บรรณานุกรม

แผนพัฒนาระบบเกษตรดิจิทัลของกระทรวงเกษตรและสหกรณ์ ระยะปี (พ.ศ.2560-2564), "การทำเกษตรยุคใหม่ด้วยเทคโนโลยีดิจิทัล(Digital Farming)"

สถาบันนวัตกรรมการเรียนรู้ มหาวิทยาลัยมหิดล, "ทฤษฎีการจัดจำแนกของบลูม (Bloom's Taxonomy) "

มูลนิธิสถาบันวิจัยระบบการศึกษา (Institute of Research on Education System Foundation: IRES) "ทฤษฎีการเรียนรู้โดยใช้ปัญหาเป็นฐาน (Problem Based Learning: PBL) "

กระทรวงศึกษาธิการ, "ทฤษฎีการเรียนรู้แบบร่วมมือ (Collaborative Learning) "

Learning Evolution, LLC and CatManHelp.com " ทฤษฎีการเรียนรู้แบบผสมผสาน "

Smart Farm(Thailand) Co., Ltd. "เกษตรแม่นยำ (Precision Farming) "

สถาบันวิจัยเศรษฐกิจป๋วย อึ๊งภากรณ์, "จุลทรรศน์ภาคเกษตรไทยผ่านข้อมูลทะเบียนเกษตรกรและสำมะโนเกษตร"

Harshkumar Prakashbhai Thakor, Sailesh Lyer, "Development and Analysis of Smart Digi-farming Robust Model for Production Optimization in Agriculture"

Peerasak Serikul, Nuttapun Nakpong, Nitigan Nakjuatong " Smart Farm Monitoring via the Blynk IoT Platform: Case Study: Humidity Monitoring and Data Recording"

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N. Kaewmard and S. Saiyod, "Sensor data collection and irrigation control on vegetable crop using smartphone and wireless sensor networks for smart farm," in 2014 IEEE Conference on Wireless Sensors (ICWiSE), 2014, pp. 106–112.

>>>>>>>>>>>>> <<<<<<<<<<<<<

ภาคผนวก

ภาคผนวก ก

หลักสูตรเพื่อการอบรม

ความรู้พื้นฐานเทคโนโลยีการสื่อสาร การตลาดดิจิทัล และการสร้างแบรนด์เพื่อการเกษตร

(Fundamentals of Communication Technology, Digital Marketing and Brand Creation for Agriculture)

ภาคผนวก ข

หลักสูตรเพื่อการอบรม

เทคโนโลยีเซนเซอร์เพื่อการเกษตร

(Sensor Technology for Smart Farming)

ภาคผนวก ค

หลักสูตรเพื่อการอบรม

อินเตอร์เน็ตของสรรพสิ่งและการประยุกต์ใช้ในการเกษตร

(Internet of Things and Its Applications in Smart Farming)

ภาคผนวก ง

หลักสูตรเพื่อการอบรม

สถิติพื้นฐานและการวิเคราะห์ทางการเกษตร

(Statistics and Analytics for Agriculture)

ภาคผนวก จ

หลักสูตรเพื่อการอบรม

ปัญญาประดิษฐ์เพื่อการวิเคราะห์ทางการเกษตร

(Artificial Intelligence for Smart Farming Analytics)

ภาคผนวก ฉ

หลักสูตรเพื่อการอบรม

การเรียนรู้ของเครื่องและระบบควบคุมทางการเกษตร

(Machine Learning for Smart Farming and Control Systems)

ภาคผนวก ช

หลักสูตรเพื่อการอบรม

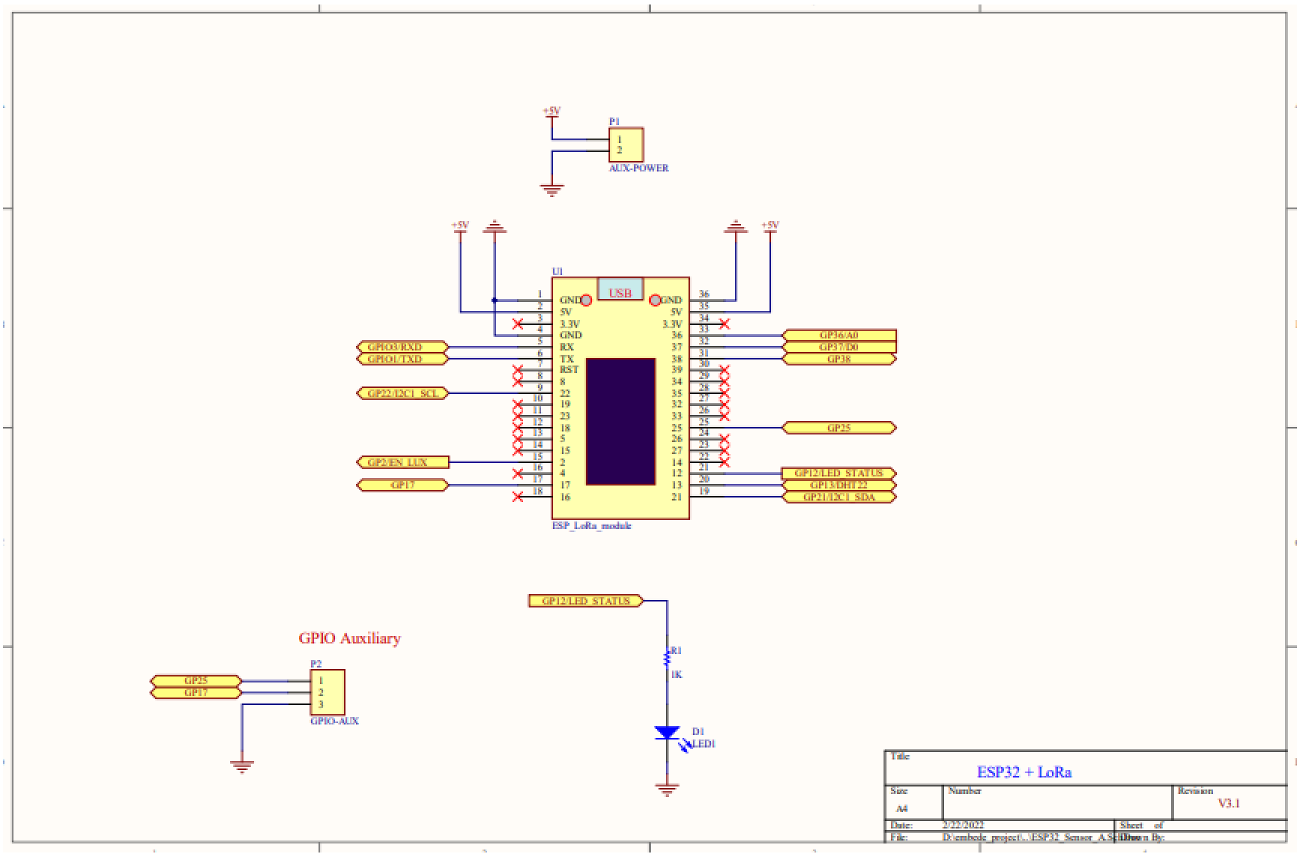
ความรู้พื้นฐานข้อมูลขนาดใหญ่เพื่อการเกษตร

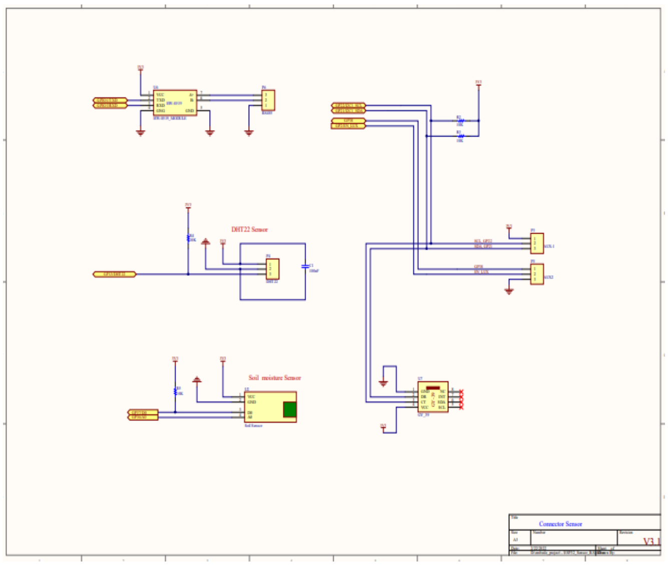
(Fundamentals of Big Data for Agriculture)

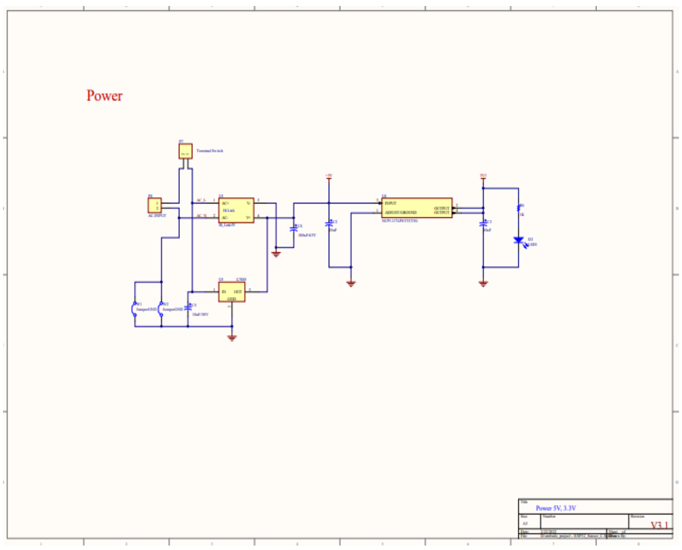
ภาคผนวก ซ

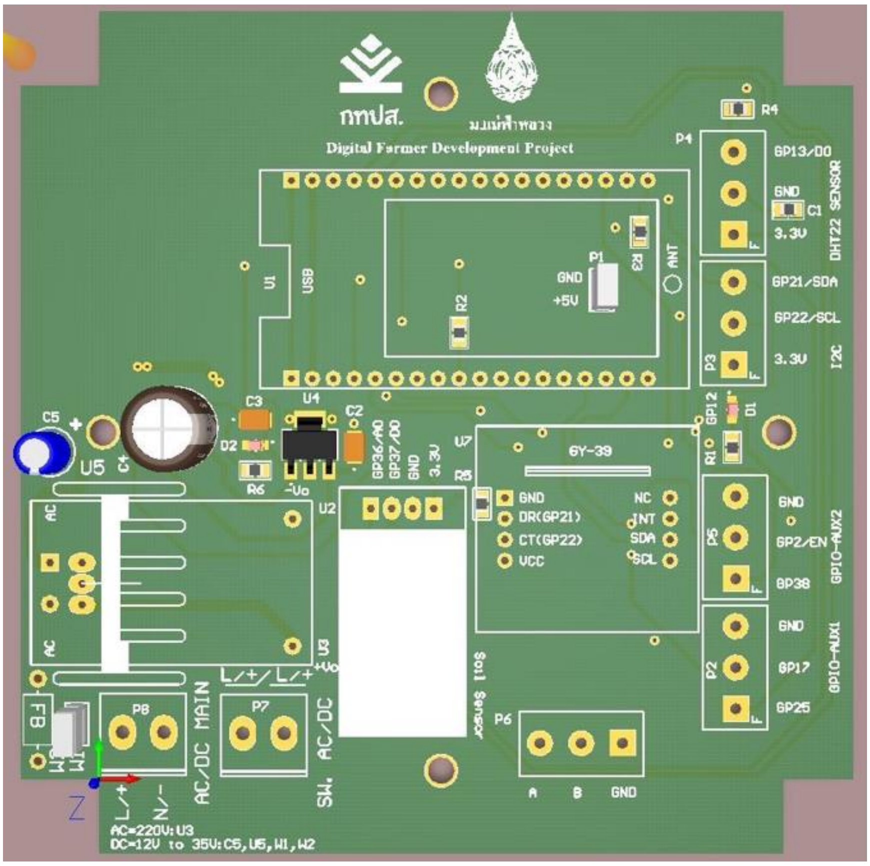
การออกแบบวงจรบอร์ดเซนเซอร์โหนด

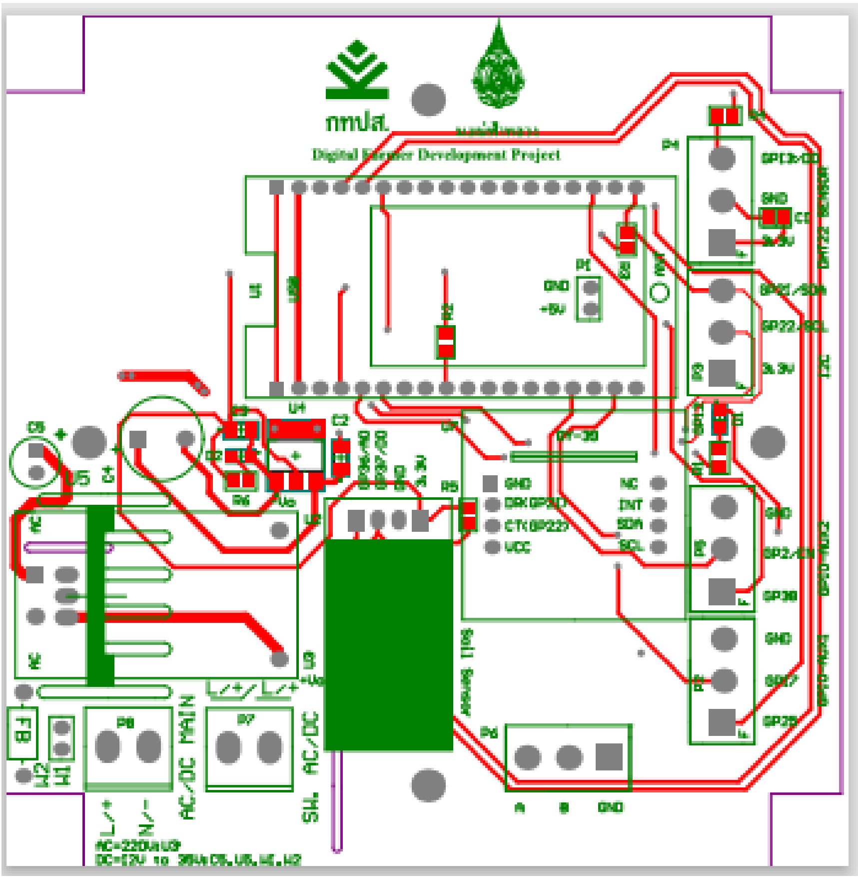
(Blueprint for Micro-climate Sensor Node)


+5V
P1
1
2
AUX-POWER
U1
USB
GND
5V
3.3V
RX
TX
RST
GPIO3/RXD
GPIO1/TXD
GP22/I2C1_SCL
GP2/EN_LUX
GP17
GP36/A0
GP37/D0
GP38
GP25
GP12/LED_STATUS
GP13/DHT22
GP21/I2C1_SDA
ESP_LoRa_module
GP12/LED_STATUS
R1
1K
D1
LED1
GPIO Auxiliary
P2
GP25
GP17
GPIO-AUX
Title
ESP32 + LoRa
Size
A4
Number
Revision
V3.1
Date:
2/22/2022
Sheet of
File:
D:\embede_project\..\ESP32_Sensor_A.S
Drawn By:


DHT22 Sensor
Soil moisture Sensor
Connector Sensor
V3.1


Power
Power 5V, 3.3V
V3.1


กทปส.
Digital Farmer Development Project
P4
GP13/D0
GND
3.3V
DHT22 SENSOR
GP21/SDA
GP22/SCL
3.3V
I2C
GND
GP2/EN
GP38
GPIO-AUX2
GND
GP17
GP25
GPIO-AUX1
GY-39
GND
DR(GP21)
CT(GP22)
VCC
NC
INT
SDA
SCL
GP36/A0
GP37/D0
GND
3.3V
Soil Sensor
P6
A
B
GND
P8
P7
AC/DC MAIN
SW. AC/DC
L/+
N/-
FB
AC=220V:U3
DC=12V to 35V:C5,U5,W1,W2

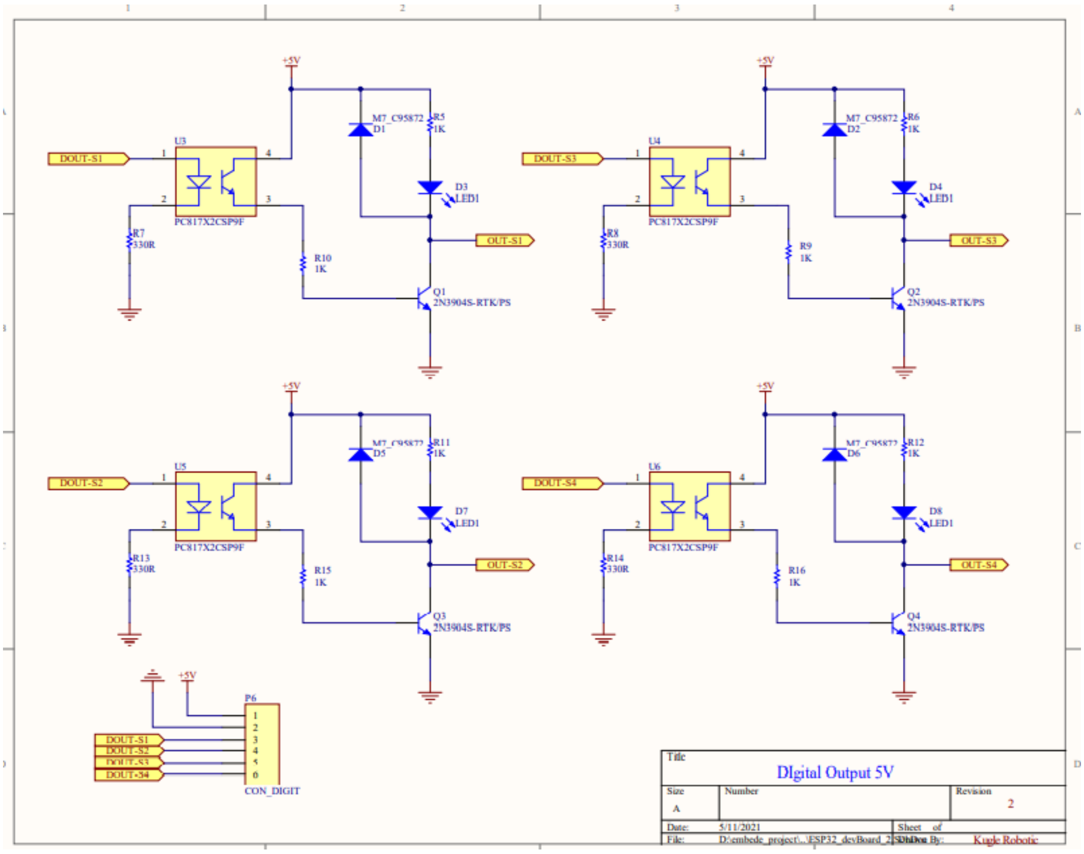

กทปส.
Digital Farmer Development Project
AC/DC MAIN
SW. AC/DC
A
B
GND
AC=220V:U3
DC=12V to 35V:C5,U5,W1,W2

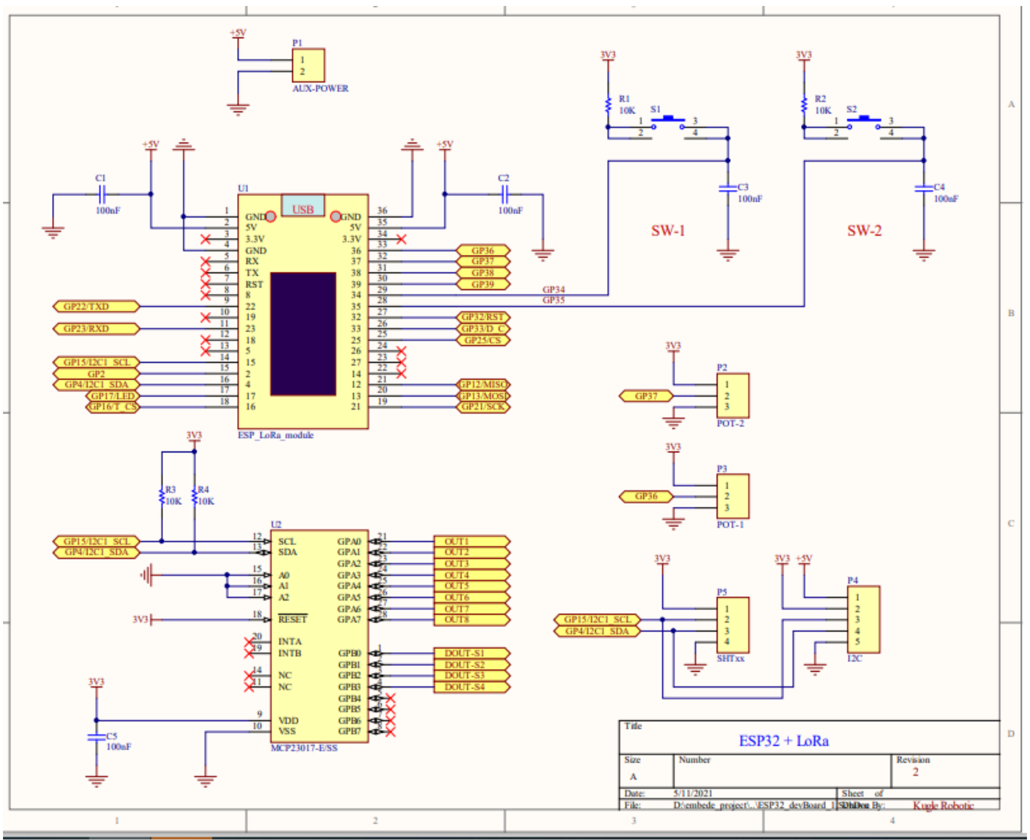
Comment	Description	Designator	Footprint	LibRef	Quantity
100nF/25V	Capacitor,Ceramic 100nF/25V 10% 0805	C1	C0805	Cap	1
10uF, 10V	E-CAP, TAJA106K010RNJ_C7177	C2, C3	CASE-A_3216	Cap Pol1	2
100uF/63V	ECAP - 100uF/63V, EGT107M1JF12RRSHP	C4	KM-SAMXON100-V	Cap Pol3	1
100uF/63V	ECAP - 100uF/63V, EGT107M1JF12RRSHP	C5	Cap2mm	Cap Pol3	1
LED1	NCD0805G1_C84260	D1, D2	Broadcom_HSMH-C170_0	LED0	2
AUX-POWER	Header, 2-Pin	P1	JMPPER	Header 2	1
GPIO-AUX	Header, 3-Pin	P2	DG126-03P	Header 3	1
AUX-1	Header, 3-Pin	P3	DG126-03P	Header 3	1
DHT22	Header, 3-Pin	P4	DG126-03P	Header 3	1
AUX2	Header, 3-Pin	P5	DG126-03P	Header 3	1
RS485	Header, 3-Pin	P6	DG126-03P	Header 3	1
Terminal Switch	Header, 2-Pin,EK500V-2P	P7	EK500V-02	Header 2	1
AC-INPUT	Header, 2-Pin,EK500V-2P	P8	EK500V-02	Header 2	1
1K 5%	Resistor 1K 5% 0805	R1, R6	R0805	Res1	2
10K 5%	Resistor 10K 5% 0805	R2, R3, R4, R5	R0805	Res1	4
ESP_LoRa_module		U1	ESP32_LoRa_Module	ESP_LoRa_module	1
Soil Sensor		U2	Soil moisture module	Soil Sensor	1
Hi_Link5V		U3		Hi_Link5V	1
NCP1117LPST33T3G		U4	ON_Semi_CASE_318H_0	NCP1117LPST33T3G	1
L7805		U5	TO220-S3 - Heatsink	L78XX	1
HW-0519_MODULE		U6	HW-0519_MODULE	HW-0519_MODULE	1
GY_39		U7	GY-39	GY_39	1
JumperGND	Jumper Wire	W1	JMPPER	Jumper	1
JumperGND	Jumper Wire	W2	FERRITE BEAD	Jumper	1

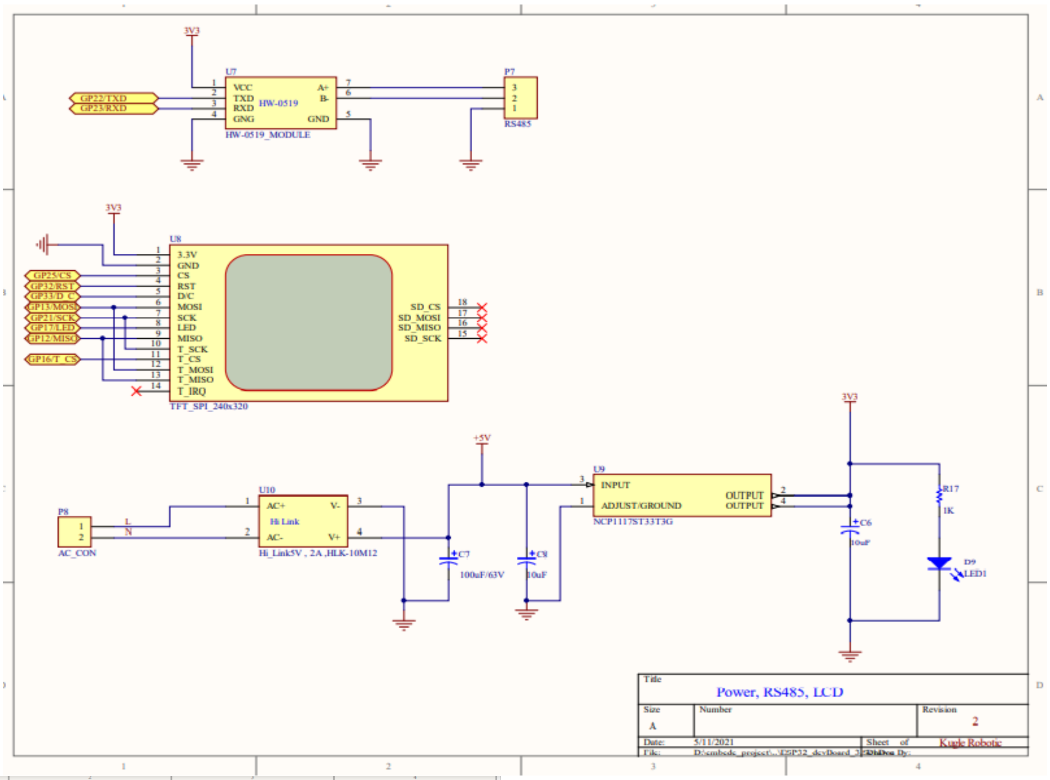
ภาคผนวก ณ

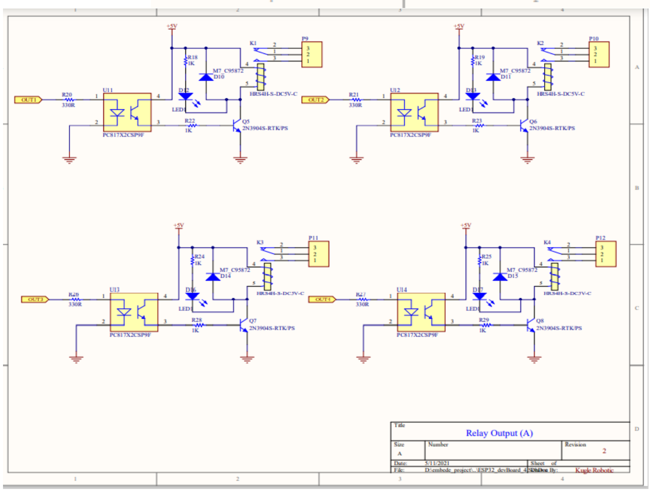
การออกแบบวงจรสำหรับบอร์ดระบบควบคุม

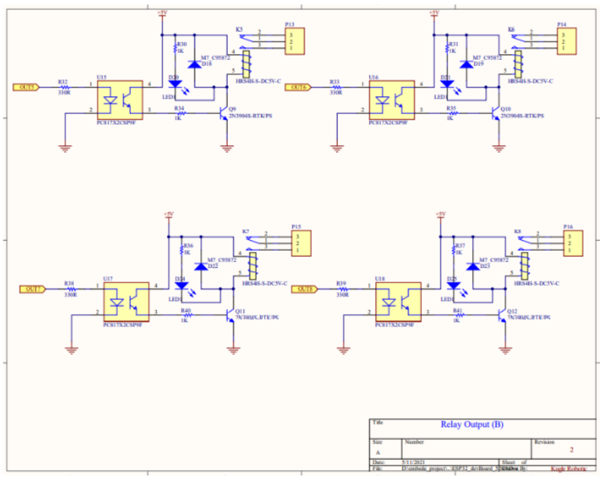
(Blueprint for System Controller Board)

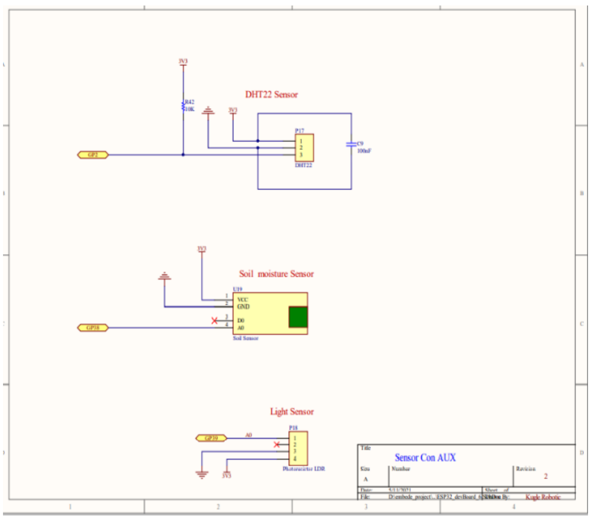

DOUT-S1
DOUT-S2
DOUT-S3
DOUT-S4
OUT-S1
OUT-S2
OUT-S3
OUT-S4
PC817X2CSP9F
2N3904S-RTK/PS
CON_DIGIT
Title
DIgital Output 5V
Size
Number
Revision
2
Date:
5/11/2021
Kugle Robotic

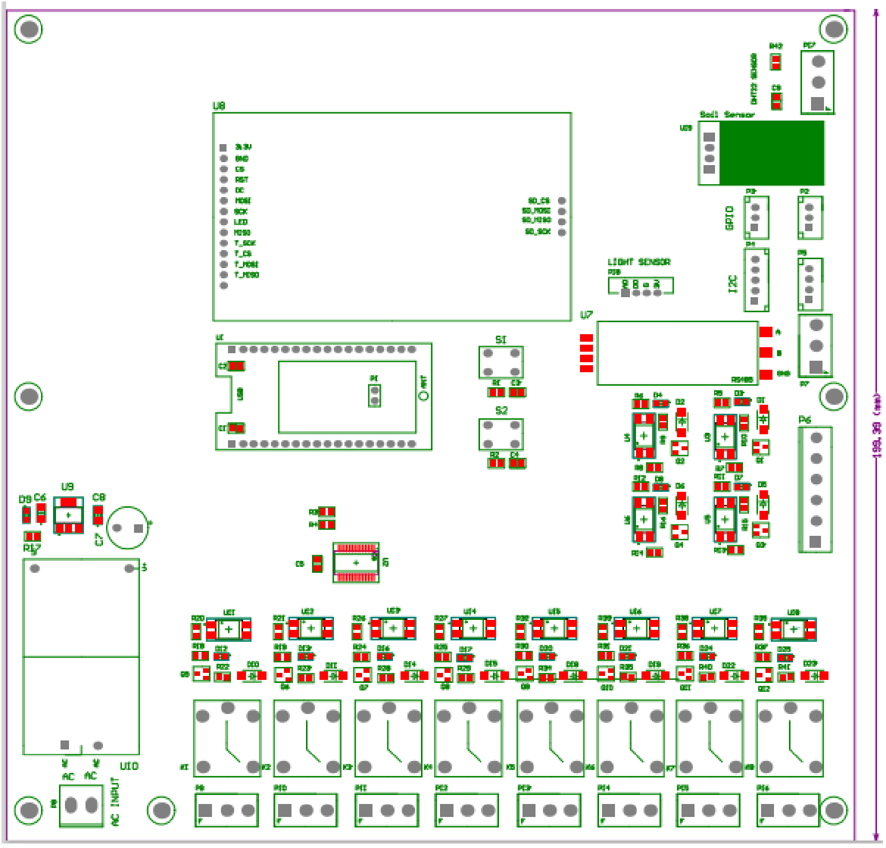

AUX-POWER
ESP_LoRa_module
MCP23017-E/SS
SW-1
SW-2
POT-1
POT-2
SHTxx
I2C
GP15/I2C1_SCL
GP4/I2C1_SDA
GP22/TXD
GP23/RXD
GP17/LED
Title
ESP32 + LoRa
Size
Number
Revision
2
Date:
5/11/2021
Kugle Robotic


3V3
U7
VCC
TXD
RXD
GNG
HW-0519
A+
B-
GND
HW-0519_MODULE
GP22/TXD
GP23/RXD
P7
RS485
U8
3.3V
GND
CS
RST
D/C
MOSI
SCK
LED
MISO
T_SCK
T_CS
T_MOSI
T_MISO
T_IRQ
SD_CS
SD_MOSI
SD_MISO
SD_SCK
TFT_SPI_240x320
GP25/CS
GP32/RST
GP13/MOSI
GP21/SCK
GP17/LED
GP12/MISO
GP16/T_CS
+5V
U10
AC+
AC-
V-
V+
Hi Link
Hi_Link5V , 2A ,HLK-10M12
P8
AC_CON
L
N
C7
100uF/63V
C8
10uF
U9
INPUT
ADJUST/GROUND
OUTPUT
OUTPUT
NCP1117ST33T3G
C6
10uF
R17
1K
D9
LED1
Title
Power, RS485, LCD
Size
A
Number
Revision
2
Date:
5/11/2021
Sheet of
Kugle Robotic


Relay Output (A)


Relay Output (B)


DHT22 Sensor
Soil moisture Sensor
Light Sensor
Sensor Con AUX



Comment	Description	Designator	Footprint	LibRef	Quantity
100nF 25V	Ceramic, 100nF 25V 10%	C1, C2, C3, C4	C0805	Cap	4
100nF/ 25V	Capacitor,Ceramic 100nF/ 25V 10% 0805	C5, C9	C0805	Cap	2
10uF, 10V	E-CAP, TAJA106K010RNJ_C7177	C6, C8	CASE-A_3216	Cap Pol1	2
100uF/ 63V	ECAP - 100uF/ 63V, EGT107M1JF12RR SHP	C7	KM-SAMXON 100-V	Cap Pol3	1
M7_C95872	Diode , M7_C95872	D1, D2, D5, D6, D10, D11, D14, D15, D18, D19, D22, D23	M7_C95872	Diode	12
LED1	NCD0805G1_C84260	D3, D4, D7, D8, D9, D12, D13, D16, D17, D20, D21, D24, D25	Broadcom_HSMH-C170_0	LED0	13
HRS4H-S-DC5V-C	HRS4H-S-DC5V-C	K1, K2, K3, K4, K5, K6, K7, K8	833H	Relay	8
AUX-POWER	Header, 2-Pin	P1	JMPPER	Header 2	1
POT-2	Header, 3-Pin	P2	100103ST	Header 3	1
POT-1	Header, 3-Pin	P3	100103ST	Header 3	1
I2C	Header, 5-Pin	P4	100105ST	Header 5	1
SHTxx	Header, 4-Pin	P5	100104ST	Header 4	1
CON_DIGIT	ED500V-06P	P6	ED500V-06P	Header 6	1
RS485	Header, 3-Pin	P7	DG126-03P	Header 3	1
AC_CON	Header, 2-Pin	P8	EK500V-02	Header 2	1
RELAY	Header, 3-Pin,DG126-03P-14-00A(H)_ES,GREEN	P9, P10, P11, P12, P13, P14, P15, P16	DG126-03P	Header 3	8
DHT22	Header, 3-Pin	P17	DG126-03P	Header 3	1
Photoresistor LDR	Header, 4-Pin	P18	LDR_Module	Header 4	1
2N3904S-RTK/ PS	NPN 2N3904S-RTK/ PS	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12	SOT23_2N3904S	2N3904	12
10K 5%	Resistor 10K 5% 0805	R1, R2, R3, R4, R42	R0805	Res1	5
1K 5%	Resistor 1K 5% 0805	R5, R6, R9, R10, R11, R12, R15, R16, R17, R18, R19, R22, R23, R24, R25, R28, R29, R30, R31, R34, R35, R36, R37, R40, R41	R0805	Res1	25
330R 5%	Resistor 330R 5% 0805	R7, R8, R13, R14, R20, R21, R26, R27, R32, R33, R38, R39	R0805	Res1	12
Switch TC-0102	Switch	S1, S2	TC-0102	SW-PB	2
ESP_LoRa_module		U1	ESP32_LoRa_Module	ESP_LoRa_module	1
MCP23017-E/ SS	16-Bit I/O Expander with Serial Interface, 28-Pin SSOP, Extended Temperature	U2	SSOP-SS28_N	MCP23017-E/ SS	1
PC817X2CSP9F	IC OPTOISOLATOR 5KV TRANS 4SMD	U3, U4, U5, U6, U11, U12, U13, U14, U15, U16, U17, U18	Sharp_PC817X2NIP0F_0	IC_Sharp_PC817X2NIP0F_sec	12

ภาคผนวก ญ

บทความวิชาการ

The Practical IoT System Designed for a Melon Farm:

A Case Study for Farmer Development in Northern Thailand Region

The Practical IoT System Designed for a Melon Farm: A Case Study for Farmer Development in Northern Thailand Region

1st Chayapol Kamyod
Computer and Communication Engineering for Capacity Building Research Center
School of Information Technology,
Mae Fah Luang University
Chiang Rai 57100, Thailand
chayapol.kam@mfu.ac.th

2nd Thongchai Yooyatiwong
School of Information Technology,
Mae Fah Luang University
Chiang Rai 57100, Thailand
thongchai.mfu@gmail.com

***Abstract*— Chiang rai is the northern Thai province with the most melon farms and the greatest potential for farmer profit. Premium melon cultivation, on the other hand, needs more preparations than a standard melon farm, such as irrigation and fertilization from seeding through harvesting. Melon requires varied watering and fertilizer for each cultivation phase to achieve excellent product output and quality per crop. Furthermore, there are other obstacles and issues along the process, such as pests and plant disease. Furthermore, owing to the change in humidity between day and night in the greenhouse throughout the winter and rainy season, numerous melon diseases may be easily detected. This can lead to illness and the breaking of the entire melon plant. If the melon is not properly cared for at the beginning of planting. Currently, all processes are carried out by humans. As a result, a large number of melon farms require a significant number of human resources and money. Furthermore, employees may make errors in measuring the amount of fertilizer solution as well as preparing the needed fertilizer solution and water for each planting phase. This can also have an impact on and damage the entire melon plant. Moreover, most of the melon farms are small and medium size farms owned by low-middle income farmers who are incapable of high investment on smart equipment. As a result, the focus of this research, sponsored by the National Broadcasting and Telecommunication Commission (NBTC), is on the design and implementation of affordable IoT solutions for the small-medium melon farms. There are two proposed systems: fertilization-irrigation system and an environmental control system. The proposed approach has been proven to be effective for small and medium-sized farms. Furthermore, the resulting technology is affordable and may be further improved for application in greenhouse cultivation of other plants.**

***Keywords*—IoT; Melon Farm; System Designed; Smart Farm**

I. Introduction

Thailand's economy has evolved, from the "Thailand 1.0" model centered on agriculture to the "Thailand 2.0" model centered on light industry and finally to the "Thailand 3.0" model centered on heavy industry. However, under the present "Thailand 3.0" model, the government has been unable to expand the economy to a level of global competitiveness. The present administration has developed a new model for economic reform and transitioning the entire country to the "Thailand 4. 0" model through major measures led by the Prime Minister. By concentrating development efforts on "preservation, prosperity, and sustainability." According to the 20-year strategic plan, the country will be developed from middle-income to high-income status through the "Pracharat" mechanism, which is a policy vision to transform the country from a traditional economy to an innovation-driven economy by focusing on the private sector, banks, people, and educational institutions. Additionally, in conjunction with the development of SMEs and startups, excellent communication and telecommunications infrastructure will be used to steer them in the same direction. To link all sectors by focusing on five technological areas and target industries: food, agriculture, and biotechnology, public health, health and medical technology (health, wellness, and biomedical), and tools and equipment. Robotics & Mechatronics Internet Technology for Connecting and Controlling Devices by the Digital Group Artificial Intelligence and Embedded Technology (Digital, Internet of Things, AI, and Embedded Technology) as well as Creative, Cultural, and High-Value Services.

The agriculture sector, which is the country's primary industry, benefits from the country's technology development program and the five priority industries stated above. That is, agricultural labor continues to be the country's primary labor force, accounting for about one-third of the entire labor force (around 12.4 million people), although agricultural GDP accounts for only 5% of overall GDP. Additionally, the majority of Thai farmers are smallholders, with 50% of farmers owning less than 10 hectares of land, indicating a significant need for smallholder adaptations to present agricultural practices. Particular attention is paid to the agriculture of economic crops, as well as the cultivation of a variety of high-value vegetables and fruits. Growing high-value vegetables and fruits successfully requires several variables in addition to those derived directly from the species, such as soil quality and fertility, plant diseases and insects, cultivation plot characteristics, temperature, soil moisture, natural disasters, and maintenance, among many others [1]–[4].

In general, vegetable and fruit cultivation, in general, can provide a variety of difficulties, as discussed previously. though as a result of breakthroughs in technology and the internet today, various technologies have been introduced to aid in the growth of more plants, vegetables, and fruits, such as smart greenhouse technology that can easily control various environmental variables, which is a favorable outcome of being able to control various variables to facilitate increased productivity. However, the primary drawback is the high expense of controlling and managing things that require skilled labor. There is a significant initial cost because the majority of supplies and equipment are imported, and the relatively high monthly expenses may be required by small farmers in general [5]–[10].

Although currently researchers in Thailand A large number of modern equipment and systems for Smart Farm have been developed using communication technology and digital technology. to be used to control the quality of cultivation and reducing the cost of farming. However, various modern equipment and systems are used in large agricultural farms with the high cost of farming. As for the general smallholders, there are still a small number of uses. Due to lack of knowledge and understanding of technology and how to apply modern equipment including loss of property This is a major reason for the slow development of smallholder farmers and Thailand's agriculture as a whole [11]–[18].

The farm under investigation is an organic or traditional melon farm that utilizes very little technologies or chemicals in its production processes. As a result, adopting the methodology while maintaining the farm's quality faces several challenges. Additionally, the Internet of Things-designed system for small and medium-sized farms, particularly organic melon farms, has not been well researched. The Internet of Things system presented in this research is for an organic melon farm. The system will be created and deployed to assist the melon farm's three primary processes: fertilization, irrigation, and environmental management within the melon plant directly. During this study phase, we will primarily focus on developing a practical Internet of Things-designed solution that is both effective and cost-effective for local farmers.

The remainder of the article is organized as follows: the next section describes the designed system. The experimental results and discussions are presented in Section III. Section IV follows with the conclusions.

II. System Designed

From the challenges and requirements of high-quality melon farming discussed above. The procedure of watering and fertilizing throughout each planting phase was shown to be the most important care process in planting that influences the quality of melon. Furthermore, managing the temperature inside the plant so that there is no extreme temperature difference or humidity in the plant reduces the risks of plant diseases such as fungus or melon cracking. This is a typical issue during the rainy and cold seasons, and this can harm the entire crop.

The researchers examined the demands and collaborated with farmers to understand the cultivation process of producing melon in depth, based on these two key problems and needs. Based on these procedures, the systems have been designed to enable the use of IoT technology to improve job efficiency and minimize workload in each operation. This may work in parallel to reduce existing mistakes and manpower. Figures 1 and 2 show the proposed system designed from the preliminary requirements.

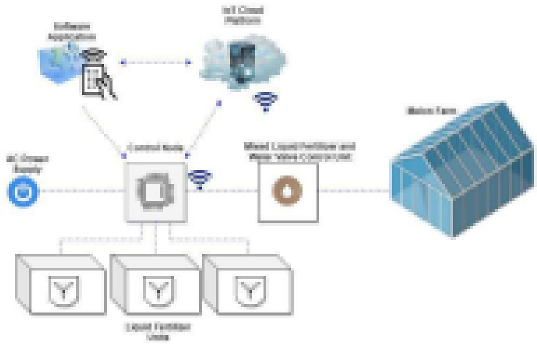


Fig. 1. Automatic fertilizer mixer and irrigation control system.

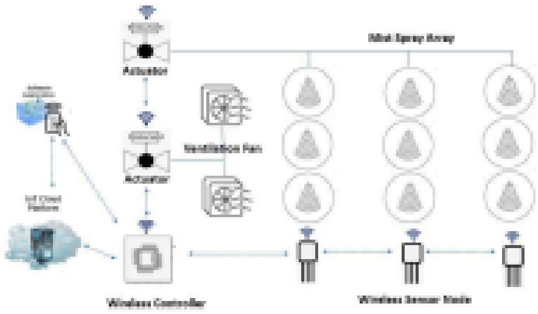


Fig. 2. Temperature and humidity IoT controlled in melon green house..

The farm will grow melon with no substance. Using sterile materials as planting material, such as sand and chopped coconut husks, at a 1: 1 ratio. Use a white bag 8 x 16 inches in size, planting 1 plant each bag in a 5 x 20-meter greenhouse, for a total of 204 plants per greenhouse. The spacing between the bags is 50 × 50 cm. The watermelon fertilizer solution recipe, in an instance, is created by mixing six main fertilizer solutions for usage at each stage of growth to maximize production. When the number of greenhouses rises and the growing period in each greenhouse varies, this can sometimes lead to fertilizing, watering, or insufficient maintenance. As a result, the system includes a separate fertilizer mixing pump, which is controlled by a microcontroller and regulates the water via an electronic valve. After the fertilizer has been effectively mixed, it will be combined with water and supplies for the melon plant. The program allows you to customize and plan fertilizer mixing formulas for each period, and control information is supplied via IoT technology. The method is intended for farmers to be simple and easy to use. The designed system in the melon plant is represented in Figure 3.

The major goal of the Environmental Control System in this study is to regulate the humidity and heat in the melon greenhouses. In Thailand, most melon fields suffer from leaf burn owing to high temperatures and dry air caused by intense sunshine. Farmers must water their melon often during the day in order to lower warmth and supply moisture to the greenhouse, which is done by hand. The design strategy for this research is to utilize general ventilation fans with a mist-spray system, controlled by IoT system and mobile application, to make the temperature and humidity control system inexpensive, easy to run, use readily accessible components, and help reduce human labor.

Fig. 3. Fertilizer mixer installation and application.

The most common size for melon greenhouses is 5x20 meters. Four 18-inch ventilation fans with widely accessible 750 watts-motors are utilized per greenhouse due to their inexpensive investment cost and low energy usage. The mist system made use of a 0.3 mm spray head and a dc diaphragm water pump, both of which were readily accessible. The environment of the greenhouse is monitored by wireless sensors that communicate environmental data such as temperature and humidity to the main system controller, which can be managed and monitored through the internet. Figure 4 represent the installation of the fan in the greenhouse.

Fig. 4. Fan installation in the melon green house..

Environmental monitoring and setting of regulated environmental parameters can be managed either at the controller or via a mobile application, as shown in Figure 5. The proposed systems are deployed in melon greenhouses and utilized by farmers for system testing to ensure that the system is user-friendly and meets farmer satisfaction.

Fig. 5. Environmental control unit.

III. Experimental Results and Conclusion

Both developed systems are capable of performing well under regular operating conditions. When it comes to farmer satisfaction, the system is quite affordable. The componentized embedded module was utilized to lower the overall cost of the hardware platform. Aside from that, modifications are made to open-source software in order to develop the IoT application. The software feature has been created to be compatible with farmer activities. As a result, farmers with limited technological abilities may easily operate and understand the system. In the case of the environmental control system. By monitoring and collecting data, the system ensures that melons have the environmental requirements they require. With a mist-spray system, it is easy to maintain the temperature in the 35-40 degree Celsius range that farmers want, and the humidity may be readily controlled by the system to a certain percent humidity level that the farmers require. In addition, the technology has the potential to significantly reduce worker hours and costs. However, there are various faults and problems that need to be addressed, such as the operating or lifetime of the hardware and sensors, as well as the installation and operation of the system under a variety of requirements and farm conditions.

IV. Conclusion

The study presented a realistic Internet of Things system that was built for a premium graded melon farm. Both systems are created under the operations and requirements of the farmer's operation. The systems were shown to be effective in enhancing the primary melon farming activities, which include fertilization, irrigation, and environmental management, among other things. It is necessary, however, to monitor and further develop the system in order to increase the overall quality of melon production.

Acknowledgment

This research work is funded by Broadcasting and Telecommunications Research and Development Fund, the National Broadcasting and Telecommunication Commission (NBTC), THAILAND in collaboration with Mae Fah Luang University. Research Team also kindly appreciates the cooperation with Young Smart Farmers Community as well as Chiang Rai Collage of Agricultural and Technology.

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“IoT Technology and Digital Upskilling for Farmers in Northern Rural Area of Thailand”

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Letter of Acception for Publication

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To whom it may concern

I am pleased to inform you that the following paper

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Author: Thongchai Yooyativong and Chayapol Kamyod

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IoT Technology and Digital Upskilling Framework for Farmers in the Northern Rural Area of Thailand

Thongchai Yooyativong[1] and Chayapol Kamyod[2]*

[1]*School of Information Technology, Mae Fah Luang University,*

[2]*Computer and Communication Engineering for Capacity Building Research Center, School of Information Technology, Mae Fah Luang University, 57100, Thailand*

E-mail: thongchai@mfu.ac.th; chayapol.kam@mfu.ac.th

**Corresponding Author*

Abstract

Agricultural industry labour in Thailand remains the major labor force of the country, which is one-third of the total labour force, while the agricultural GDP is still less than 10% of the total GDP. Furthermore, half of the Thai farmers are smallholders with less than 4 acres of land and low incomes. As a result, smallholders must adapt from traditional farming methods, particularly in the cultivation of economic crops such as high-value fruits and vegetables. Although researchers in Thailand have invented many devices and systems for smart farming using communication technology and IoT technology to control the quality of cultivation and reduce the cost of farming, modern equipment and systems are still being used by small numbers of farmers. This is due to the lack of knowledge and understanding of technology, lack of skills to apply modern equipment, the lack of smart farming as a learning prototype, as well as a lack of financial investment. These are major reasons for the slow development of smallholder farmers and Thailand's agriculture.
The Broadcasting and Telecommunications Research and Development Fund for Public Interest, Office of the National Broadcasting and Telecommunications Commission, Thailand (NBTC), has funded research and development projects that seek to formulate a development framework for small-scale farmers to be able to upskill and keep up with the trends of modern digital technology and smart farming equipment. This project has proposed the Digital Farmer Development Framework as a guideline for raising the level of smallholder farmers to become digital farmers. The project has gathered important knowledge and organized upskill training to provide the necessary digital knowledge and skills, including the creation of basic digital equipment for smart farming such as sensor systems and environmental control systems in agricultural farms using IoT technology to be used for training and for farmers to apply on their farms. The training and upskill development are based on the concepts of Problem/Project Based Learning and Collaborative Blended Learning theories, which aim to upgrade smallholder farmers to become digital farmers. Project implementation, according to the Digital Farmer Development Framework that the project has set, demonstrates that the farmers clearly have the knowledge and skills to use digital technology effectively and are considered to become digital farmers. Every farm in the project puts the equipment from the project into practice on the farms, making them able to manage farms better as well as apply digital equipment in various forms. Knowledge is shared among farmers and formed into a Digital Farmer Community that provides learning resources for other small-scale farmers as well.

Keywords. Smart farmer, digital farmer, project-based learning, problem-based learning, blended learning, IoT, learning framework.

1. Introduction

Thailand has historically developed its economy from the agriculture-focused "Thailand 1.0" model to the light industry-focused "Thailand 2.0" model and then transitioned to the "Thailand 3.0" model, which emphasizes heavy industry. However, under the current "Thailand 3.0" model, the nation has been unable to increase its economic competitiveness on the international stage. Under the leadership of the Prime Minister, the current government has created a new model to reform the country's economy and lead its citizens to the "Thailand 4.0" model as part of its key strategy. The development of "security, prosperity, and sustainability" is emphasized. According to the 20-year strategic plan, "strength from within" is driven by the "Sufficiency Economy Philosophy" via the "Pracharat" mechanism, which is a policy vision to develop the country from middle-income to high-income by shifting from a traditional economy to an innovation-driven economy. By emphasizing the participation of the private sector, banks, individuals, educational institutions, and research institutes, as well as promoting SMEs and start-ups, it will be possible to steer these entities in the same direction. To connect all sectors, a high-quality communication and telecommunications infrastructure is required. The focus is on five technology groups and target industries: food, agriculture, and bio-tech; health, wellness, and bio-med; smart devices; robots; and mechanical systems [1]–[5].

The agricultural industry, which is the country's primary industry, benefits from the technology development policy and the five target industries listed above. In other words, agricultural labor employs roughly one-third of the total labor force (approximately 12.4 million people), despite agricultural GDP accounting for only 5% of total GDP. Furthermore, the majority of Thai farmers are smallholders, with 50% having less than 10 hectares of land, so there is a significant need for smallholder adjustments to current farming methods. Specifically, the success of economic crop farming, which includes the production of high-value vegetables and fruits, depends on a wide range of factors beyond those inherent to the species themselves, including the quality and fertility of the soil, the prevalence of plant diseases and insect pests in individual cultivation areas, the weather, the amount of care taken to prevent or recover from natural disasters, and so on. Nevertheless, Thai farmers and academics are working on creating and implementing cutting-edge machinery and systems for "smart farms," which will use communication and digital technology to regulate crop quality and lower production costs. However, large agricultural farms that incur high costs due to their operations use a wide variety of cutting-edge machines and systems. Small-scale farmers and ranchers still have a limited number of applications because of issues like poverty and a lack of education regarding the proper use of modern tools and technology. This is a significant contributor to the slow growth of smallholder farmers and Thai agriculture. Therefore, it is crucial and urgent to develop Thai smallholder farmers, particularly the next generation of smallholder farmers, so that they can utilize digital technology to create their own farming techniques. We also need to keep up with the fast pace of change in digital farming tools and the rollout of 4G/5G wireless Internet across the country [5]–[15].

According to the aforementioned issue, most farmers lack knowledge of agricultural technologies and digital agriculture technology capabilities. As a result, understanding digital technology is critical for developing smart agriculture. Furthermore, basic digital farming skills may be used to build low-cost farming systems for their unique agricultural settings, increasing productivity and quality. As a result, we developed and evaluated a novel learning framework to provide a new generation of small-scale farmers with the knowledge and skills needed to leverage digital technology to develop their own solutions, resulting in a new generation of digital farmers (Young Digital Farmer). In addition, we developed smart farming (Smart Farm) training courses for general smallholder farmers interested in self-development through the acquisition of fundamental knowledge of digital agriculture technology, such as communication technology in agricultural farms, Sensor Technology for Agriculture (Sensor Technology), Internet of Things (IoT), Artificial Intelligence and Machine Learning, Statistical Analysis, and Fundamentals of Big Data for Farmers. Farmers were able to create and implement smart farming techniques for their own farms. Furthermore, the participants in the program form a community of young digital farmers to build and share knowledge (Collaborative Blended Learning Approach) as a case study and learning resource for other farmers. However, diverse sectors must work together to encourage farmers to use more digital technologies. Academic, government, farming, and business sectors are all required for project completion and sustainability.

2. Related Theory

To identify patterns, methodologies, and bodies of information that can be used to construct a farmer's learning framework, the following concepts, theories, and research have been examined:

Benjamin Bloom, an American educational psychologist, studied human learning behavior and divided cognitive behavior into six levels of complexity, called Bloom's Taxonomy, which was later modified as follows: The first is remembering, which involves using memory to create or search for definitions, facts, or reviews of previously learned information. The second is understanding, which is to create meaning from many types of usage patterns. It could be text, pictures, or activities like figuring out what it means, making examples, putting it into groups, or making a summary. The third is applying, which means the knowledge gained can be put into practice through media such as models, presentations, interviews, and impersonations. The fourth is analyzing, which divides the content or concept into sub-sections. Identify the interconnection of each section and the connection to the overall structure. The fifth is evaluating, which uses rules and standards to be considered through review and criticism. The sixth is creation, which gathers elements and puts them together. Reorganize to form a form or structure through creation, planning, and production [16]–[19].

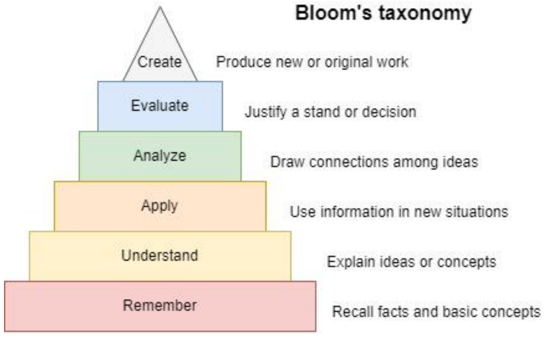

Figure 2.1. Bloom’s learning taxonomy [17]

Learning theory that emphasizes problem-solving is known as problem-based learning (PBL) or problem-based learning management system (PBLMS). Problem-based learning (PBL) is a method of education in which students learn through the resolution of actual problems. The issue is immediate and relevant to the students. They might find it useful for students, who can use it to build their own learning process by differentiating between two types of problems: simple and complex. Answers to questions or concerns can be discovered through problem-based learning. PBL aspires to provide students with real-world practice. As a result, drills are emphasized to help students improve. In addition, PBL is a powerful learning motivator. The final challenge might be seen as an opportunity to hone critical thinking and problem-solving abilities. Therefore, problem-based learning (PBL) is the use of problems to gain insight. The following are some of the many advantages of adopting PBL in learning management systems: Learning that emphasizes learning together, learning that emphasizes the pursuit of knowledge, learning that emphasizes the integration of knowledge, and a form of learning that focuses on the ability of the learners to control and assess the learning process are all characteristics of this learning approach. Metacognition is a style of learning in which students are encouraged to manage their own learning (independent study) [20]–[24].

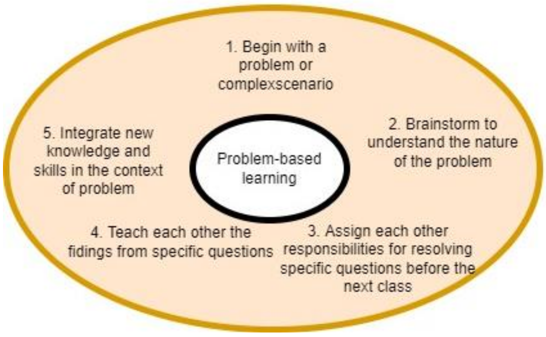

Figure 2.2. The PBL concept

Cooperative learning theory and collaborative learning have comparable meanings since the process appears to be one of cooperative learning. It is the degree to which students work together that distinguishes cooperative from collaborative learning. According to Sunyoung, J. (2003), pre-structure, task-structure, and content-structure distinguish between cooperative learning and collaborative learning. Learning through collaboration is typically better organized in advance. Collaborative learning was less pre-structured and more open-ended, whereas independent learning was linked to activities that required predetermined answers and learning more within a predetermined framework of information and abilities. This unstructured assignment necessitates innovative approaches as well as cutting-edge knowledge and skill development, neither of which is guaranteed in the context of online education. According to the research of Nagata and Ronkowski (1998), the term "collaborative learning" encompasses a wide range of cooperative learning contexts, from small project groups to a more specialized kind of working group known as cooperative learning. Johnson & Johnson pioneered collaborative learning in the 1960s, and it is still widely used today. Collaborative learning is defined by Penn State University's College of Education (2004) as "a process in which individuals working toward a common objective have a shared knowledge of that purpose, accept and trust one another, and have a clear awareness of the roles they play." The conclusion was reached by reaching an agreement among all the parties involved. Wherein the educator acts as a facilitator, helping students arrive at their own conclusions on how to solve the problem [25]–[30].


Figure 2.3. Cooperative learning

Blended learning refers to the learning process that mixes diverse learning styles, such as classroom learning mixed with learning outside of the classroom when learners and teachers are not face-to-face, or the use of a range of learning materials. The learning process and activities are influenced by a range of instructional strategies. The primary objective is for students to achieve their learning goals. Using a blended learning approach, teachers might simultaneously employ two or more instructional modalities. For instance, teachers provide course information using a combination of technology and face-to-face instruction. However, the teacher then posted the article's substance online. Then, follow up the teaching activities with conversations with instructors in the classroom, etc., utilizing e-

Learning using an LMS (Learning Management System). According to Graham, Allen, and Ure (2003), blended learning includes three dimensions: the integration of teaching through teaching materials; a mixture of teaching techniques; and the mixing of face-to-face instruction with online instruction [31]–[35].

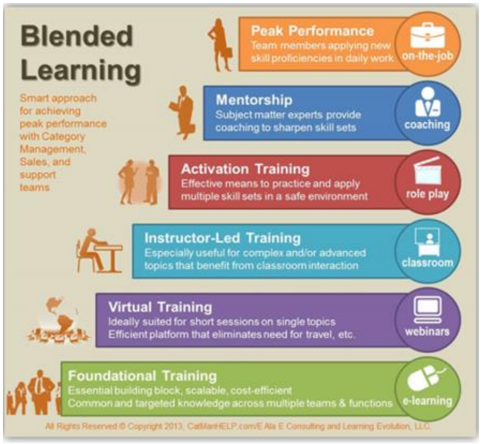

Figure 2.4. Sources: Learning Evolution, LLC and CatManHelp.com.

Digital farming is the use of digital technology to modernize agriculture by using digital technology to facilitate automated farming, such as a remotely managed smart farm system. Automation links data from various measuring equipment for scheduling, making decisions, and anticipating various events to create an optimal environment for farming, agriculture, and livestock farming with the goal of maximizing precision and productivity in agricultural activities while lowering manufacturing expenses and enhancing profitability. The goal is to increase the efficiency of inputs by using digital technology as a tool. Another goal is to promote agriculture by using information as a tool to reduce the risks caused by a climate and environment that are always changing [36]–[40].

Figure 2.5. Digital Agricultural Development Plan of the Ministry of Agriculture and Cooperatives, year period (2017-2021)

Precision farming arises from the idea that crop cultivation has environmental factors that affect both the weather and the climate, so the fields are different in each area. Even within the same farm, this difference results in different yields. The idea is, therefore, to adjust the care to suit different conditions. They are used to effectively increase productivity by adopting high-precision technology to help manage, such as soil inspection to select suitable crops, fertilizer and pesticide-controlled harvest self-propelled fertilizer trucks, a drone that will perform the task of exploring the area, and the storage of product information [37], [38].

Figure 2.6. Source: Smart Farm(Thailand) Co., Ltd.

3. The Experimental Processes and The Proposed Upskilling Framework

Implementing a research training program to provide farmers with digital technology knowledge and abilities will lead to the study and development of a methodology to encourage the next generation of farmers to become digital farmers by utilizing the foundational digital farming technologies and a collaborative blended learning approach. The research development procedures might be structured as follows:

1. Research teams set up working groups in various fields and prepare project implementation plans. knowledge gathering plan and course design Training plans and practical application of knowledge and equipment a plan for the development and construction of various equipment and systems, as well as an initial monitoring and evaluation plan including preparing the criteria for selecting farmers and farms to participate in the research project (Project Plan Design).
2. An invitation to all small farmers who are interested in signing up for the project. Through a survey and selection process, 12 farms will be chosen from the farmers who are interested in the four provinces of the higher north: Chiang Rai, Phayao, Phrae, and Nan.
3. Organize a seminar for farmers participating in the project to establish a knowledge of the actions and aims of the project, including performing studies and evaluating data on farm conditions and agricultural practices utilized by farmers. In addition, to gather problems and needs of farmers in smart farm equipment from the project, as well as analyze the needs of farmers in terms of knowledge of digital skills such as skills in using electronic devices and control systems, to bring the information for development training and application for farmers.
4. Researchers look at each farm's real condition, talk to farmers about their needs, and make different tools and systems based on the project's conceptual framework.
5. Design, develop, and build equipment and systems that will be utilized in educating farmers to implement on their farms. According to the findings of the study of items 3 and 4.
6. Design and construct training course material, techniques, and outcomes from various trainings based on project principles in Problem Based Learning and Collaborative Blended Learning Approach.
7. Conduct training in accordance with the standards to provide knowledge and skills in the operation of farming equipment and systems. Furthermore, farmers must study and apply their learning skills to their smart farm systems based on their own requirements. As a result, farmers will learn and build problem-solving abilities. So, the study team has to go to each farm and work with the farmers to set up equipment and systems, train them, and evaluate how well they can learn and use what they've learned.
8. The research team works with farmers as a guide and mentor to assist them in applying their knowledge, skills, and tools to enhance the planting process and manage their own farms.
9. Follow up, collect data, and verify the applications and smart systems in different farms and farmers' learning, as well as provide a forum for exchanging knowledge and experience of using real equipment and systems (Knowledge Management) from time to time to learn lessons and improve the course content and activities (After Action Review) throughout the project.
10. Build a unified database of information and create printed and digital course materials. Increase the efficiency of existing machinery and distribution channels so that they can serve as a template for other farmers.
11. Publish information and evaluate the achievement of project objectives.

According to the experimental processes and requirements, a conceptual framework for introducing a new generation of small-scale farmers to digital agriculture could be developed. It will incorporate and apply the numerous learning theories (learning theories) stated previously together with the appropriate digital technology knowledge (digital technology knowledge) and basic digital equipment for smart farms in real use (essential fundamental digital tools) to integrate to develop new generations of farmers to gain knowledge and skills (digital knowledge and skills) and then use the integrated results to synthesize development patterns to be a model for further application to other farmers. The development chain comprises of determining the essential information (knowledge), determining the equipment used to practice learning and skill development (tools), and sharing practical applications for learning in a problem-based learning technique (Problem Base Learning), knowledge for mutual learning (Collaborative Learning), to build a digital farmer community (Digital Farmer Community). All phases of development involve the use of collaborative learning and a variety of strategies. (Collaborative Blended Learning Approach), as seen in Figure 3.2 below.

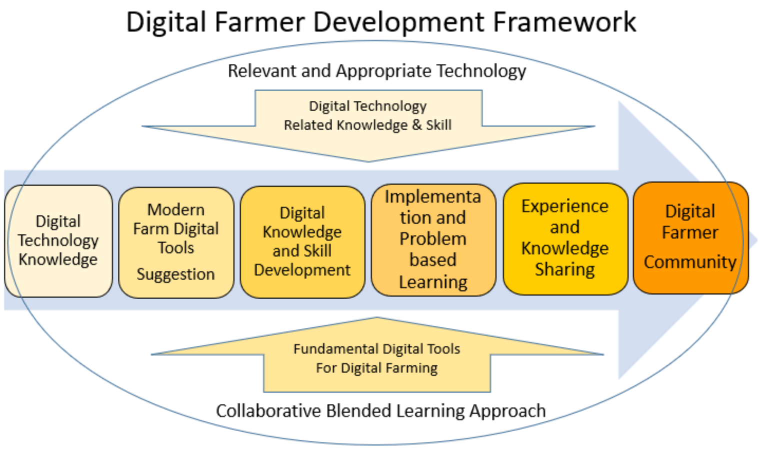

Figure 3.1. The proposed digital farmer development framework.

4.Experimental Results and Discussion

Instead of organizing a large group meeting with cooperation from local networks, namely Mae Jo University (Phrae Campus) and Chulalongkorn University (Nan Provincial Learning Center), to gain insights directly from the farmer and appropriate to the current situation of the COVID-19 epidemic, interviews with farmers will be conducted. The interview parameters established by the study team include the following crucial topics: general conditions of the agricultural area, including the environment, area conditions, soil conditions, and water sources; farming techniques because of the planting that is done, including the plants planted, how to water, fertilize, and care for them; problems in agriculture, including labor, environmental control, soil care, irrigation, and production quality; knowledge, abilities, and requirements for intelligent agricultural machinery; the digital technological abilities of farmers, such as the capacity to utilize computers, cell phones, and electronic social networking equipment; a farmer possesses intelligent farm equipment; intelligent agricultural equipment; agricultural equipment; agricultural equipment that farmers require to solve issues or make farming easier or more efficient; knowledge of settings suited for caring for crops, vegetables, and fruits cultivated by farmers, such as temperature, sunshine, humidity, pH value in soil, and the amount of fertilizers and minerals required by the plant; and comments and other ideas from farmers. Fig. 4.1 depicts the visiting and interviewing actions of farmers.

Figure 4.1. Interviewing farmers activities from Nan, Prae, and Chiang Rai provinces, Thailand.

Based on the interview, the farmer's issues can be summed up as follows: A labor shortage problem exists since some farms are family-owned and use local labor. Furthermore, there were issues because local companies or factories pulled employees. Climate change circumstances result in illnesses, insects, and poor production quality. Weather difficulties with overheating and heavy rain cause harm to crops. Non-seasonal rain produces uneven growth of vegetables, and there are diseases and insects that arrive with hot weather. A shortage of water during the dry season prevents agricultural production. Watering problems as the farm is currently irrigated with a hose and sprinkler system, where watering is observed to monitor soil moisture around the area without knowing if it is sufficient for the needs of the plants. There are problems with diseases and insects due to a lack of cultivation in the surrounding area. Therefore, it is the only green place in that region that leads insects to damage the fruit; the storm damages the greenhouses where vegetables are grown. We may summarize what farmers expect from smart agricultural equipment based on the requirements listed above as follows:

1. A temperature control system in the greenhouse. Since the temperature is low in winter and very hot during the afternoon, peach tomatoes cause the tomato blooms to shrink, with no mixing, resulting in no productivity. This difficulty can be solved if the house has a temperature control system. Furthermore, if the greenhouse temperature is too high, the vegetables grow slowly and become infected.
2. An automatic watering system to assist in resolving the watering scheduling and labor issues. Also, water systems with sensors that measure how much water and how moist the soil needs to be for each plant can prevent overwatering, cut down on plant diseases, save water, make sure crops get enough water, and improve the quality of production.
3. Systems that can monitor air humidity and temperature in the greenhouse aid in ventilation by providing farmers with data on heat and humidity. Because humidity and heat can cause some diseases and insects, they need to be well-prepared to avoid or stop the damage that will happen. This will help them be more productive.
4. A system that can monitor soil quality or soil nutrients in fertilizers to determine the quantity of nutrients needed to enhance soil quality as much as feasible. It will also assist in terms of utilizing less fertilizer and lowering production expenses.

Furthermore, farmers' knowledge demands may be stated as follows:

1. They want to be advised on how to operate smart farm equipment appropriately for the most efficient usage.
2. They desire ongoing monitoring of the study team. Farmers can utilize different equipment or tools more efficiently if information and expertise are added to them on a regular basis.

3. They want the project to prepare them to the point where they can increase their own abilities and ensure the initiative's long-term viability. Farmers have come across initiatives in the form of putting equipment in the region and collecting data, and after they complete studying, they return with nothing.

Design and prototype of equipment and systems for use in training and allowing farmers to utilize them on their farms based on their aims and farmer's requirements. It can be used to train and develop individuals, and farmers may utilize it on real farms. It is made up of the following sections:

- A Microclimate Sensor Node is a tool for measuring the weather on a farm or at home.
- Water pump control system for drip irrigation systems, sprinkler system, pipeline fertilizer system, as well as the home ventilation system
- Weather Station
- Automated measurement and control system (monitoring and controlling system).
- Internet of Things Platform with multiple displays (Monitoring Application Platform/Dashboard).

The research group has concentrated on designing electrical devices or boards that can be implemented across a wide range of systems, including but not limited to water pump control systems for drip irrigation or sprinkler systems, pipeline fertilizer systems, home ventilation systems, and so on. Each one of these systems is a monitoring and control system that functions across the Internet of Things (IoT Platform). In addition, the interaction between various requirement modules influenced the creation of the system's architecture. Figure 4.2 displays the intended module, and Figure 4.3 displays the implementation system architecture.

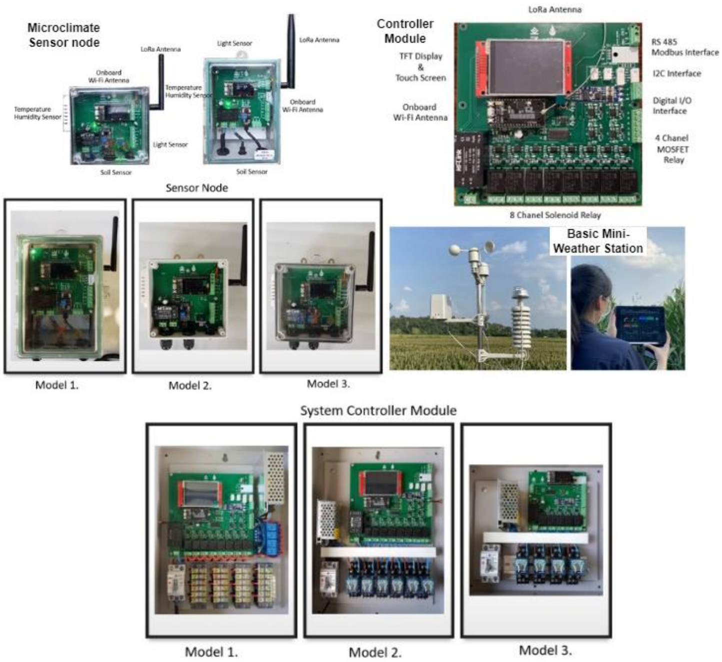

Figure 4.2. Some designed equipment and module for different farming conditions

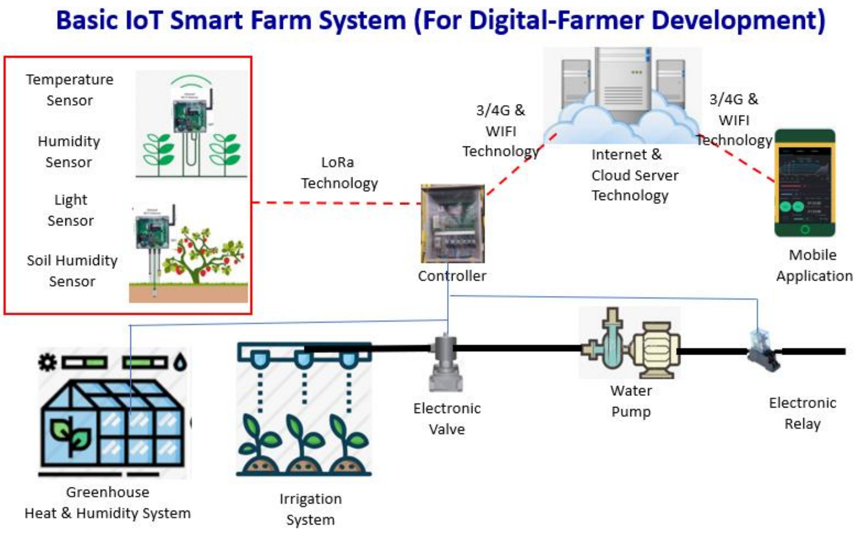

Figure 4.3. The conceptual designed system architecture

The project's purpose is to transform farmers into digital farmers. As a result, in the installation and development of various systems, the researchers collaborated closely with farmers from system design to installation and implementation, based on the concepts of the proposed learning framework (collaborative blended learning framework), with an emphasis on practical needs and farmer requirements, as well as problems that farmers want to solve with IoT systems and digital devices. Three training sessions were given (problem-based, collaborative learning). The training seeks to enhance their agriculture and farming operations via the use of IoT technologies and digital marketing to expand sales and distribution channels. Thirty farmers were trained on how to use smart agricultural equipment and create systems for their fields. The following are the main training contents: smart farm equipment fundamentals and operations; basic system use cases; basic electronics and IoT systems; irrigation systems; greenhouse heating and humidification systems; the pipeline fertilizer system; problem-based learning and collaborative learning. Following the training, farmers were required to analyze their needs or challenges and design a smart system for their own farm. The farmers will then show their concept to other farms while receiving feedback and comments from the research team. As a result, the study team obtained the needed information and comprehended their problems. The next step is for the researchers to visit the farms, in which they will finalize the design of the system based on the specifics of the farm and install the intelligent system. Because the majority of the farms in the project are smallholders, certain infrastructure, including irrigation systems, electrical systems, and dwelling structures, must be created to facilitate the adoption of IoT and Smart Farm technologies. The installation of the planned equipment and the development of the system will be carried out in partnership with a team of researchers and farmers. Farmers may thus study in parallel using the project's problem-based learning and collaborative learning concepts. The result is that systems are put to good use immediately upon installation. Most of the systems will concentrate on irrigation, fertilizer, drying agricultural goods, and environmental monitoring in planting plots. Some training and experimental procedures are depicted in Figures 4.4 and 4.5


Figure 4.4. The training based on the proposed framework.

Figure 4.5. System installation at Cocoa farm, Thailand

From the evaluation of the farmer's development process according to the proposed learning framework, using Bloom's taxonomy as a guideline for evaluating the knowledge and skills in digital technology of farmers in the project, which includes measuring, assessing, remembering (remembering), understanding (understanding), application (applying), analysis (analyzing), evaluation (evaluating), and creation (creating) by using questionnaires, brainstorming. Figures 4.6 and 4.7 summarizes the assessment outcomes from the twelve farms that completed the project.

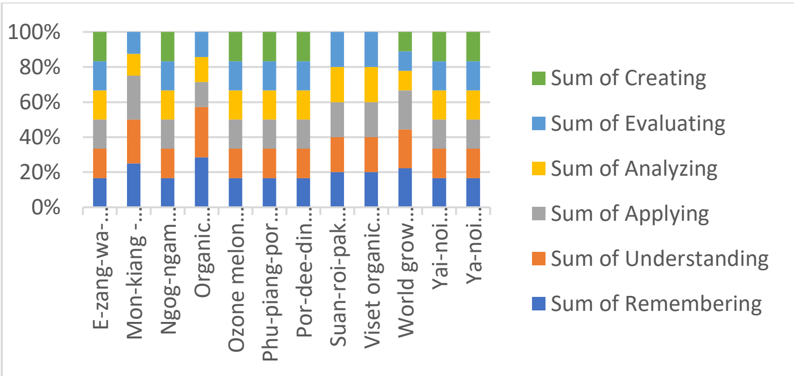

Figure 4.6. Evaluation of farmer development using Bloom's classification theory.

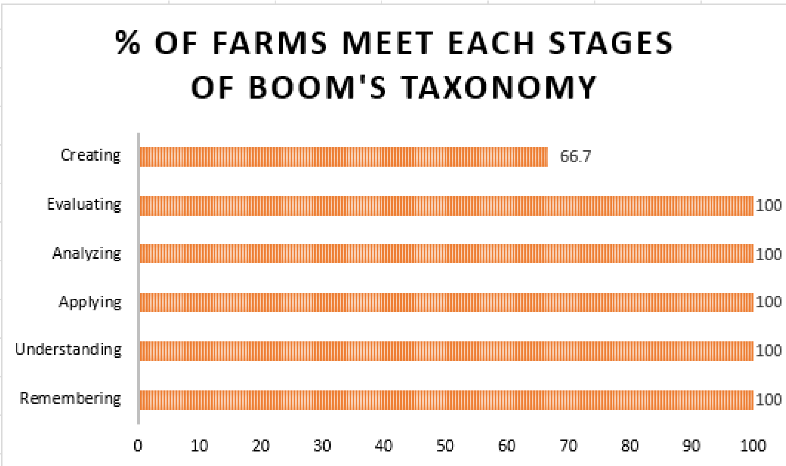

Figure 4.7. Bloom's theory-based average evaluation results.

Based on the evaluation of the project's innovative process in digital farmer development (Digital Farmer Development Framework), it is regarded as an efficient and effective procedure. It may be used to transform smallholder farmers into digital farmers in Thailand. In terms of creativity, the gap is mostly related to the farmers' fundamental understanding. If a farmer is of a younger generation or has a background in mechanics or technology, he or she will possess a greater number of talents in this area than farmers with no prior experience in this area. However, the overall learning results were that the participating farmers were able to improve their learning abilities to the level of decision-making and were able to independently address technological challenges.

5.Conclusion

Researchers are now able to identify the difficulties and demands of farmers in various sectors based on the research results, which took around a year to collect. We have developed rules for operations that have resulted in a learning model of a collaborative blended learning framework that is capable of fostering rapid skill development among farmers. Farmers gain an understanding of their actual challenges and requirements via study. It has been built and designed in terms of both the equipment and understanding of vital technology, including important expertise in numerous domains such as digital marketing, where farmers may apply their newly acquired knowledge practically. In addition, the collaboration of a group of experts with expertise in a variety of fields, both in agriculture and technology, facilitates learning and increases productivity. The attention and desire to learn and be receptive to new information of the participating farmers is crucial, since it is an integral element of the task that both researchers and farmers must do in a short amount of time. This learning approach may also be utilized to train employees in many industries who wish to improve their technological skills and system development in order to satisfy the demands of other businesses. For the enhancement and development of the learning model in the future, the component of sustainable and continuous learning that takes time and the research of several important factors to accommodate the growth and learning of farmers and business groups may be further improved.

6. Acknowledgment

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Biographies

Assist. Prof. Grp. Capt. Dr. Thongchai Yooyativong is currently a senior lecturer at School of Information Technology, Mae Fah Luang University, Thailand. He was a Vice President of Mae Fah Luang University and Dean of School of Information Technology. He has been involving in many projects concerning rural area development such as the Tele-centre for rural education and rural area development project, the digital ancient city: Chiang Saen Project, the IT entrepreneur development in Chiang Rai Province Project, and Digital Administration System for Schools (e-School) to enhance the quality of rural area education. Currently, his research focus on smart farming and rural area digital-farmer development.

Chayapol Kamyod received his Ph.D. in Wireless Communication from the Center of TeleInFrastruktur (CTIF) at Aalborg University (AAU), Denmark. He received M. Eng. in Electrical Engineering from The City College of New York, New York, USA. In addition, he received B.Eng. in Telecommunication Engineering and M. Sci. in Laser Technology and Photonics from Suranaree University of Technology, Nakhon Ratchasima, Thailand. He is currently a lecturer in Computer Engineering program at School of Information Technology, Mae Fah Luang University, Chiang Rai, Thailand. His research interests are resilience and reliability of computer network and system, wireless sensor networks, embedded technology, and IoT applications.