C LCD consists of an HD44780 based character LCD and an I2C LCD adapter (Lastminuteengineers.com, 2020).

In this study, the "I2C LCD Adapter" refers to the LCD used in the development of the device that will show the current temperature of the biofreezer.

The MAX6675 -- a sophisticated thermocouple-to-digital converter with a built-in 12-bit analog-to-digital converter (ADC). (Maxim Integrated, 2021).

In this study, "MAX6675" refers to the sensor amplifier module used in conjunction from the thermocouple to the microcontroller.

MQTT protocol (Message Queuing Telemetry Transport) -- is a lightweight messaging protocol that was developed by IBM. It uses the pub/sub pattern and translates messages between devices, servers, and applications (Spofford, 2019).

┌ In this study, "MQTT protocol" refers to the ┌
communications satellites to link the sensor on the Ultra-
Low Biofreezer with an emphasis on minimal battery loss and
bandwidth consumption.

My Structured Query Language (MySQL) -- is a freely
available open-source Relational Database Management System
(RDBMS) that uses Structured Query Language (SQL) (Siteground
Hosting LTT, 2021).

In this study, "MySQL" was the database management
system used by the researchers for storing data.

NodeMCU -- is an open-source Lua-based firmware and
development board specially targeted for IoT-based
Applications. (Components101, 2021).

In this study, "NodeMCU" refers to the microprocessor
used in the development of the device.

NodeMCU Base Board -- It extends the GPIO of NodeMCU to
header pins, which also includes the Vin, VUSB, 5V, 3.3V, and
GND. It can be further used for prototyping, with the male to
female jumper wires (Factoryforward, 2021).

In this study, "NodeMCU Baseboard" refers to the
expansion board used in developing the device to ease
prototyping.

┌┐
Notification -- a written or printed matter that gives notice (Merriam-Webster, n.d., 2021).

In this study, "Notification" refers to the notice sent to the user's mobile phone.

QR code -- A quick response (QR) code is a type of barcode that can be read easily by a digital device and which stores information as a series of pixels in a square-shaped grid (Hayes, 2021).

In this study, "QR code" refers to the type of barcode to be scanned from the vials that contain samples inside the biofreezer.

Scrum Methodology -- Scrum is an adaptable, fast, flexible and effective agile framework that is used in the development of Software based on iterative and incremental processes. (Digite, Inc., 2022).

In this study, the "Scrum Methodology" will be the agile framework chosen by the researchers to be adapted in the development of the project.

Thermocouple -- A thermocouple is a simple, robust, and cost-effective temperature sensor used in a wide range of temperature measurement processes (Omega Engineering Inc., 2020).

┌ In this study, "Thermocouple" refers to the temperature
└ probe sensor used in the biofreezer.

Ultra-low BioFreezer -- also known as a ULT freezer, typically has a temperature that ranges from -45°C to -86°C and is used for the storage of drugs, enzymes, chemicals, bacteria, and other samples (Froilabo, 2021).

In this study, the "Ultra-low BioFreezer" refers to the biofreezer used in the Biological and Physical Sciences Laboratory Department in West Visayas State University.

Delimitation of the Study

This study initially proposed a Real-time Monitoring of Shelf Lives of Materials in Ultra-low Biofreezer using the Mean Kinetic Temperature Model. But after further research and careful consideration of the consultant expert's suggestion regarding the monitoring of shelf life, the researchers decided not to go through with it since it was not feasible, timewise.

This study centered primarily on developing a Prototype IoT Inventory Management System based on emerging technology. In addition, the researchers were only limited to developing

┌ a prototype IoT device for temperature monitoring and a mobile
└ application with QR code technology for the inventory
management of biospecimens inside the Ultra-low Biofreezer.
Also, this study promoted paperless transactions in the
temperature monitoring and inventory of the laboratory.

This study also focused on developing a standalone web
system for the admin mainly for the purpose of adding item
inventory and generation of QR code for the biospecimen vials
to be put inside the biofreezer.

This study was exclusively for the Biological and
Physical Sciences Laboratory Department Laboratory Head and
Faculty Researchers of West Visayas State University.

Lastly, this study only focused on presenting the basic
functionality of the IOT temperature monitoring device for
proof of concept, which was to detect temperature readings
that range from 0 to 15 degrees Celsius.

CHAPTER 2 REVIEW OF RELATED STUDIES

Review of Existing and Related Studies

Current Systems

The Biological and Physical Sciences Department of West Visayas State University holds laboratory assessments for ISO accreditations. The Faculty Researchers and Laboratory head are usually in charge of monitoring laboratory equipment such as the biofreezer that contains academic biological samples. For industry-standard, a daily temperature log of the biofreezer is essential. Currently, the department keeps records of the temperature data in the biofreezer manually thus, making documentation difficult. Also, there are issues of power interruptions that result in temperature fluctuation that compromise biological samples. Providing temperature log reports for fluctuations and monitoring renders it difficult when not everyone is available to check for 24 hours a week.

Related Systems

Infant Incubator Temperature Controlling and Monitoring System by Mobile Phone-Based on Arduino. Khotimah et al. (2019) developed a remote system for controlling and monitoring the temperature inside an infant incubator in a

┌
└ compartment on an Arduino-based mobile device. As defined in the study, an infant incubator is a commonly used environmental control and maintenance device in neonatal areas. The system consists of hardware components such as Arduino Uno, HC 05 module, DHT 11 sensor, relays and a heater. The system helps create a more sterile and easier to monitor environment of an infant incubator even when it is far away. In particular, the communication between the hardware located in the incubator and the mobile phone works fine at a maximum distance of 12.25 meters.

The similarity between this study and the system is the process of monitoring temperature via a mobile phone using a microcontroller.

Real-Time Temperature Mapping in Ultra-Low Freezers as a Standard Quality Assessment. Powell et al. (2019) developed a unique monitoring approach based on permanent thermocouple installation and real-time temperature readings of several zones. The researchers utilized an online cloud-based program to monitor temperature fluctuations with 1-minute intervals, and its 24-hour warning system that sends text messages to a predetermined group of users when temperature readings exceed an established threshold.

┌ The similarity of the study with the system is the ┐
approach of using thermocouples for temperature monitoring,
an online cloud-based application to record temperature
variations with a specific interval, and its notification to
a predetermined group of users that triggers in case of
temperature fluctuations.

*Enhancing Chemical Inventory Management in Laboratory
through a Mobile-Based QR Code Tag.* Shukran et al. (2017)
gives an overview of the QR tag inventory system and its
implementation developed at the National Defense University
of Malaysia's chemical laboratory. The major goal of this
study is to develop a standalone application running with a
database that is synchronized with the inventory software
hosted on the computer and connected to a specialized network.
The first step in setting up this centralized system is to
use the documented data available in the chemical laboratory
to create a database. To ensure that the produced application
is dedicated to its core aims, some customizations and
enhancements were made to the open-source QR code technology.
The system's ability to track the position of all inventory
scanned chemical labels was demonstrated at the conclusion of
the study.

┌ The similarity of the study with the system is its
└ process of adding a QR tag inventory system to track the position of materials inside the biofreezer, showing real-time information about scanned biospecimen labels.

Smart Monitoring Temperature and Humidity of the Room Server Using Raspberry Pi and WhatsApp Notifications.
Kurniawan et al. (2019) developed an Internet of Things (IoT) device together with a Raspberry Pi and Wemos DHT Shield wireless sensor where Temperature and humidity log is gathered and stored in a MySQL database and is shown in a real time chart diagram. The users are notified through WhatsApp apps on their mobile devices once an established IoT reaction is triggered.

The similarity of the study with the system is the use of a microcontroller and a temperature sensor for temperature monitoring. Also, the IoT response of giving user notifications via SMS on mobile devices.

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

Description of the Proposed Study

The proposed study aimed to develop an IoT Inventory Management System based on emerging technology to manage the biospecimen in an Ultra-low Biofreezer. The study focused on developing a Biospecimen Inventory Management Mobile Application with the following characteristics:

- a. The system can monitor the real-time temperature of the Ultra-low Biofreezer.
- b. The system can notify the user of temperature fluctuations using MQTT Protocol and SMS Technology.
- c. The system can provide a temperature log over a specific time interval.
- d. The system can manage the inventory of biospecimens inside the biofreezer based on QR codes.

┌

The study also focused on developing a web standalone system with the following characteristics:

- a. The system can add inventory inside the Biofreezer Inventory Management System.
- b. The system can generate a QR code for printing right after adding inventory.

Methods and Proposed Enhancements

Sources of Information

Related Literature. The researchers reviewed past and recent related studies to gather enough information in conducting the proposed study. Documents such as journals, published papers, and articles were referenced and served as a guide to the researchers in the whole duration of the study. The researchers gathered data through web browsing and most of the mentioned related documents were taken and can be found online.

Repositories. The researchers took advantage of the open-sourced codes from online repositories such as GitHub, for reference and to aid in the development of the system. Open-sourced applications that exhibited relevance in the

┌
proposed study were reviewed and utilized in the development
of the application. └

Experiences and Observations. Experiences and observations were the first sources of information in the initial stage of the study. Through the firsthand information from the product owner's experiences and/or observations, the researchers were able to come up with an idea that led to the development of the proposed study.

Evaluation. The software was evaluated based on the ISO/IEC 25010 Standard Software Evaluation Tool. This form is used to evaluate the qualities of a software or system. A form that determines the usability and effectiveness of the application based on the ISO Standard Evaluation Tool was answered by the "product owner" or the laboratory head of the Biological and Physical Sciences Department of West Visayas State University.

Proposed Enhancements

QR Technology. Users can identify and manage materials in the biofreezer by scanning the QR code on vials. Since the system will be integrated into a mobile application, it makes scanning QR easier through mobile camera phones.

┌
Real-time. Laboratory heads and research facilitators
└
can monitor temperature and manage inventory in the
biofreezer real time.

User Notification. In case of temperature fluctuations,
notification will be sent to the email and SMS of a
predetermined set of users.

Convenience. Unlike other related and existing
developmental studies, the system can be accessed on an
android mobile phone. No other specialized hardware is
needed.

Components and Design

System Architecture

The system architecture of the proposed system shows the hardware and software components configuration of the system and how they are connected.

The system starts as the thermocouple sensor device installed in the biofreezer sends temperature data to the database through the IoT gateway. As for the temperature monitoring and inventory management inside the biofreezer, a mobile application is developed. Adding of item inventory, account creation for the laboratory head and faculty researchers, as well as the generation of QR codes for the biospecimen materials will be done by the laboratory head using the standalone web system. Inventory and Temperature data over time will be stored on a MySQL database which can be accessed by both the head and facilitators later on through the Bio Lab mobile application. A QR Scanner feature will also be included in the mobile application for the loading in and out of material from the biofreezer. In case of temperature fluctuations, the data from the sensor device is subscribed and processed on the Cayenne MQTT Service Broker

through the IoT gateway. Depending on the set threshold, the Cayenne MQTT Service will publish a notification via email, and will send an alert via SMS to a predetermined set of users, specifically, the laboratory head and research facilitators of the Biological and Physical Sciences Department of West Visayas State University.

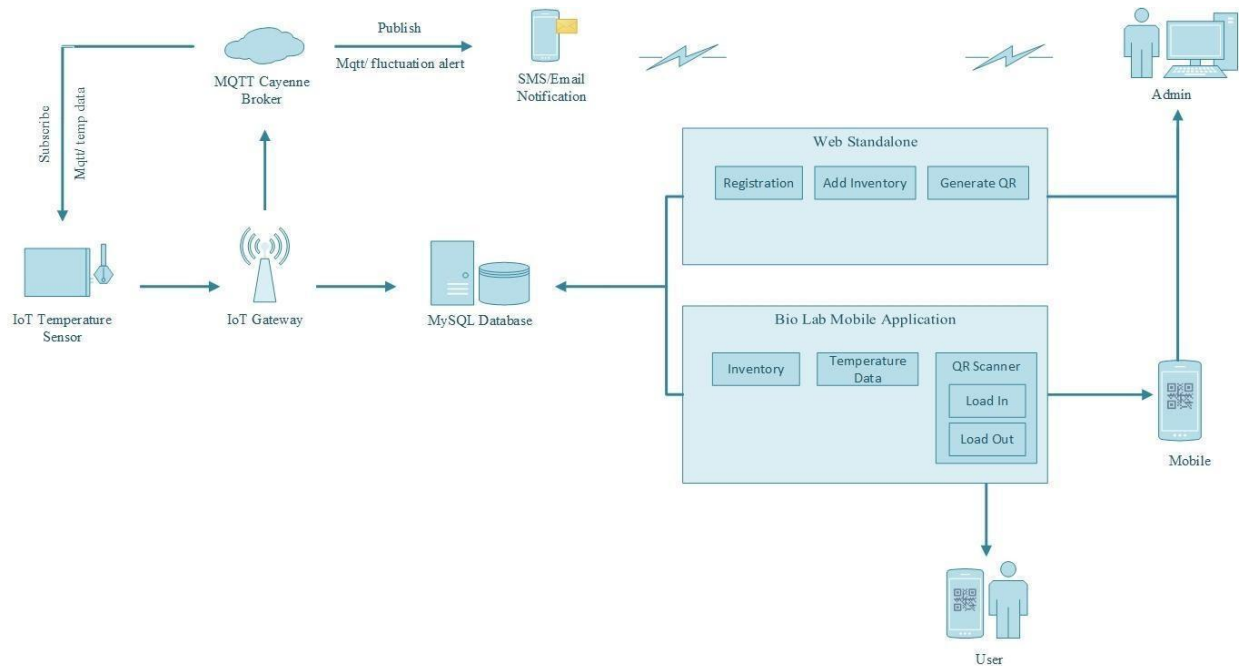


Figure 2. System Architecture

┌
Database Design

The database design of the system illustrates the normalization of the tables used in the actual database of the system. Normalization is the process of organizing the data to minimize redundancy and to isolate data so that additions, deletions, and modifications of a field can be made in just one table and then propagated through the rest of the database via the defined relationships.

tblusers

user id	username	fname	mname	lname	contactno
1	admin	Stephen	Gabayeron	Sabinay	09786547834
2	ayuuhj	Ayrra Jane	Romualdez	Amio	09876567812
3	wongj	Jose Mari	Cabanilla	Wong	09786543512
4	xenonc	Mc Kelly	Doctora	Castro	09876754315
5	clarence.keith	Clarence Keith	Sabinay	Rebaya	09785643451

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userpass
21232f297a57a5743894a0e4a801fc3
21232f297a57a5743894a0e4a801fc3
21232f297a57a5743894a0e4a801fc3
21232f297a57a5743894a0e4a801fc3
21232f297a57a5743894a0e4a801fc3

tblmaterials

matID	dateentry	sampletype	source
1	2021-11-30	RBC	Blood Sample
2	2021-11-30	Nails	N/A
3	2021-11-30	DNA	N/A
4	2021-11-30	Skin Cell	N/A
5	2021-11-30	Synovial Fluid	N/A

collector	location	userid	timelogged
ayuuhj	2	1	2021-11-30
ayuu	4	1	2021-11-30
xenonc	6	4	2021-11-30
xenonc	7	4	2021-11-30
xenonc	8	4	2021-11-30

tblinventorydata

inv	itemid	userid	desc	datetimelogged
1	1	1	in	2021-11-30 20:09:21
2	2	1	in	2021-11-30 20:13:38
3	3	4	in	2021-11-30 20:14:30
4	4	4	in	2021-11-30 20:14:45
5	5	4	in	2021-11-30 20:15:18

tbltemperature

tmpid	temp	timelogged
1	21.23	2021-11-13
2	22.50	2021-11-13
3	33.75	2021-11-13
4	33.50	2021-11-13
5	33.25	2021-11-13

┌
tbl_location

locid	loc_name	val
1	A1	0
2	A2	0
3	A3	0
4	A4	0
5	A5	0

Figure 3. Database Tables of the System

Procedural Design

The procedural design explains the procedural details using any of the graphical or tabular design notations such as a structured flowchart. Illustration of the procedural details on how to operate the system and its processes used are illustrated.

As shown in figure 4, in the proposed standalone web system, the process will start when the admin creates an account for the users who will be using the Bio Lab mobile application. The admin will be the Laboratory Head and the users will be the Research Facilitators. The proposed web system will function solely for adding material inventory and for QR generation. To start, the admin must login. Next, the

admin must input the needed information for the material. After that, the admin decides whether to add it to the inventory or not. Upon adding inventory, the system generates QR code for the admin to print.

As shown in figure 5, in the proposed mobile application, the admin or user must first login. The system will validate, and the admin can now select a process. Users can either view temperature data, inventory logs, scan QR to load in and out materials from the biofreezer.

As shown in figure 6, this figure shows the function of the QR Scanner. The admin scans QR on material vials to load item information and will select a process whether to load it in or out of the biofreezer. The admin can only load in what was loaded out of the biofreezer and can only load out what is currently inside the biofreezer.

As shown in figure 7, the temperature data, where the admin and users manage and view temperature data over time inside the biofreezer. The user can also generate reports that can be downloaded in csv file format.

As shown in figure 8, the inventory logs, where the admin and users manage and view inventory logs as well as generate log reports that can be downloaded in csv file format. A

specific Item Inventory report can only be viewed and generated by the Laboratory head.

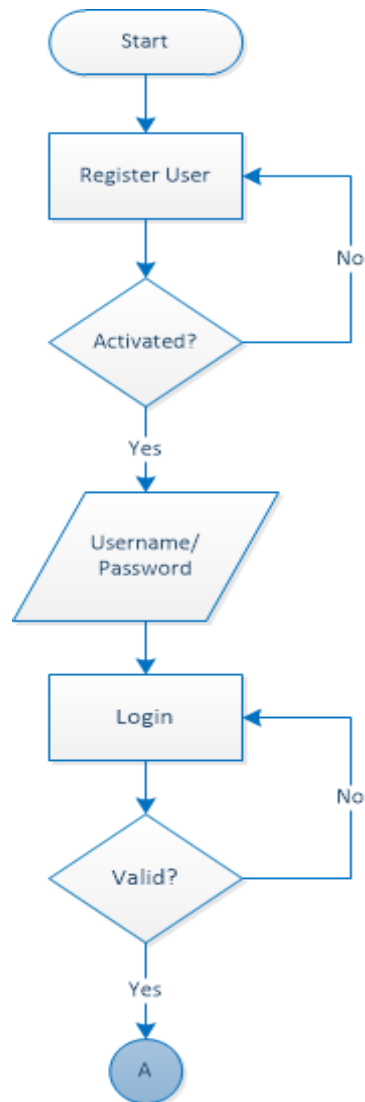
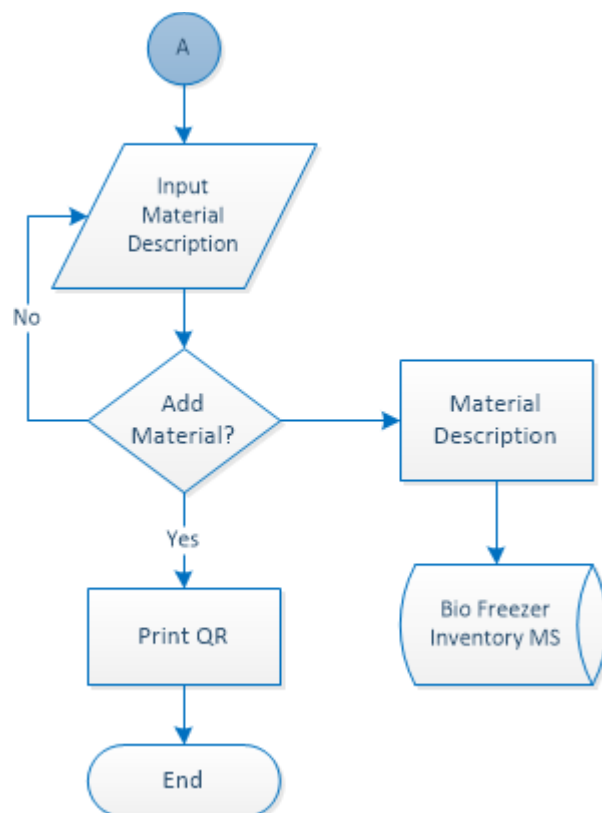


Figure 4. Flowchart of the proposed Standalone Web System for admin.



(Cont..)

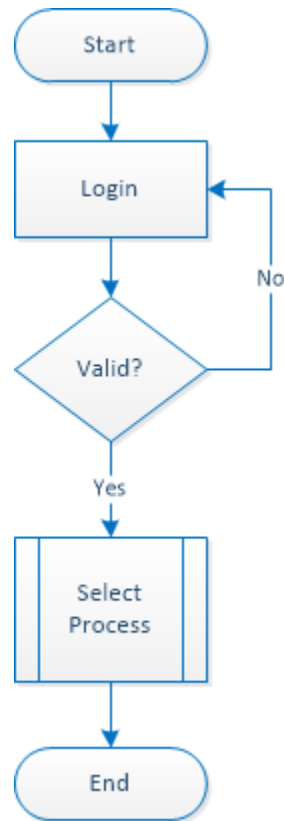
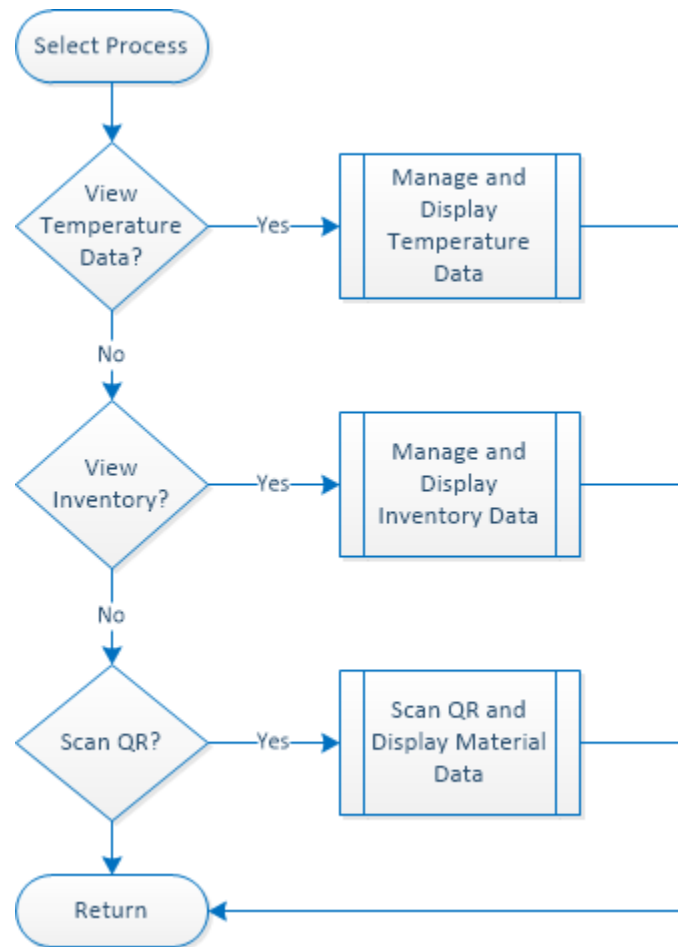


Figure 5. Flowchart of the Proposed Bio Lab Mobile Application



(Cont.)

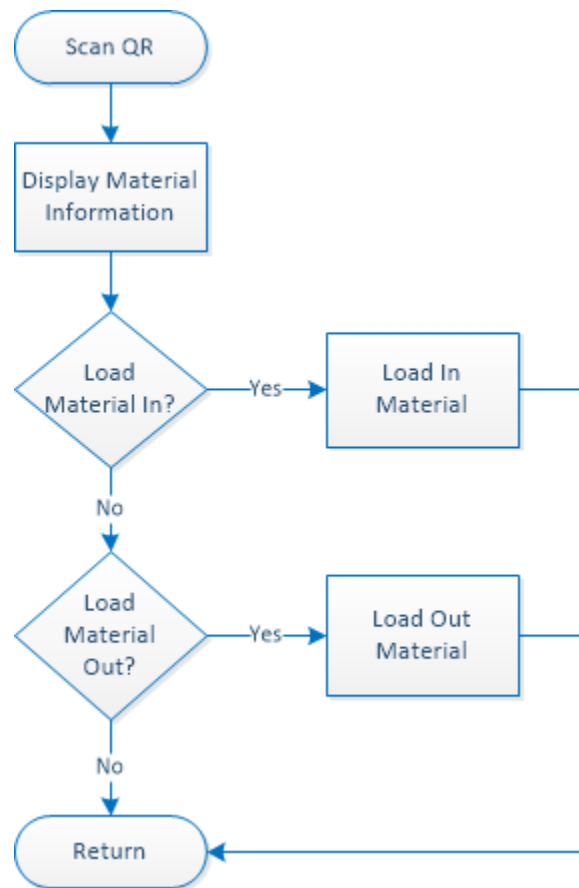


Figure 6. Flowchart of the QR Scanner

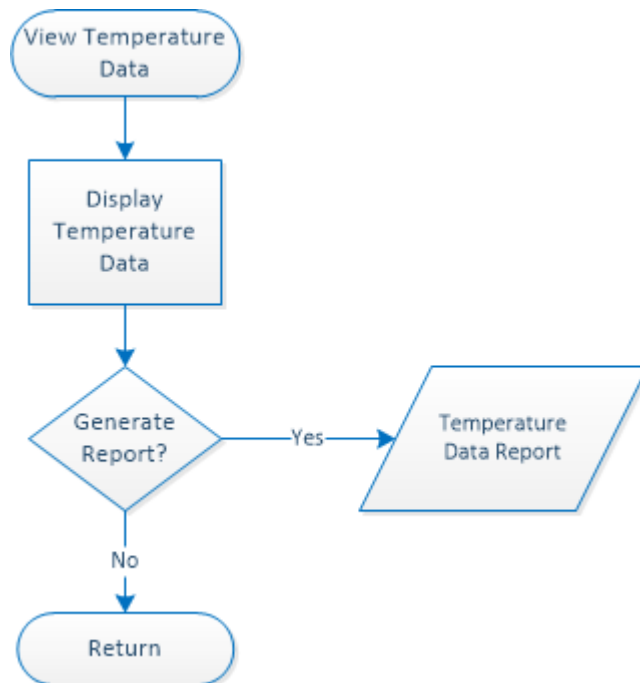


Figure 7. Flowchart of the Temperature Data

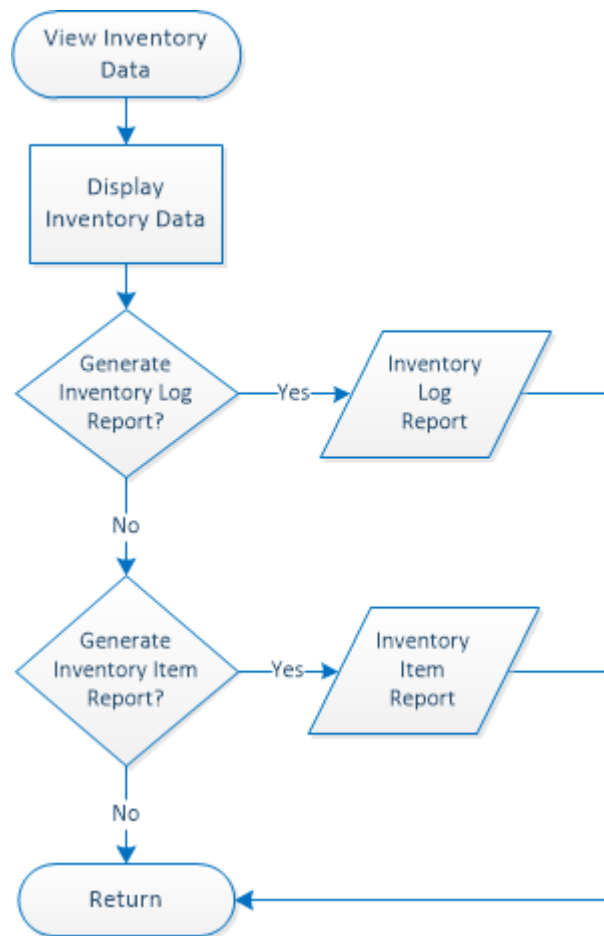


Figure 8. Flowchart of the Inventory Data

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Object Oriented Design

The object-oriented design shows the relationship and interaction between the classes or objects created in the system. As shown in figure 10, the use case diagram specifies the externally visible system behavior from the admin and user perspective. The admin will be the Laboratory head while the users will be the Research Facilitators of the Biological and Physical Sciences Department of West Visayas State University. Both the admin and the user have access to the software and its functions along with the inventory and temperature data. Both can also generate and download reports of the inventory and temperature logs recorded but only the admin can add, edit, and delete item inventory as well as print the QR code needed for the material identification and create an account for a fellow admin or user.

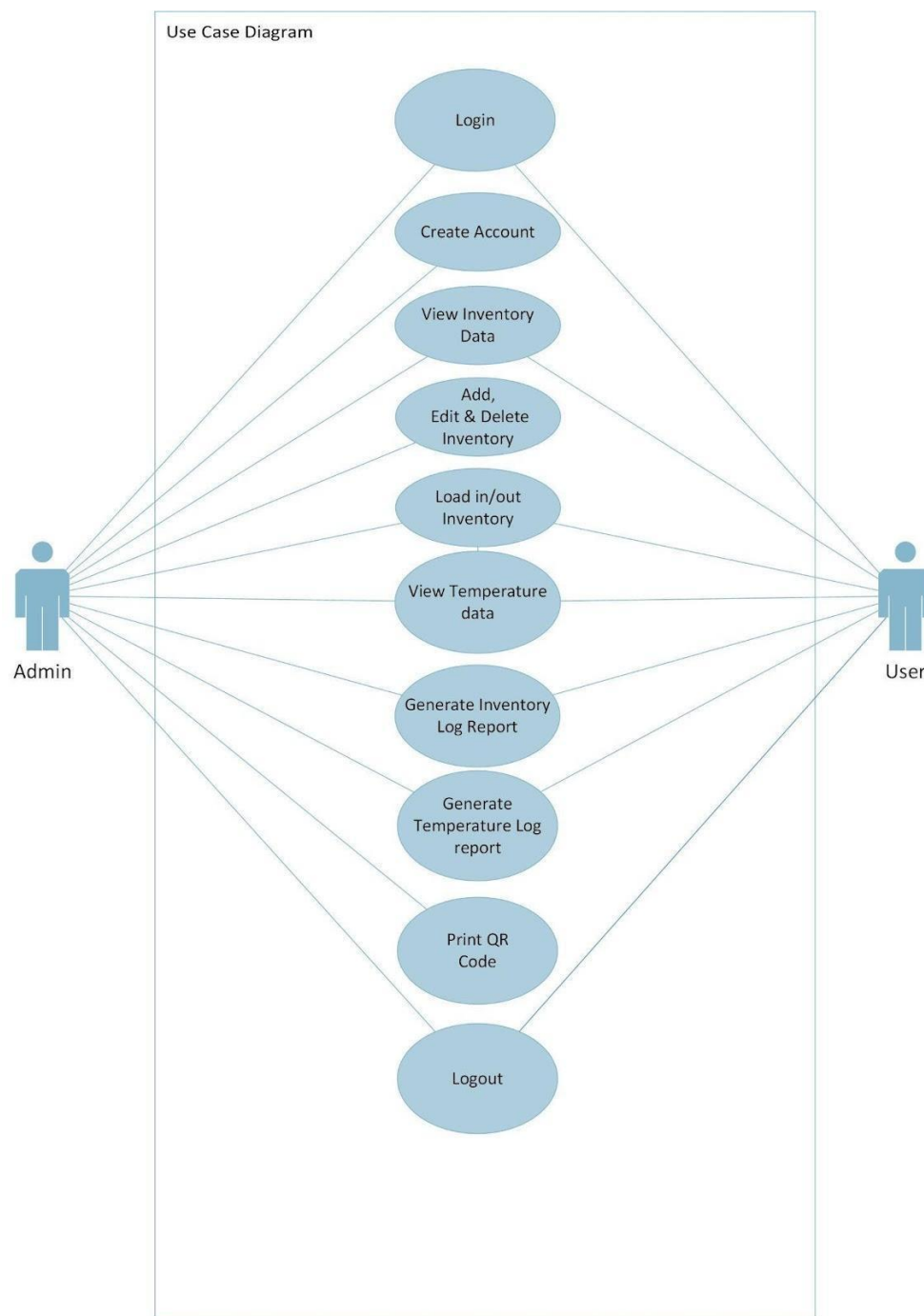


Figure 9. Use Case Diagram

┌
Process Design

The process design maps out the flow of information in the system of the study.

As shown in figure 10, the flow of data is only accessible depending on the type of user that uses the system. The Laboratory Head may obtain the inventory logs, generated QR code, QR load in and out reports, temperature logs, description for biospecimen material and as well as QR load in and out. Furthermore, the Laboratory Head may input the biospecimen material description. On the other hand, the Research Facilitator may acquire the inventory logs, temperature logs, description for biospecimen material and QR load in and out. Both users may input their username and password and the Laboratory Head is required to create not only his/her own account but also that of the Research Facilitator.

As shown in figure 11, the level 1 web diagram shows the specified flow of data that is accessible to the Laboratory Head. The Laboratory Head may register his/her data as well as that of the Research Facilitator using the username and password, user type and contact information and encode the biospecimen material description to the system. Moreover, the

┌ Laboratory Head may secure the inventory logs, generated QR
└ code, QR load in and out reports, temperature logs,
description for biospecimen material and as well as QR load
in and out.

As shown in figure 12, the level 1 mobile diagram specified flow of data that is accessible to both the Research Facilitator and Laboratory Head. The Research Facilitator may login his/her username and password to use the mobile applications feature as well as may utilize QR load out/load in, biospecimen material description, temperature logs, and inventory logs.

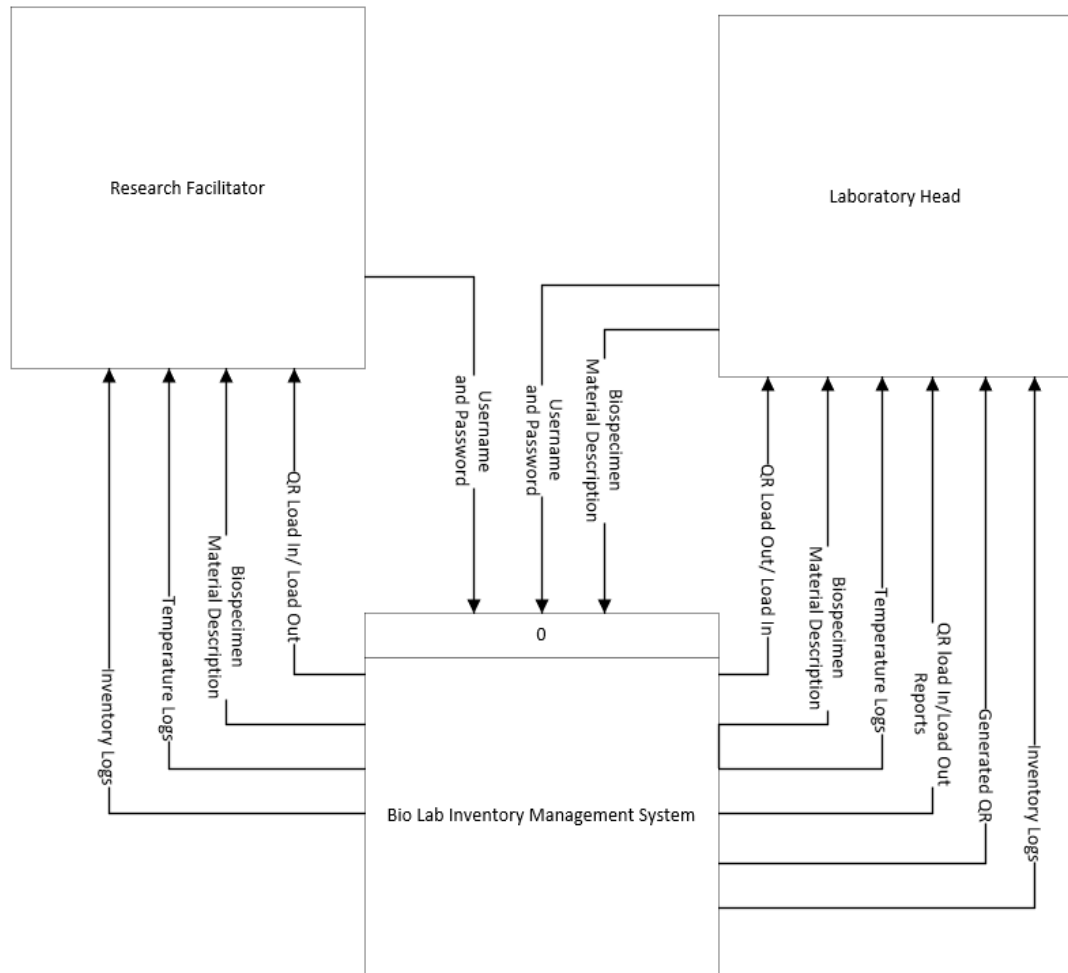


Figure 10. Context Diagram of the System

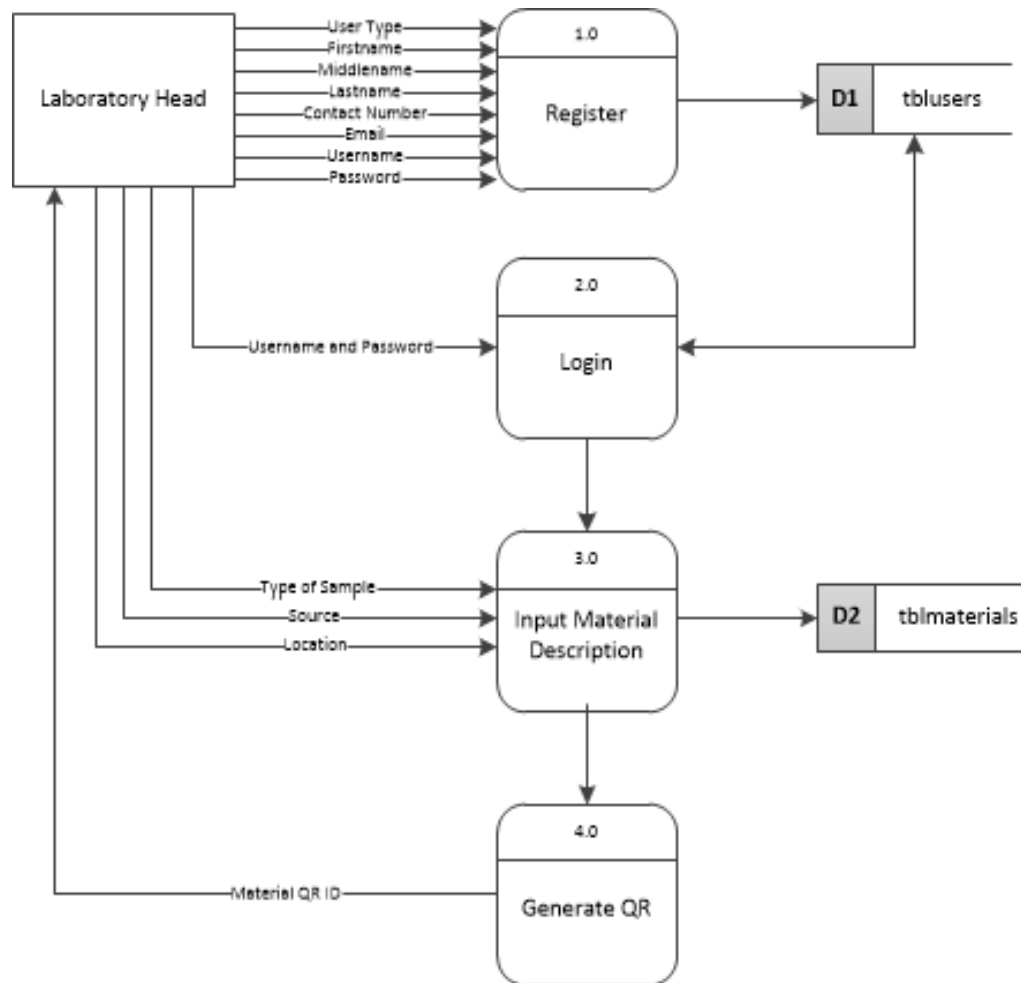


Figure 11. Level 1 Bio Lab Standalone Web System

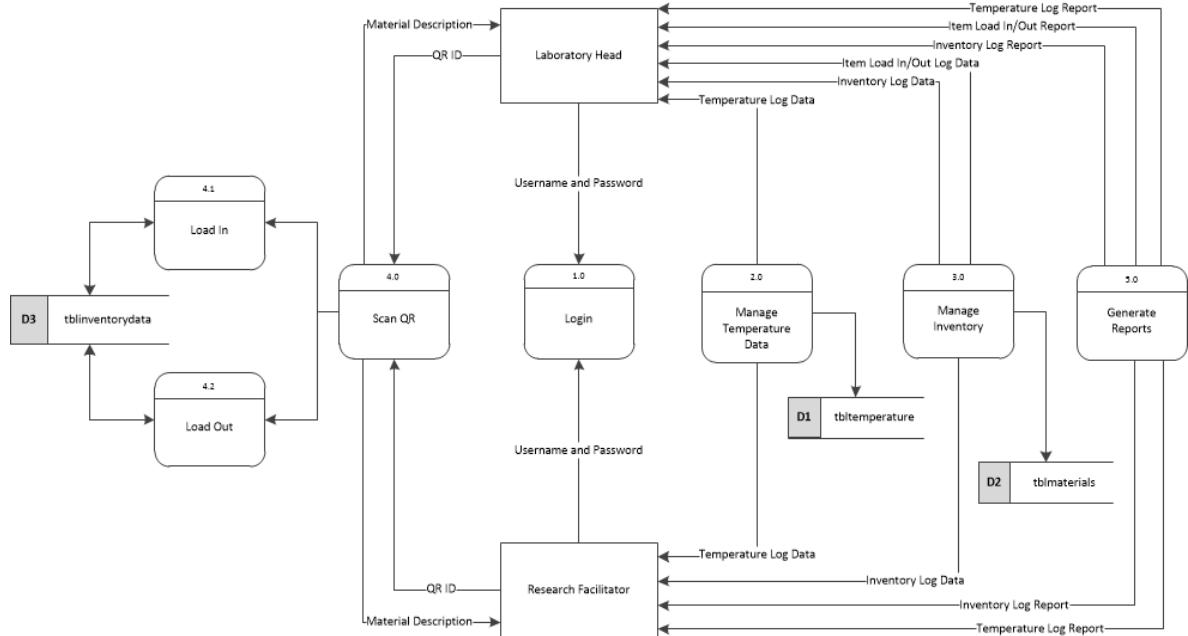


Figure 12. Level 1 Bio Lab Mobile Application

System Development Life Cycle

This study adopts the Scrum agile method where new features are developed incrementally in short sprints. At the end of each Sprint, a potentially usable Increment of product can be made available. This helps the researchers to potentially release a much earlier version of the product in the development cycle enabling benefits and risk to be realized earlier than otherwise may have been possible if the researchers waited for the entire product to be "complete" or

fully finished before a release. As shown in figure 16, the Agile-Scrum Method was composed of the following stages:

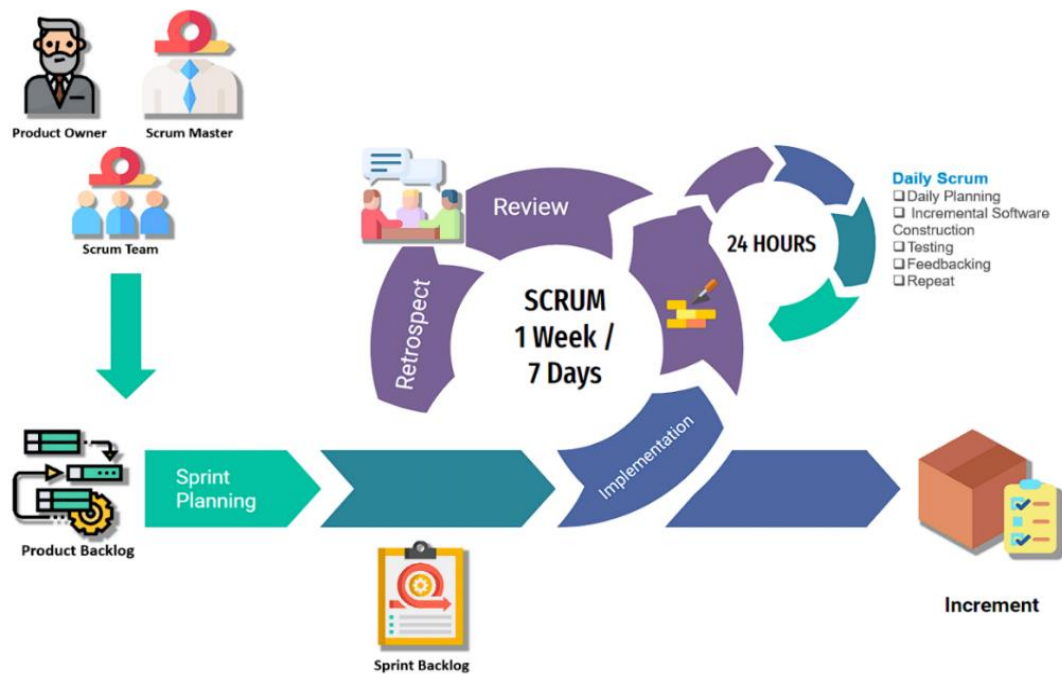


Figure 13. Scrum Agile Method

Maintaining quality is a key principle of development with Scrum. Testing occurs every Sprint, enabling regular inspection of the working product as it develops. This allows the Scrum Team early visibility of any problems and allows them to adjust where necessary. This method encourages active Product Owner or client involvement throughout the

development of this study. Transparency is therefore much higher, both around progress and of the state of the product itself, which in turn helps to ensure that expectations are effectively managed. Other benefits the researchers can get from this method are flexibility, Cost control, Customer satisfaction, and speed to market.

Product Backlog Creation. The Product Owner, scrum master, and scrum team meet to create the final vision of the project. Therefore, a product backlog is created with the full list of features, functions, and requirements needed to build the full final product. For the product backlog of this study the client being the Assistant Professor and Head of Center for Biotechnology and Biomedical Research, administration of West Visayas State University, aims to have a system that can both monitor real-time temperature and notify the user via SMS during temperature fluctuation for Ultra-low Biofreezers and has a QR Code-integrated software application that detects the QR code for the biospecimens. The software application can store and record data logs and can generate a daily record of fluctuations and manifesto reports. All project vision was taken note of by the scrum

┌ master and the scrum team and was able to create a list of
└ features, functions, and requirements needed for the study.

The Product Backlog. The scrum team with the guidance of their adviser came up with an initial system design that utilizes a "Node MCU ESP8266", a "K-Type Thermocouple" with the "MAX6675 module" which is a sophisticated thermocouple to digital converter with a built-in 12-bit analog-to-digital converter, a "Node MCU Baseboard", and a "12c LCD Adapter", all of these composes the Hardware device and is connected to a "MySQL" which is a database management system where the client can use functions such as "add", "delete", and "edit" inventory list and lastly an android application that will output the inventory and temperature data and will have a feature that scan QR codes and can notify the user via SMS.

Sprint Planning and Sprint Backlog Creation. After meeting with the client, the scrum master again meets with the scrum team to discuss, schedule, prepare and plan for the first sprint therefore a sprint planning or a sprint meeting was commenced and sprint backlog is therefore created, within the sprint backlog contains a subset of requirements taken

┌ from the product backlog which were chosen and set to priority
└ to be done first.

Sprint Backlog. The scrum master and the scrum team decided to prioritize the construction of the given hardware components mainly to integrate the NodeMCU ESP8266, the MAX6675, and the 12c LCD Display. The building of the subset requirements indicated in the scrum team's sprint log commences. Within the duration of the sprint, there are daily scrums composed of Incremental hardware components and software code construction.

Testing and Product Demonstration. At the end of each iteration, the scrum master scrum team will hold a meeting to review potential product deliverables. The team then reviewed and continued to improve the incremented final product.

Retrospective and The Next Sprint Planning. After the review meeting, the scrum master again meets with the scrum team to discuss, schedule, prepare and plan for the second sprint therefore a second sprint planning or a sprint meeting was commence and another sprint backlog is therefore created, within the sprint backlog contains a new subset of requirements taken from the product backlog which were chosen to be done and the whole sprint begins again with daily scrums

┌
ending with an increment of the final product and a sprint
retrospective review.

CHAPTER 4 RESULTS AND DISCUSSION

Implementation

The whole system which includes both the IOT temperature monitoring device, and the inventory management system was tested several times to ensure its reliability.

The system was set in the laboratory of the Biological and Physical Sciences Department of West Visayas State University. The researchers were assisted by the Head and the respected staff of the Biological and Physical Sciences Department of the said University.

For the testing, the researchers required any cold storage container whose temperature ranges from 15°C to 0°C, where the temperature measuring device was attached as well as a digital thermometer for comparison purposes. It was where the system acquired the temperature inside the freezer and was processed as input. For the arranged tests, the researchers' goal is to present the basic functionality of the IOT temperature monitoring device for proof of concept, which was to detect temperature readings of cold storage containers.

┌
└

For the installation of the IoT Device, the extending thermocouple probe from the device was inserted inside the provided storage container, in the researcher's case would be the laboratory's Incubator with a built-in temperature probe for comparable temperature readings. Outside the said incubator, the device was attached via a wall mount or placed nearby the container and is plugged to an accessible power source 220w socket using a 9v AC adapter.

For the installation of the Inventory Management System, the researchers required a computer or laptop where it acted as the localhost of the system. A browser of choice was installed in the computer to run the standalone web application. Moreover, the mobile application version was installed in an Android Smartphone. Admins' phone number and email address will be provided for testing the user notification features.

System Inputs and Outputs

The inputs and outputs of the application are fully described below. To start, Figure 14 shows the IoT device thermocouple probe installed on a cold storage for temperature monitoring.



Figure 14. IoT Device thermocouple probe

Figure 15 shows the web login page for the admin where they can either login or register an account for co-admins or users.

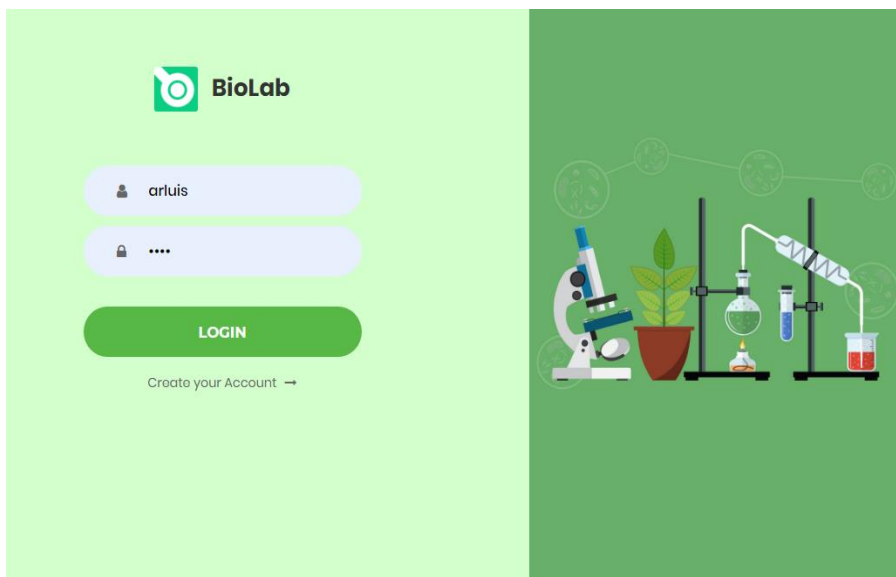


Figure 15. Web Login Page

Figure 16 shows the web registration page where admin registers an account for fellow admins or users.

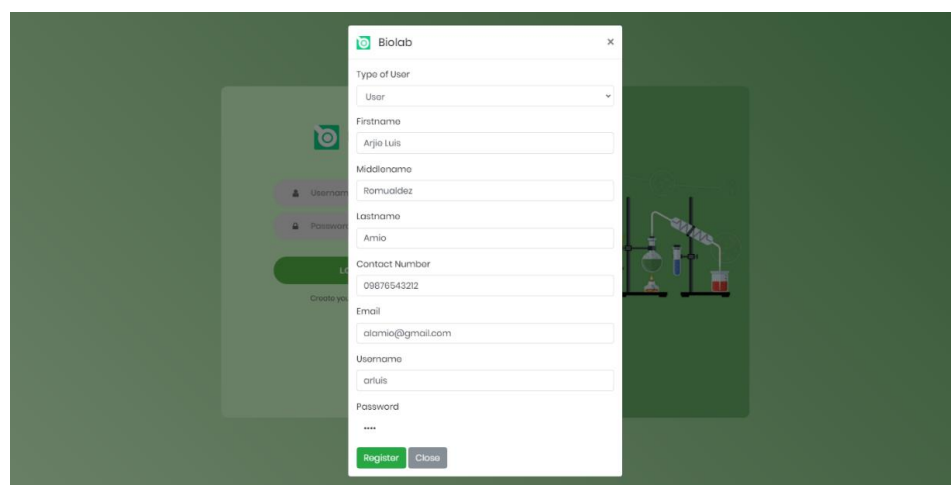


Figure 16. Web Registration Page

Figure 17 shows the mobile application login page for the admin and users where they can login to the Bio Lab.

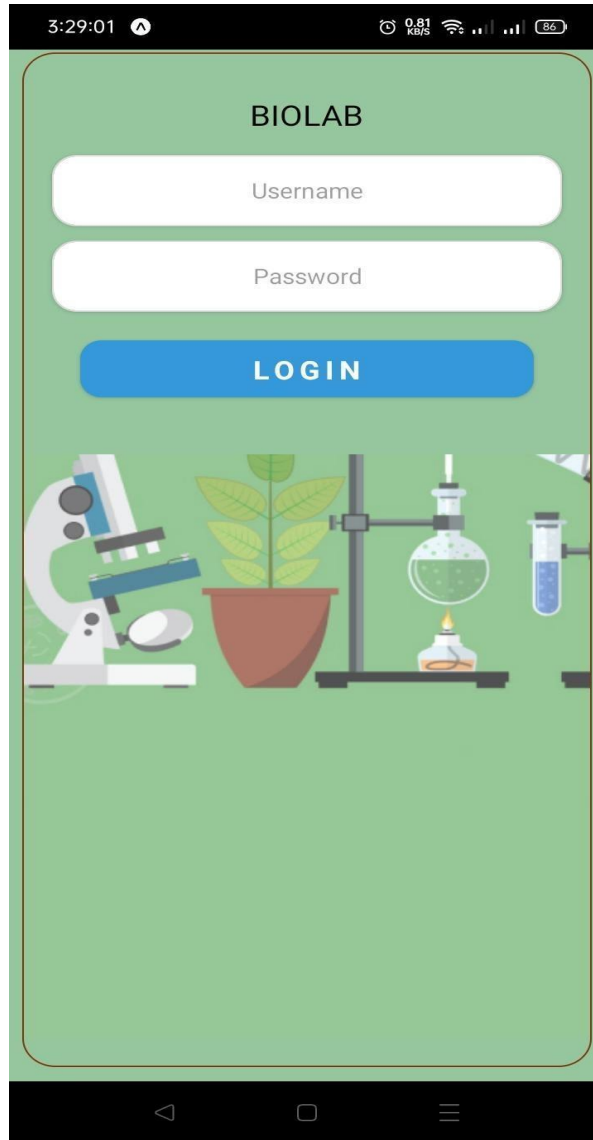


Figure 17. Mobile Application Login Page

Figure 18 shows the web standalone adding of an item inventory for the admin. The admin must input the material description needed for inventory.

The screenshot displays a web form titled "Material Description" with a user profile "Arjo Luis" in the top right corner. The form contains several input fields: "ID:" with the value "00023", "Date:" with "11/23/2021", "Sample:" with "Plasma", "Source:" with "Blood Sample", and "Collector:" with "arjulis". Below these fields is a table with three rows (A, B, C) and five columns (1, 2, 3, 4, 5). Row A has green cells for columns 1, 2, 3, and 5. Row B has green cells for columns 1, 2, 3, and 5. Row C has green cells for columns 1, 2, 3, and 5. At the bottom left, there is a "Location:" dropdown menu with a list of options: A4, B3, B4, C1, C2, C3, and C4. The "C1" option is currently selected. To the right of the dropdown are two buttons: "Reset" and "Save". On the right side of the form, there is an illustration of a person in a lab coat working with scientific equipment.

Figure 18. Web Add Item Inventory Page

Figure 19 shows the adding of inventory, QR code shows up for the admin to print on a recommended sticker paper and to be put on vials for inventory.

Material Description

ID: 00023

Date: 11/23/2021

Sample: Plasma

Source: Blood Sample

Collector: anulis

QR Code

	1	2	3	4	5
A					
B					
C					

Location: B4

Next Save

Figure 19. Web QR Generation

Figure 20 shows the mobile application QR scanner part where the admin and user can Load In and Out materials inside the biofreezer.

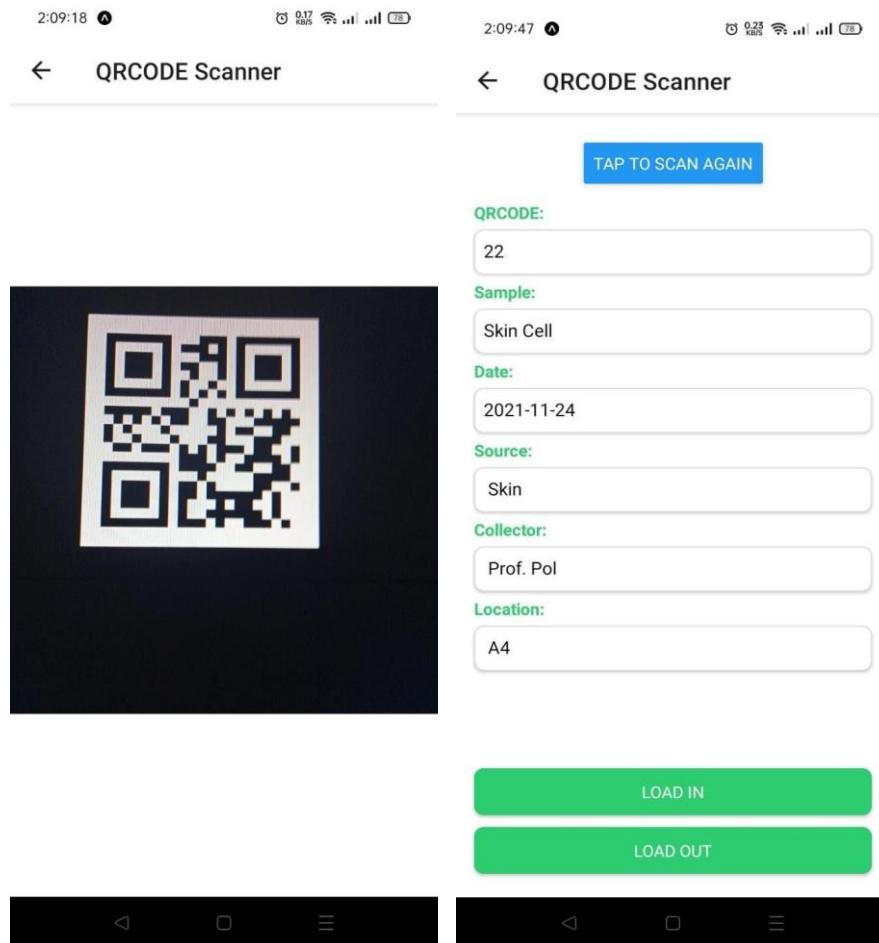


Figure 20. Mobile Application QR Scanner

Figure 21 shows the main menu of the mobile application. This page is where the admin and user have an option to view inventory, temperature data or use the QR scanner.

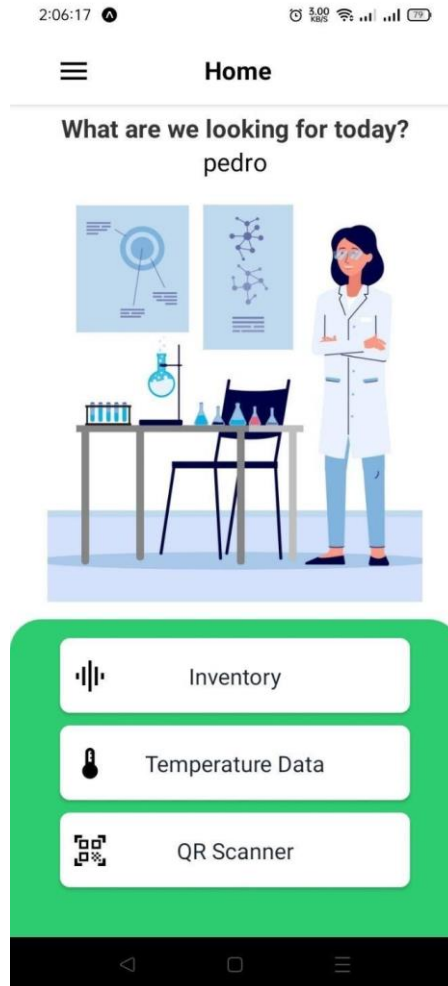


Figure 21. Mobile Application Main Menu Page

Figure 22 shows the mobile application Inventory Page where admin and user can see a list of inventory logs.



Figure 22. Mobile Application Inventory Page

Figure 23 shows the mobile application Temperature Data Page where admin and user can see temperature logs during a specific date and time.

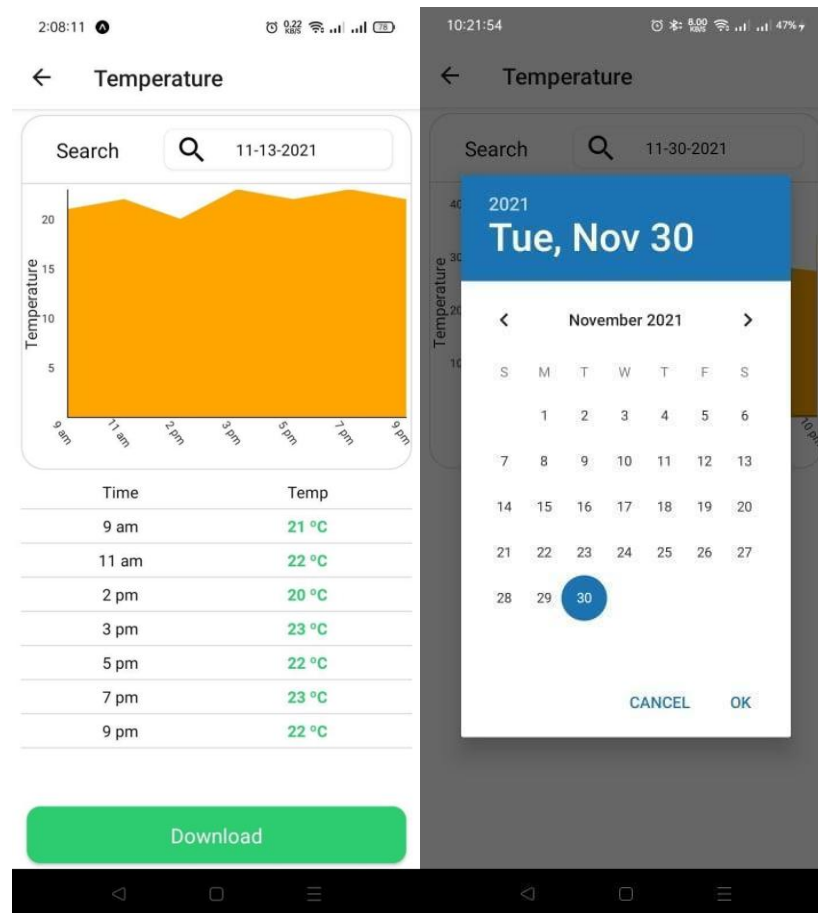
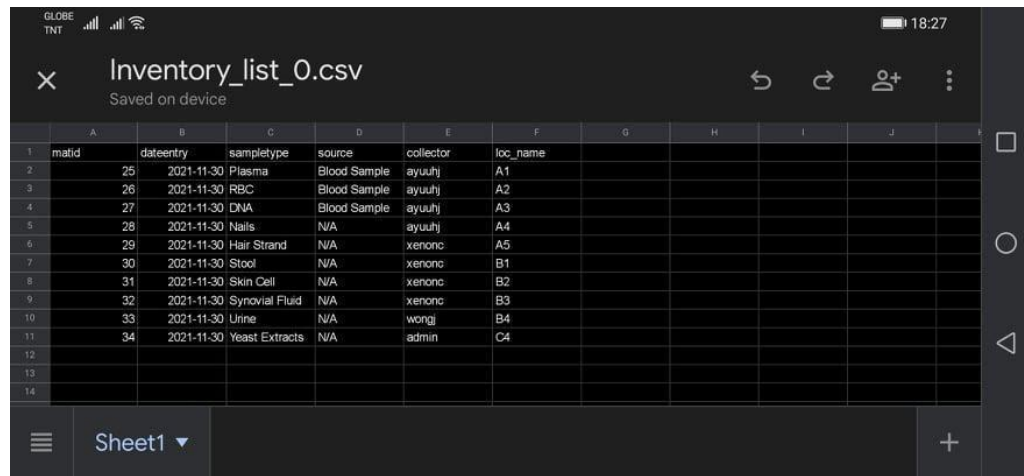


Figure 23. Mobile Application Temperature Data Page

Figure 24, 25, and 26 shows the downloadable reports that are generated through the mobile application which

include the inventory, Item Load In and out and the temperature data log reports. The downloadable reports will be in csv format.



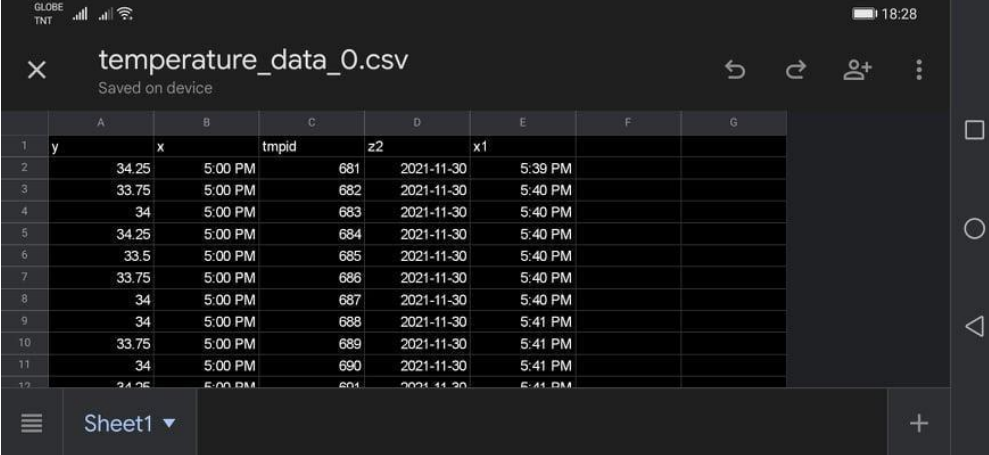
	A	B	C	D	E	F	G	H	I	J
1	matid	dateentry	sampletype	source	collector	loc_name				
2	25	2021-11-30	Plasma	Blood Sample	ayuuhtj	A1				
3	26	2021-11-30	RBC	Blood Sample	ayuuhtj	A2				
4	27	2021-11-30	DNA	Blood Sample	ayuuhtj	A3				
5	28	2021-11-30	Nails	N/A	ayuuhtj	A4				
6	29	2021-11-30	Hair Strand	N/A	xenonc	A5				
7	30	2021-11-30	Stool	N/A	xenonc	B1				
8	31	2021-11-30	Skin Cell	N/A	xenonc	B2				
9	32	2021-11-30	Synovial Fluid	N/A	xenonc	B3				
10	33	2021-11-30	Urine	N/A	wongj	B4				
11	34	2021-11-30	Yeast Extracts	N/A	admin	C4				
12										
13										
14										

Figure 24. Inventory Log Report



	A	B	C	D	E	F	G	H	I
1	inv	sampletype	desc	datetimedlogged	name				
2	33	Hair Strand	IN	2021-11-30 20:15	Castro, Mc Kelly				
3	39	Hair Strand	OUT	2021-11-30 20:31	Sabinay, Stephen				
4	40	Hair Strand	IN	2021-11-30 20:36	Rebaya, Clarence Keith				
5	42	Hair Strand	OUT	2021-12-01 15:25	Amio, Ayra Jane				
6	43	Hair Strand	IN	2021-12-01 16:12	Rebaya, Clarence Keith				
7									
8									
9									
10									
11									
12									

Figure 25. Inventory Item Load in and out Report



	A	B	C	D	E	F	G
1	y	x	tmpid	z2	x1		
2		34.25	5:00 PM	681	2021-11-30	5:39 PM	
3		33.75	5:00 PM	682	2021-11-30	5:40 PM	
4		34	5:00 PM	683	2021-11-30	5:40 PM	
5		34.25	5:00 PM	684	2021-11-30	5:40 PM	
6		33.5	5:00 PM	685	2021-11-30	5:40 PM	
7		33.75	5:00 PM	686	2021-11-30	5:40 PM	
8		34	5:00 PM	687	2021-11-30	5:40 PM	
9		34	5:00 PM	688	2021-11-30	5:41 PM	
10		33.75	5:00 PM	689	2021-11-30	5:41 PM	
11		34	5:00 PM	690	2021-11-30	5:41 PM	
12		34.25	5:00 PM	691	2021-11-30	5:41 PM	

Figure 26. Temperature Data Log Report

Simulation Environment and Scenarios

The first simulation process started when the researchers opened the standalone web application for the creation of either an admin or a user account. The researchers then added an inventory item then prints the QR code generated and labeled it to the vial of the desired specimen or sample for storage. The researchers opened the mobile application and logged in with the registered admin account. Now, the researchers had access to the inventory logs, inventory item load ins and outs, and the temperature data. The admin account could edit and delete inventory data and can also generate reports by downloading a generated csv file. The researchers could also go to the QR scanner portion for scanning to view

┌ certain sample descriptions and has the option to load it in
└ or out if it has been "loaded in" or "loaded out".

The researcher then logged as a user, to test what features the user could access. Same with the admin account, the user account could also see the inventory, temperature data and could use the "QR scanner" built with-in the mobile application and could generate reports. The only thing the user could not access is the load in and out inventory logs.

To assess the functionality of the IoT device, the device was installed inside a consumer grade refrigerator whose temperatures ranged from 0c to 15c in-order to measure the reliability and consistency of the temperature readings. The thermal probe was inserted inside the refrigerator's chiller and was left inside for one hour. The device was set to get temperatures with a 10 second interval.

For the second simulation, a consumer grade icebox was prepared and then filled with ice. A digital thermometer is then inserted inside together with a thermocouple probe for comparison. The built cold storage container was then enclosed or sealed properly in-order to make sure proper simulation temperatures were generated.

┌ To assess the functionality of the notification alert, ┐
the researchers manipulated environmental variables that
caused the observed temperature readings to fluctuate inside
the storage container such as opening the storage and exposing
it to the outside temperature and by exposing the probe to a
lighted candle. The manipulation of the temperature triggered
an Email and SMS alert notifying to the user that the current
parameter or threshold that had been set has been reached.
For simulation purposes the researcher had set the limit to
38.5c, any temperature beyond that will cause a trigger event.
The MQTT then sent E-mail and SMS alerts to the user.

Results Interpretation and Analysis

The device was tested on a commercial grade refrigerator and was left for 1 hour. The researchers had inserted the thermocouple through the door and had it sealed completely in order to observe and avoid any unnecessary sudden fluctuation in the temperature inside the refrigerator.

For 10 minutes the researcher had observed that the device was reading a temperature at around 7 to 9 degrees Celsius as indicated by the device's onboard LCD screen. By the 30-minute mark the temperature reading stayed constantly at around 9 degrees Celsius. After 50 minutes had passed, the researchers then removed the thermocouple inside the refrigerator and exposed it to room temperature which resulted a gradual increase in the temperature. By the 55-minute mark the researcher then tested the notification function of the device by exposing the thermocouple next to a cigarette lighter until the temperature had reached the set threshold.

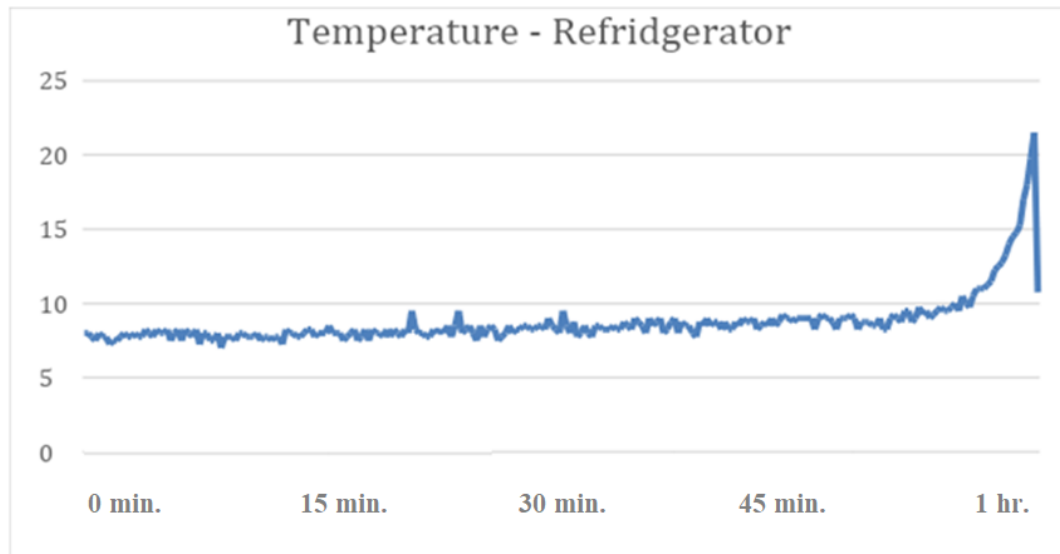
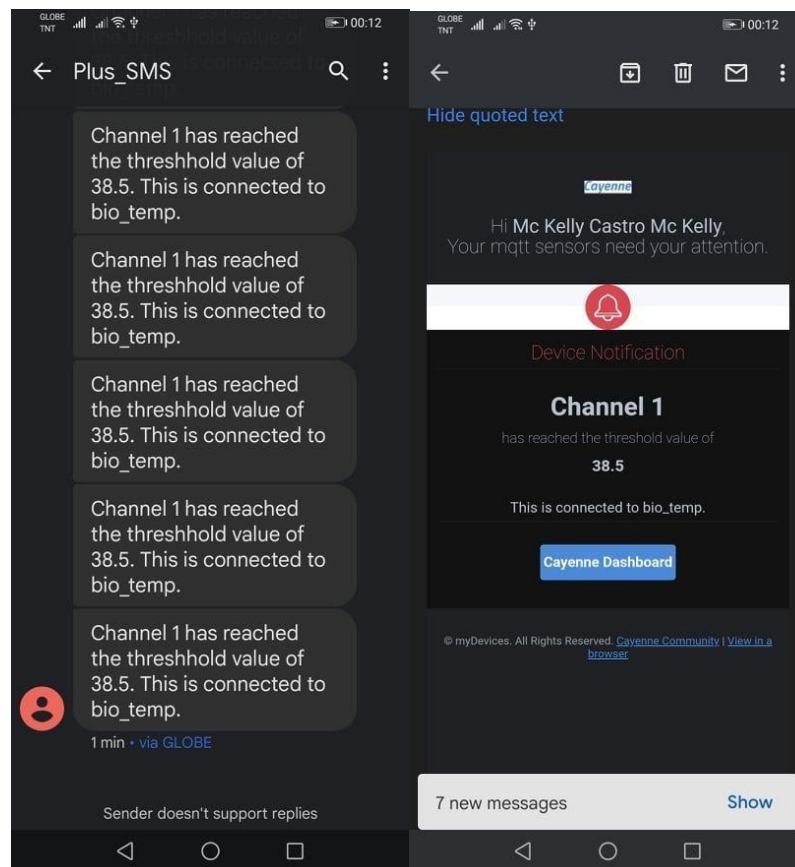


Table 1. Temperature over time inside the consumer grade refrigerator

Figure 27 shows the sample screenshot of the Email and SMS alert sent every time by the Cayenne MQTT Service to the user when the device reads a fluctuation of temperature inside the consumer grade refrigerator.

The fluctuation was controlled by the researchers by setting a threshold value of 38.5 degrees Celsius in the Cayenne MQTT Service and by purposely heating the tip of the probe to increase the temperature. When the reading exceeded 38.5 degrees Celsius, the Cayenne service automatically

notified a predetermined group of users via email and text message alerts.



*Figure 27. User Notification through SMS and Email by the
Cayenne MQTT Service*

System Evaluation Results

The results were evaluated by getting the mean of results for each category. A scale system, seen in Table 2, was used to rate the application's performance in certain areas. Five (5) for Excellent, Four (4) for Very Satisfactory, Three (3) for Satisfactory, Two (2) for Fair, and One (1) for poor.

Scale	Description
5.00 - 5.99	Excellent
4.00 - 4.99	Very Satisfactory
3.00 - 3.99	Satisfactory
2.00 - 2.99	Fair
1.00 - 1.99	Poor

Table 2. Mean Scale System

To evaluate the application, only the "product owner" which was the laboratory head of the Biological and Physical Sciences Department was chosen. The evaluation form used was

┌
based on the ISO/IEC 25010 Standard Software Evaluation
└
Questionnaire. As shown in table 3, the results of the user
evaluation were performed.

The results mostly showed the application having performed "Very Satisfactory" and "Excellent" in one area. Based on the results of the user evaluation, the device's temperature measurements were accurate, having scored a mean of 4.8, which means that it scored 96% in the System evaluation report by the product owner. The device scored the highest with a score of a 5.0, marked as 'Excellent', in 5 different areas such as (1) Functionality and Suitability, (2) Compatibility, (3) Usability, (4) Maintainability and (5) Portability for having accomplished its basic functions and the studies' objectives. For the performance area it scored a 4.7, marked as 'Very Satisfactory'. Scoring the lowest is the reliability criteria. This means that the product owner found the application and its hardware not that reliable in terms of monitoring temperature and that can be further refined and improved. For the application the user experience can be further polished by enhancing its aesthetics. For the hardware, the device can be built on a smaller platform reducing size and weight though it scores a perfect 5 in the

portability area; these suggested improvements are geared towards better reliability and security of the components inside and for the device itself.

Overall, the result of the evaluation for the system was "Very Satisfactory", meaning, the application was found by the product owner to be useful, easy to use and responsive.

Criteria	Mean	Description
Functional Suitability	5	Excellent
Performance Efficiency	4.7	Very Satisfactory
Compatibility	5	Excellent
Usability	5	Excellent
Reliability	4	Very Satisfactory
Security	4.8	Very Satisfactory
Maintainability	5	Excellent
Portability	5	Excellent
Overall Evaluation	4.8	Very Satisfactory

Table 3. Evaluation Results for the Proposed System

Jurors' Suggestion for Improvement

During the evaluation and consultation, the expert consultant/product owner and adviser suggested that the

┌
system can also be implemented to not only Ultra-low
└
Biofreezers but also Biomedical freezers, cold storages, and
Incubators. The system should also instead use a line graph
in showcasing temperature data over time for better readings
and analysis. The system should store data on the cloud for
easy storage and accessibility, better security, and fault
tolerance.

In the standalone web system, the graphic container for
choosing a location should present the exact locations inside
the biofreezer.

CHAPTER 5 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Proposed Study Design and Implementation

The Bio Lab Inventory Management System is an android mobile application designed for the Biological and Physical Sciences Department Laboratory Head and Faculty Researchers of West Visayas State University to aid their current system in the department as well as manage inventory inside biofreezers using QR-code technology. Not only that, but the system also provides temperature data from the developed IoT Device sensor. The said sensor is installed inside the storage and is also inserting data to an MQTT service broker, Cayenne, for the purpose of sending user notification via SMS and email in case of temperature fluctuations.

The Bio Lab IMS is very useful to laboratory researchers since it is portable given that it is a mobile application. If it is implemented, it will be easier to monitor data inside storages and generate reports.



Summary of Findings

The system is still subject to improvements that will further enhance its capabilities in the future. It is very object-oriented and can be integrated and upgraded as needed.

The IoT inventory management system uses QR code technology for managing biospecimen materials inside the biofreezer. This also includes a web standalone for the purpose of generating QR codes and adding item inventory. Not only that, but the system also provides temperature data from the developed IoT Device sensor. The sensor is also inserting data to an MQTT service broker, Cayenne, for the purpose of sending user notification via SMS and email in case of temperature fluctuations.

The system is portable which greatly helps users manage materials and monitor temperature inside the biofreezer regardless of its location. Inventory and temperature data are now automated and secured which can be used to show efficiency in the department's monitoring process for compliance of a good laboratory practice.

In testing the application, the product owner was given the evaluation form based on the ISO/IEC 25010 Standard

Software Evaluation Tool. After navigating through the application, the results were examined and showed a very satisfactory rating from the target user of the application.

The researchers conclude that the Biological and Physical Sciences Department should use this system to assist laboratory personnel in managing biospecimens and monitoring temperature inside biofreezers. They also need to have a server that can hold the inventory and temperature data. This system is well-designed and is easy to use. It cannot only be used in the Biological and Physical Science Department but also in other laboratories that use similar equipment.

Conclusions

Using Ultra-low Biofreezer is one of the most important tools used in the laboratory. The biofreezer protects the biological sample by keeping it at a very low temperature. The failure of it not only results in significant financial loss, but can also endanger samples that disrupt critical research. With the increasing number of biospecimens being stored and monitored inside cold equipment, especially in the

┌ field of medical education, there will be a need for a ┐
systematic way to manage its storage. The researchers
proposed to develop a functional IoT inventory management
system for the Biological and Physical Sciences Laboratory of
West Visayas State University, to manage the biospecimens in
Ultra-low Biofreezers. The developed application was able to
give the product owner the features of temperature
monitoring, user notification and management of inventory
based on QR technology.

The researchers therefore concluded that the system
had successfully accomplished the set objectives that were
specified in the first phase of the study namely:

1. The system is a Biospecimens Inventory Management
Mobile Application integrated with QR code
technology for an inventory of biospecimens inside
Ultra-Low Biofreezers and real time temperature
monitoring.
2. The system has an IoT device using ESP8266 NodeMCU
that can continuously send temperature data to
Biospecimens Inventory Management Mobile
Application.

┌

┐

3. The system integrated a user notification using Cayenne MQTT Framework and SMS Technology for user notification in the event of sudden temperature fluctuations in Ultra-low Biofreezers.
4. The system was implemented, tested, and evaluated based on usability and effectiveness using the ISO/IEC 25010:2011 Systems and Software Quality Requirements.

Furthermore, the researchers were able to implement a standalone web system recommended in the application. The standalone web system was further developed solely for the purpose of a convenient adding of item inventory and the generation of QR codes for printing. The user evaluation results overall showed a "Very Satisfactory" rating from the product owner. It can therefore be inferred that the product owner is enthusiastic and interested in using IoT for the temperature monitoring and Inventory system based on emerging technology to manage biospecimens in ultra-low biofreezers.

Recommendations

To further improve the efficiency and effectiveness of the system, the researchers recommend the following:

1. The system can add features like the temperature readings can go below -0c which then can be used effectively in Ultra-low Biofreezer.
2. The researchers would like to recommend asking for help and guidance of electronic engineering professionals for the development of the IoT device.
3. For temperature readings, a line chart should instead be used in showcasing temperature data over time for better readings and analyses.
4. For the standalone web system, the graphic container for choosing a location for an item should present exactly at the same location inside the biofreezer.

5. The inventory system should be cloud-based so that it would not be limited to the localhost only, and so it can be accessed anywhere in any network. Also, this helps improve security and fault tolerance.

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APPENDICES

West Visayas State University
COLLEGE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY
La Paz, Iloilo City, Philippines

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Appendix A

Letter to the Adviser

March 2, 2021

DR. EVANS B. SANSOLIS

Instructor I
College of Information and Communications Technology
West Visayas State University - Main Campus
Luna Street, La Paz, Iloilo City

Dear Dr.
Sansolis,

The undersigned are BSIT 4th year students of CICT in this university. Our thesis/capstone project title is **"Internet-of-Things Inventory Management System for Ultra-low Biofreezer in MQTT Framework"**.

Knowing your expertise in research and on technology, we would like to request you to be our **THESIS ADVISER**.

We are positively hoping for your acceptance. Kindly check the corresponding box and affix your signature on the space provided. Thank you very much.

Respectfully yours,

1. Amio, Ayrra Jane R.
2. Castro, Mc Kelly D.
3. Sevilla, Winston C.
4. Soncio, Paul Adrian D.
5. Wong, Jose Mari C.

PS:

Advisers are tasked to work with the students in providing direction and assistance as needed in their thesis/capstone project. They shall meet with the students weekly or as needed to provide direction, check on progress and assist in resolving problems until such a time that the students pass their defenses and submit their final requirements, as well as, preparing their evaluations and grades.

West Visayas State University
COLLEGE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY
La Paz, Iloilo City, Philippines

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Action Taken:

☒ I Accept.

☐ Sorry. I don't accept.


EVANS SANSOLIS

Signature over printed name of the Adviser

CC:

CICT Dean

Research Coordinator

Group

Appendix B

Letter to the English Editor

May 25, 2022

SIMOUN OMAR DYLAN B. PADILLA

Faculty, DEFLLS

West Visayas State University - Main Campus

Luna Street, La Paz, Iloilo City

Dear Sir Padilla,

We BSIT 4th year students of CICT of this university conducted our thesis/capstone project entitled "**Internet-of-Things Inventory Management System for Ultra-low Biofreezer in MQTT Framework**".

Knowing your expertise in research, we would like to request you to be our **THESIS GRAMMARIAN**.

We believe that your expertise in this area will significantly improve and help us for the final presentation and format of our thesis worthy to serve as an example or basis for the other BSIT students in the future.

May we have your reply by May 30, 2022. Your positive response will mean a lot to us.

Respectfully yours,

1. Amio, Ayrra Jane R.
2. Castro, Mc Kelly D.
3. Sevilla, Winston C.
4. Soncio, Paul Adrian D.
5. Wong, Jose Mari C.

Action Taken:

☐ I Accept.

☐ Sorry. I don't accept.

Signature over printed name of the Adviser

West Visayas State University
COLLEGE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY
La Paz, Iloilo City, Philippines

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Appendix C

ISO 9126 Software Quality Evaluation Questionnaire

ISO/IEC 25010:2011 SYSTEMS AND SOFTWARE QUALITY REQUIREMENTS AND EVALUATION QUESTIONNAIRE

Title/name of System/Software being evaluated: _____

Name of Evaluator: _____ Date: _____

Designation: _____ Company: _____

Instruction:

After accessing and running the system/software from the web address provided, kindly evaluate the degree of compliance of the system/software to the ISO/IEC 25010:2011 System and Software Quality Requirements and Evaluation criteria by checking the column corresponding the degree to which you deemed the system/software being evaluated complied or achieved using the scale below.

Legend:

5 – Excellent; 4 – Very Satisfactory; 3 – Satisfactory; 2 – Fair; 1 – Poor

ISO/IEC 25010:2011 Systems and Software Quality Characteristics	5	4	3	2	1
A. Functional Suitability. Degree to which a product or system provides function as that meet stated and implied needs when used under specified condition.					
a.1 Functional Completeness. Degree to which a set of functions covers all the specified task and user objectives.					
a.2 Functional Correctness. Degree to which a product or system provides th correct results with the needed degree of precision.					
a.3 Functional Appropriateness. Degree to which the function facilitate the accomplishment of specified task and objectives.					
B. Performance Efficiency. Performance relative to the amount of resources used under stated condition.					
b.1 Time Behavior. Degree to which the response and processing times and throughput rates of a product or system, when performing its function, meet requirements.					
b.2 Resource Utilization. Degree to which the amounts and types of resources used by a product or system, when performing its function, meet requirements.					
b.3 Capacity. Degree to which the maximum limits of a product or system parameter meet requirements.					
C. Compatibility. Degree to which a product, system or component can exchange information with other products, systems or components, and/or perform its required functions, while sharing the same hardware or software environment.					
c.1 Co-existence. Degree to which a product can perform its required functions efficiently while sharing a common environment and resources with other products, without detrimental impact on any other product.					
c.2 Interoperability. Degree to which two or more systems, products or components can exchange information and use information that has been exchange.					
D. Usability. Degree to which a product or system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.					
d.1 Appropriateness Recognizability. Degree to which users can recognize whether a product or system is appropriate for their needs.					
d.2 Learnability. Degree to which a product or system can be used by specified users to achieve specified goals of learning to use the product or system with effectiveness, efficiency, freedom from risk and satisfaction in a specified context of use.					
d.3 Operability. Degree to which a product or system has attributes that make it easy to operate and control.					
d.4 User error Protection. Degree to which a system protects users against making errors.					

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La Paz, Iloilo City, Philippines

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ISO/IEC 25010:2011 Systems and Software Quality Characteristics ... page 2		5	4	3	2	1
d.4 User Interface Aesthetics.	Degree to which a user interface enables pleasing and satisfying interaction for the user.					
d.5 Accessibility.	Degree to which a product or system can be used by people with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use.					
E. Reliability. Degree to which a system, product or component performs specified functions under specified conditions for a specified period of time.						
e.1 Maturity.	Degree to which a system, product or component meets needs for reliability under normal operation.					
e.2 Availability.	Degree to which a system, product or component is operational and accessible when required for use.					
e.3 Fault Tolerance.	Degree to which a system, product or component operates as intended despite the presence of hardware or software faults.					
e.4 Recoverability.	Degree to which, in the event of an interruption or a failure, a product or system can recover the data directly affected and re-establish the desired state of the system.					
F. Security. Degree to which a product or system protects information and data so that the persons or other products or systems have the degree of data access appropriate to their types and levels of authorization.						
f.1 Confidentiality.	Degree to which a product or system ensures the data are accessible only to those authorized to have access.					
f.2 Integrity.	Degree to which a system, product or component prevents an authorize access to, or modification of, computer programs or data.					
f.3 Non-repudiation.	Degree to which actions or events can be proven to have taken place, so that the events or actions cannot be repudiated later.					
f.4 Accountability.	Degree to which the action of an entity can be traced uniquely to the entity.					
f.5 Authenticity.	Degree to which the identity of the subject or resource can be proved to be the one claimed.					
G. Maintainability. Degree of effectiveness and efficiency with which a product or system can be modified by the intended maintainers.						
g.1 Modularity.	Degree to which a system or computer program is composed of discrete components such that a change to one component has minimal impact on other components.					
g.2 Reusability.	Degree to which an asset can be used in more than one system, or in building other assets.					
g.3 Analysability.	Degree of effectiveness and efficiency with which it is possible to assess the impact on a product or system of an intended change to one or more of its parts, or to diagnose a product for deficiencies or causes of failures, or to identify parts to be modified.					
g.4 Modifiability.	Degree to which a product or system can be effectively and efficiency modified without introducing defects or degrading existing product quality.					
g.5 Testability.	Degree of effectiveness and efficiency with which test criteria can be established for a system, product or component and test can be performed to determine whether those criteria have been met.					
H. Portability. Degree of effectiveness and efficiency with which a system, product or component can be transferred from one hardware, software or other operational or usage environment to another.						
h.1 Adaptability.	Degree to which a product or system can be effectively and efficiently be adapted for different or evolving hardware, software or operational or usage environment.					
h.2 Installability.	Degree of effectiveness and efficiency with which a product or system can be successfully installed and/or uninstalled in a specified environment.					
h.3 Replaceability.	Degree to which a product can replace another specified software product for the same purpose in the same environment.					

Signature of the Evaluator

Appendix D

Certificate of Completion and Acceptance



CERTIFICATE OF COMPLETION AND ACCEPTANCE

RESEARCH TITLE: "INTERNET-OF-THINGS INVENTORY MANAGEMENT SYSTEM FOR ULTRA LOW BIO FREEZER IN MQTT FRAMEWORK"

This is to certify that the researchers;

1. AMIO, AYRRA JANE R.
2. CASTRO, MC KELLY D.
3. SEVILLA, WINSTON C.
4. SONCIO, PAUL ADRIAN D.
5. WONG, JOSE MARI C.

has fully completed all objectives, tested and finally evaluated the IoT Inventory Management System based on usability and effectiveness using ISO-standard Usability Evaluation Tools.

CERTIFIED AS COMPLETED AND ACCEPTED BY:

A handwritten signature in blue ink, appearing to read 'Stephen G. Sabinay', is written over a faint, oval-shaped background.

DR. STEPHEN G. SABINAY
Laboratory Head, Center for Biotechnology and Biomedical Research
West Visayas State University

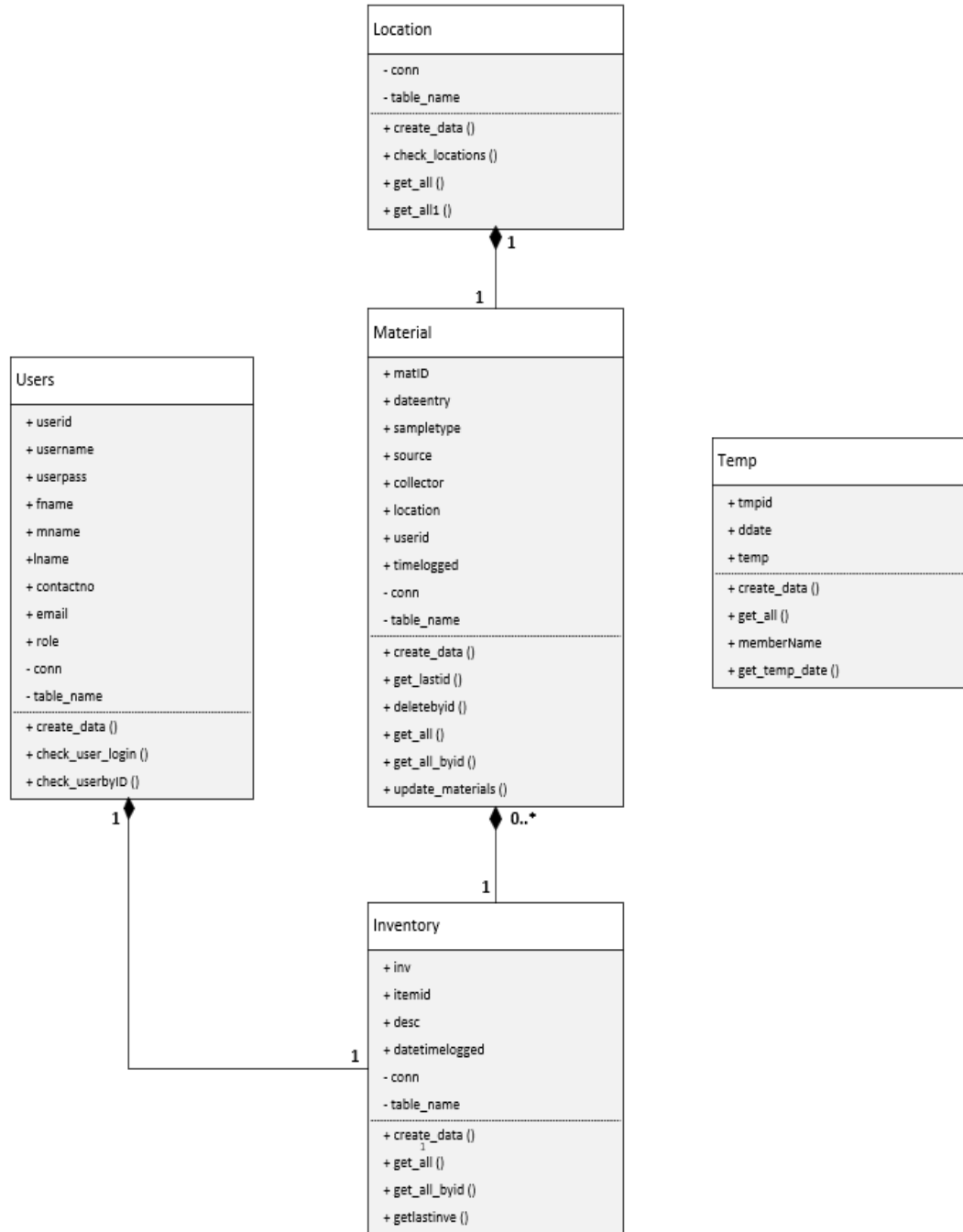
Date: November 29, 2021

Gantt Chart

[illegible]

Appendix F

Entity Relationship Diagram



Appendix G

Data Dictionary

tblusers	: userid + username + userpass + fname + mname + lname + contactno + email + role +
tblmaterials	: matID + dateentry + samplotype + source + collector + location + userid + timelogged +

└

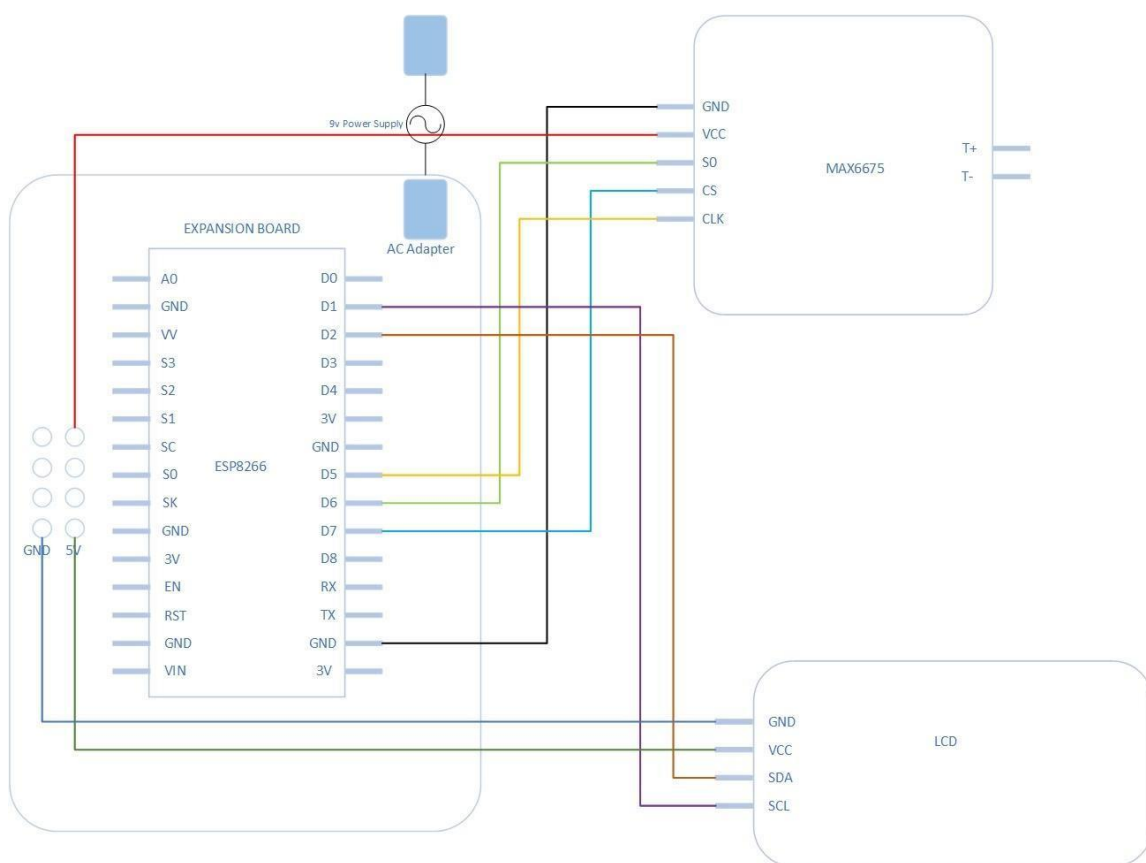
```
tblinventorydata      : inv +  
                        itemid +  
                        userid +  
                        desc +  
                        datetimelogged +
```

```
tbllocation           : locid +  
                        loc_name +  
                        val +
```

```
tbltemperature        : tmpid +  
                        temp +  
                        timelogged +
```

Appendix H

Circuit Diagram



Appendix I

Sample Program Codes

Final Arduino Code

```
#include <ArduinoJson.h>
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
#include <max6675.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <WiFiClientSecure.h>

//MQTT
#include <CayenneMQTTESP8266.h>
#define CAYENNE_DEBUG
#define CAYENNE_PRINT Serial

//Pin
int ktcSO=12; //GPIO 12 D6
int ktcCS=13; //GPIO 13 D7
int ktcCLK=14; // GPIO 14 D5

MAX6675 ktc(ktcCLK,ktcCS, ktcSO);
LiquidCrystal_I2C lcd(0x27,20,4);

//Declarations
const char* ssid = "";
const char* password = "";

//Cayenne Authentication info.
//This should be obtained from the Cayenne Dashboard

char username[] = "c56067c0-4cf9-11ec-ad90-75ec5e25c7a4";
char mqtt_password[] = "e5786f446e971cf800527c1c3b6af64e922d1a5f";
char client_id[] = "717fab10-4cfa-11ec-9f5b-45181495093e";

WiFiClientSecure client;
void setup() {
    Serial.begin(9600);
```

```
// Start the Serial communication to send messages to
the computer
  delay(500);
  lcd.init();
//Initialize lcd screen --
  lcd.backlight();
//From LiquidCrystal_I2C library

  Serial.println('\n');
  WiFi.begin(ssid, password);
    // Connect to the network
  Serial.print("Connecting to ");
  Serial.print(ssid); Serial.println(" ...");

  int i = 0;
  while (WiFi.status() != WL_CONNECTED) {
    // Wait for the Wi-Fi to connect
    delay(1000);

  Serial.print(++i);
  Serial.print(' ');

  Cayenne.begin(username, mqtt_password, client_id,
  ssid, password);
  }

  Serial.println('\n');
  Serial.println("Connection established!");
  Serial.print("IP address:\t");
  Serial.println(WiFi.localIP());

// Send the IP address of the ESP8266 to the computer

}

void loop() {

  if (WiFi.status() == WL_CONNECTED) {
//Check WiFi connection status

    float tempData = ktc.readCelsius();
    //converts data into float digits
```



```
lcd.print("C= ");
  lcd.print(ktc.readCelsius());
  lcd.setCursor(0, 0);

Serial.print("C = ")
Serial.print(ktc.readCelsius());
  Serial.print("\t");

Cayenne.virtualWrite(1, tempData, TYPE_TEMPERATURE,
UNIT_CELSIUS);

  WiFiClient client;
  HTTPClient http;

http.begin(client,"http://192.168.254.103/bioapi/v1/ad
dtemp.php"); //Specify request destination
  http.addHeader("Content-Type","application/json");
  StaticJsonDocument<200> doc;
  doc["temp"] = tempData;

  String requestBody;
  serializeJson(doc, requestBody);
  int httpCode = http.POST(requestBody);

  if (httpCode > 0) { //Check the returning code

    String payload = http.getString();
    //Get the request response payload
    Serial.println(payload);
    //Print the response payload
    Serial.println(tempData);

    } else {

      Serial.println("oops");
    }

    http.end(); //Close connection
  }

  delay(10000); //Send a request every 5 seconds
}
```

Gettemp class

```
<?php

//include headers
header("Access-Control-Allow-Origin: *");
header("Content-type: application/json; charset: UTF-8");
header("Access-Control-Allow-Methods: GET");

//include database
include_once("../config/database.php");
//include users
include_once("../classes/temp.php");

$db = new Database();

$connection = $db->connect();

$Temp = new Temp($connection);

if($_SERVER['REQUEST_METHOD'] === "GET") {

    }

    else {
        http_response_code(500); //404 service not
        available
        echo json_encode(
            array(
                "Status" => 0,
                "Message" => "ss Error"
            )
        );
    }

?>
```

Inventory class

```
<?php
class Inventory{

    public $inv;
    public $itemid;
    public $userid;
    public $desc;
    public $datetimelogged;

    private $conn;
    private $table_name;

    public function __construct($db){
        $this->conn = $db;
        $this->table_name = "tblinventorydata";
    }

    //INSERT inventory
    public function create_data(){
        $query = 'INSERT INTO '. $this->table_name.'
SET itemid = ? , userid= ? , `desc` = ? ,
datetimelogged = ? ' ;
        // prepare sql
        $obj = $this->conn->prepare($query);
        // binding parameters with prepare statement
        $obj->bind_param("iiss" , $this->itemid ,
$this->userid , $this->desc , $this-
>datetimelogged );

        if($obj->execute()) {

            return true;
        }
        return false;
    }

    public function get_all() {
        $sql_query = "SELECT inv,
sampletype, `desc`, datetimelogged ,concat(lname, ',
',fname) as name FROM tblinventorydata inner join
```

```
tblmaterials on matid = itemid inner join tblusers on  
tbl materials.user id = tblusers.userid" ;
```

```
    $std_obj = $this->conn->prepare($sql_query);
```

```
    $std_obj->execute();
```

```
    return $std_obj->get_result();
```

```
    }  
    public function get_all_byid() {
```

```
        $sql_query = "SELECT inv, itemid,  
sampletype, `desc`, datetimelogged ,concat(lname, '  
,fname) as name FROM tblinventorydata inner join  
tblmaterials on matid = itemid inner join tblusers on  
tbl inventory data.user id = tblusers.userid where  
itemid = ? " ;
```

```
        $std_obj = $this->conn->prepare($sql_query);
```

```
        $std_obj->bind_param("i", $this->itemid );
```

```
        $std_obj->execute();
```

```
        return $std_obj->get_result();
```

```
    }
```

```
    public function getlastinve() {
```

```
        $sql_query = 'select inv, `desc` from  
tblinventorydata where itemid = ? order by inv desc  
limit 1';
```

```
        $std_obj = $this->conn->prepare($sql_query);
```

```
        $std_obj->bind_param("i", $this->itemid );
```

```
        $std_obj->execute();
```

```
        return $std_obj->get_result();
```

```
    }
```

```
}
```

```
?>
```

Location class

```
<?php
class Location{

    private $conn;
    private $table_name;

    public function __construct($db){
        $this->conn = $db;
        $this->table_name = "tbl_location";
    }

    //INSERT EMPLOYEES
    public function create_data(){

        $query = 'INSERT INTO '. $this->table_name.'
SET username = ? , userpass = ? , fname = ?, mname = ?
, lname = ?, contactno = ?,email = ?, role = ? ';;

        // prepare sql
        $obj = $this->conn->prepare($query);

        // sanitize variables
        $this->username =
htmlspecialchars(strip_tags($this->username));
        $this->userpass =
md5(htmlspecialchars(strip_tags($this->userpass)));
        $this->fname =
htmlspecialchars(strip_tags($this->fname));
        $this->mname =
htmlspecialchars(strip_tags($this->mname));
        $this->lname =
htmlspecialchars(strip_tags($this->lname));
        $this->contactno =
htmlspecialchars(strip_tags($this->contactno));
        $this->email =
htmlspecialchars(strip_tags($this->email));
        $this->role =
htmlspecialchars(strip_tags($this->role));

        //binding parameters with prepare statement
```

```

    $obj->bind_param("ssssssss" , $this->username
, $this->userpass, $this->fname , $this->mname
, $this->lname, $this->contactno , $this->email ,
$this->role );

    if($obj->execute()) {

        return true;
    }
    return false;

}

public function check_locations() {

    $query = 'SELECT locid, loc_name , if(location
is null , 0 , location) as loc FROM tbl_location left
join tblmaterials on locid = tbl materials.location';
    $obj = $this->conn->prepare($query);
    if($obj->execute()){

        $data = $obj->get_result();
        return $data->fetch_assoc();

    }
    return array();
}
public function get_all() {
    $sql_query = "SELECT locid, loc_name ,
if(location is null , 0 , location) as loc FROM
tbl_location left join tblmaterials on locid = tbl
materials.location where location is null" ;

    $std_obj = $this->conn->prepare($sql_query);
    $std_obj->execute();

    return $std_obj->get_result();

}

public function get_all1() {
```

```
$sql_query = "SELECT locid, loc_name ,
if(location is null , 'white' , '#68AF69') as loc FROM
tbl_location left join tblmaterials on locid = tbl
materials.location" ;

$stmt_obj = $this->conn->prepare($sql_query);

$stmt_obj->execute();
return $stmt_obj->get_result();

}

}
?>
```

Material class

```
<?php
class Material{

    public $matID;
    public $dateentry;
    public $sampletype;
    public $source;
    public $collector;
    public $location;
    public $user id;
    public $timelogged;

    private $conn;
    private $table_name;

    public function __construct($db){
        $this->conn = $db;
        $this->table_name = "tblmaterials";
    }

    //INSERT materials
    public function create_data(){

        $query = 'INSERT INTO '. $this->table_name.'
SET dateentry = ? , sampletype= ? , source = ? ,
collector = ? , location = ? , userid = ?';
```

```

    // prepare sql
    $obj = $this->conn->prepare($query);

    //binding parameters with prepare statement
    $obj->bind_param("sssssi" , $this->dateentry
, $this->samplotype , $this->source , $this-
>collector , $this->location , $this->userid );

    if($obj->execute()) {

        return true;
    }
    return false;

}

public function get_lastid() {
    $sql_query = 'CALL procGetLastID()';

    $std_obj = $this->conn->prepare($sql_query);
    $std_obj->execute();
    return $std_obj->get_result();

}

public function deletebyid() {
    $sql_query = 'delete from tblmaterials where
matID = ?';

    $std_obj = $this->conn->prepare($sql_query);

    $std_obj->bind_param("i", $this->matID );
    $std_obj->execute();

    return $std_obj->get_result();
}

public function get_all() {
    $sql_query = "SELECT matID, dateentry,
samplotype, source, collector , loc_name FROM
```



```
tblmaterials inner join tbl_location on
tbl_location.locid = tblmaterials.location" ;

        $std_obj = $this->conn->prepare($sql_query);

        $std_obj->execute();

        return $std_obj->get_result();

    }

    public function get_all_byid() {
        $sql_query = "SELECT matID, dateentry,
        samplotype, source, collector , loc_name FROM
        tblmaterials inner join tbl_location on
        tbl_location.locid = tblmaterials.location where matID
        = ?" ;

        $std_obj = $this->conn->prepare($sql_query);

        $std_obj->bind_param("i", $this->matID );

        $std_obj->execute();

        return $std_obj->get_result();

    }

    public function update_materials() {
        $sql_query = "Update tblmaterials SET
        dateentry= ? , samplotype = ?, source = ?, collector =
        ? where matID = ?" ;

        $std_obj = $this->conn->prepare($sql_query);

        $std_obj->bind_param("ssssi", $this-
        >dateentry , $this->samplotype , $this->source ,
        $this->collector , $this->matID );

        $status = $std_obj->execute() or die
        ($std_obj->error);
        return $std_obj->get_result();

    }
}
```

```
}  
?>
```

Temp class

```
<?php  
class Temp{  
  
    public $tmpid;  
    public $temp;  
    public $ddate;  
  
    private $conn;  
    private $table_name;  
  
    public function __construct($db){  
        $this->conn = $db;  
        $this->table_name = "tbltemperature";  
    }  
  
    //INSERT EMPLOYEES  
    public function create_data(){  
  
        $query = 'INSERT INTO '. $this->table_name.'  
SET temp = ?';  
  
        // prepare sql  
        $obj = $this->conn->prepare($query);  
  
        // binding parameters with prepare statement  
        $obj->bind_param("d" ,  $this->temp );  
  
        if($obj->execute()) {  
  
            return true;  
        }  
        return false;  
    }  
  
    public function get_all() {
```

```
        $sql_query = "SELECT * FROM tbltemperature "
    ;

    $std_obj = $this->conn->prepare($sql_query);

    $std_obj->execute();

    return $std_obj->get_result();

}

public function get_temp_date() {
    $sql_query = " SELECT temp as y, timelogged
as x, tmpid FROM tbltemperature where date(timelogged)
= ?" ;

    $std_obj = $this->conn->prepare($sql_query);

    $std_obj->bind_param("s" , $this->ddate );

    $std_obj->execute();

    return $std_obj->get_result();

}

}
?>
```

Users class

```
<?php
class Users{
public $userid;
public $username;
public $userpass;
public $fname;
public $mname;
public $lname;
public $contactno;
public $email;
public $role;

private $conn;
```

```
private $table_name;

public function __construct($db){
    $this->conn = $db;
    $this->table_name = "tblusers";
}

//INSERT EMPLOYEES
public function create_data(){

    $query = 'INSERT INTO '. $this->table_name.'
SET username = ? , userpass = ? , fname = ?, mname = ?
, lname = ?, contactno = ?,email = ?, role = ? ';

    // prepare sql
    $obj = $this->conn->prepare($query);

    // sanitize variables
    $this->username =
htmlspecialchars(strip_tags($this->username));
    $this->userpass =
md5(htmlspecialchars(strip_tags($this->userpass)));
    $this->fname =
htmlspecialchars(strip_tags($this->fname));
    $this->mname =
htmlspecialchars(strip_tags($this->mname));
    $this->lname =
htmlspecialchars(strip_tags($this->lname));
    $this->contactno =
htmlspecialchars(strip_tags($this->contactno));
    $this->email =
htmlspecialchars(strip_tags($this->email));
    $this->role =
htmlspecialchars(strip_tags($this->role));

    // binding parameters with prepare statement
    $obj->bind_param("sssssss" , $this->username
, $this->userpass, $this->fname , $this->mname
, $this->lname, $this->contactno , $this->email ,
$this->role );

    if($obj->execute()) {
        return true;
    }
}
```

```
        return false;
    }

    public function check_user_login() {

        $query = 'SELECT * FROM ' . $this->table_name .
        ' where username = ? and userpass = ?';
        $obj = $this->conn->prepare($query);

        $this->userpass = md5($this->userpass);

        $obj->bind_param("ss" , $this->username,
        $this->userpass);

        if($obj->execute()){

            $data = $obj->get_result();
            return $data->fetch_assoc();

        }

        return array();
    }

    public function check_user_login_admin() {

        $query = 'SELECT * FROM ' . $this->table_name .
        ' where username = ? and userpass = ? and role =
        "Admin"';
        $obj = $this->conn->prepare($query);

        $this->userpass = md5($this->userpass);

        $obj->bind_param("ss" , $this->username,
        $this->userpass);

        if($obj->execute()){

            $data = $obj->get_result();
            return $data->fetch_assoc();

        }

    }

}
```

```
        return array();
    }

    public function check_userbyID() {

        $query = 'SELECT * FROM ' . $this->table_name .
' where empid = ?';
        $obj = $this->conn->prepare($query);

        $obj->bind_param("i" , $this->empid);

        if($obj->execute()){

            $data = $obj->get_result();
            return $data->fetch_assoc()
        }

        return array();
    }
}
?>
```



Disclaimer

This software project and its corresponding documentation entitled "IOT INVENTORY MANAGEMENT SYSTEM FOR ULTRA-LOW BIOFREEZER IN MQTT FRAMEWORK" is submitted to the College of Information and Communications Technology, West Visayas State University, in partial fulfillment of the requirements for the degree, Bachelor of Science in Information Technology. It is the product of our own work, except where indicated text.

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JUNE 2022