บทความวิจัย

การพัฒนาชุดกิจกรรมการเรียนการสอนแบบสะเต็มศึกษากรณีศึกษา เรื่อง โรงเรือนอัจฉริยะ

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สาขาวิชาวิศวกรรมไฟฟ้าศึกษา ภาควิชาครุศาสตร์ไฟฟ้า คณะครุศาสตร์อุตสาหกรรม มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าพระนครเหนือ

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บทคัดย่อ

การวิจัยครั้งนี้มีความมุ่งหมายเพื่อ 1) การพัฒนาชุดกิจกรรมการเรียนการสอนแบบสะเต็มศึกษา กรณีศึกษา เรื่อง โรงเรือนอัจฉริยะ 2) ประเมินความพึงพอใจของผู้เรียนในการใช้ชุดกิจกรรมการเรียนการสอน เครื่องมือที่ใช้ในการวิจัยประกอบด้วย คู่มือครู คู่มือผู้เรียน ชุดฝึกปฏิบัติการโรงเรือนอัจฉริยะ แบบทดสอบก่อนเรียน-หลังเรียน แบบทดสอบผลสัมฤทธิ์ทางการเรียน และแบบประเมินความพึงพอใจของผู้เรียน กลุ่มตัวอย่างในการวิจัยเลือกจากกลุ่มเป้าหมาย คือ นักศึกษาจำนวน 12 คน ที่ลงทะเบียนเรียนในรายวิชาการประยุกต์ใช้ไมโครคอนโทรลเลอร์ ของสาขาวิชาไฟฟ้าและอิเล็กทรอนิกส์อุตสาหกรรม ภาควิชาเทคโนโลยีอุตสาหกรรม คณะเทคโนโลยีการเกษตรและเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏนครสวรรค์ สถิติในการวิจัยเพื่อการวิเคราะห์ข้อมูล ได้แก่ ค่าเฉลี่ยและส่วนเบี่ยงเบนมาตรฐาน ผลการวิจัยพบว่า ชุดกิจกรรมการเรียนการสอน เรื่อง โรงเรือนอัจฉริยะ มีประสิทธิภาพในการนำไปใช้ในการจัดการเรียนการสอนให้กับนักศึกษา และผลการประเมินความพึงพอใจของผู้เรียนในการใช้ชุดกิจกรรมการเรียนการสอน อยู่ในระดับมาก (ค่าเฉลี่ย = 4.34 และ S.D. = 0.62) สรุปได้ว่าการพัฒนาชุดกิจกรรมการเรียนการสอนแบบสะเต็มศึกษา กรณีศึกษา เรื่อง โรงเรือนอัจฉริยะ สามารถนำไปใช้ในการจัดการเรียนการสอน เรื่อง การประยุกต์ใช้งานไมโครคอนโทรลเลอร์ได้อย่างเหมาะสม และพัฒนาการเรียนรู้ให้ก้าวหน้า โดยผู้เรียนสามารถนำเทคนิคการเรียนแบบโครงงานเป็นฐานในการแก้ไขปัญหา ด้วยการคิด วิเคราะห์ได้อย่างเป็นลำดับ สร้างโอกาสการเรียนให้สูงขึ้น

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Research Article

Development of an Instructional Activity Package Based on STEM Education: A Case Study of Smart Farm

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Abstract

The objectives of this research are 1) to develop an instructional activity package based on STEM education: a case study for smart farm, and 2) to evaluate students' satisfaction towards the package. The package contains a guideline of learning activities based on STEM education, a teacher manual, a student manual, a smart farm practice set, virtual instructional media, pre- and post-tests, and a learning outcome evaluation form. The sample group was selected from the target group which consists of 12 students enrolling in the Microcontroller Application course of the Industrial Electrical and Electronic program, Department of Industrial Technology, Faculty of Agricultural and Industrial Technology, Nakhon Sawan Rajabhat University. Mean and standard deviation were used to analyze the data. The result showed that the developed package can be effectively applied for teaching and learning management. The students' level of satisfaction towards the package was high ($\bar{X}$ = 4.32 and S.D. = 0.51). In conclusion, the instructional activity package based on STEM education: a case study of smart farm can be effectively applied in a Microcontroller Application course and develop the learning progress. It can be used with project-based learning techniques to improve students to think and analyze problems step by step and enhance higher learning opportunities.

Keywords: Instructional Activity Package, Smart Farm, STEM Education

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1. Introduction

Agriculture is the main career and the main income of Thailand. Traditional way of farming has long been an important part of communities' life from generations to generations. The productivity depends greatly on weather. Thailand counts 138 million rai or about 220,800 Sq. Km. of agricultural land. The income generated from agriculture represents 10% of the country's GDP and 68% of farmers' overall income [1]. Agriculture is the main activity that generates income for most Thai households. It is also vital for daily life and economy of the country. However, the farmers are still encountering problems, especially regarding the produce due to the lack of insightful data and the weather conditions including drought, flood, and any other natural disasters [2]. Controlling and improving favorable condition for farming brings about good quality agricultural produce in enough amount for domestic and international consumption. Since 2015, Thailand had entered Thailand 4.0 era and implemented the government's policy to help the agricultural sector control the produce quality and expand market. Related government agencies provide tools and transmit knowledge to communities, as well as accompany them in every stage of farming from the farm to the market. To do so, "smart faming" is applied.

The Internet of Things is an emerging topic of technical, social and economic importance. Consumer products, durable goods, cars and trucks, industrial components and facilities, sensors, and other everyday objects are combined with internet connectivity and powerful data analysis capabilities that promise to transform the way we live and work [3]. In today's world, technology is constantly evolving; various instruments and techniques are available in the agricultural field. And within the agrarian division, the IoT preferences are knowledge processing [4]. IoT plays important role because it corresponds to farmers' needs for convenience and precision in every stage of farming, from planting, harvesting, until selling. This system can also predict favorable environment, yield quality, harvest dates, and sales channel. It can be stated that smart farming applies to Thailand 4.0 scientific knowledge to sustainably develop the country's economy and transform traditional way of farming into modern farming with the use of innovation and technology.

Developing technology to create agricultural innovation requires knowledge and skills based principally on education. Education in institutes lays a solid foundation to increase crops, leading to the success of agriculture development of the country. Therefore, it is important for the education in Thailand 4.0 to focus on how to equip workforce with skills to innovate. Teaching and learning that emphasizes on interdisciplinary approach becomes necessary to enhance students' knowledge, skills, and attitude.

STEM-based education is an innovative learning approach focusing on learners. It is an interdisciplinary approach integrating science, technology, engineer, and mathematics that enables students to learn from real practice in daily life. It also provides students an opportunity to express their opinion, solve problems, and apply project-based learning [5]. Teachers design teaching methods and organize learning activities that stimulate students' knowledge and skills. Students can learn from these activities

before studying the contents of each lesson. Learning experience is then shared among students and between students and teachers [6].

Consequently, this research has developed of an instructional activity package based on STEM education approach for smart farm to develop students and related staff. Which the develop of modern technology is growing importantly and becoming more necessary for professional and everyday life activities, including the application of the IoT in the agricultural sector. However, it was worth noted that some researcher, interested community members still lack the knowledge, the understanding and the information about the IoT application in agricultural activities [7]. STEM education is applied to help design in-class learning activities to boost students' understanding and skills and adjust their attitude to prepare them to be agricultural innovator. In addition, this approach allows students to learn how to apply technology appropriately for their daily and professional life.

1.1 Purposes of the Study

To develop of an instructional activity package based on STEM education approach for smart farm and to evaluate students' satisfaction towards the instructional activity package.

1.2 Theory and Literature Review

The authors of this article have searched for information and studied theory and related research about designing and creating instructional activity package that applied STEM education, as well as smart farm.

Figure 1 The STEM education approach.

STEM Education is an interdisciplinary approach integrating science, technology, engineer, and mathematics. The outstanding points and learning method of each discipline constituting STEM are combined harmoniously to enhance students' skills of information searching, problem solving, and innovation creating in modern world [8]. STEM approach is applied in engineering education together with the project-based approach to enable students to learn from real practice, think systematically, solve problems creatively, and work in team. Moreover, it constitutes a platform for students to share and exchange workpiece or experience with more insightful understanding. Students can use modern technology to search for information. All of the above-mentioned behaviors correspond to the desired 21st century skills. Thus, STEM education can effectively improve students' knowledge, skills, creative thinking, responsibility, and professional ethics, as shown in Figure 1.

Instructional activity package is the teaching materials or documents that were created by the teacher to be used in teaching [9]. An instructional activity package is considered an educational innovation that includes media, process, and learning activities that link the teachers to the students to efficiently achieve expected learning outcomes. The Instructional activity package is developed to address the problem occurred in courses where

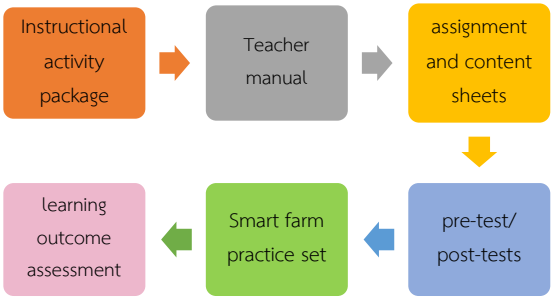

Figure 2 The instructional activity package for this research.

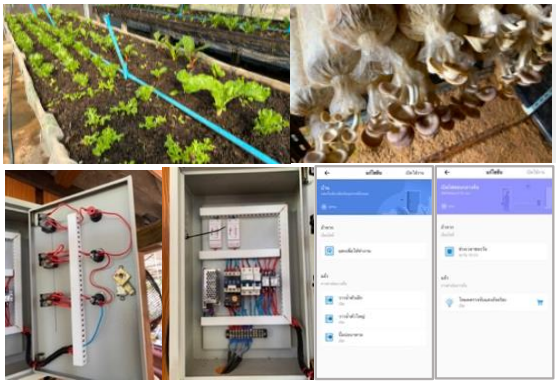

Figure 3 Modern agricultural technology.

learning experience and outcomes did not meet the objectives. Developing an instructional activity package requires information about the needs and especially the purpose of such package whether it is for lecture class, group activity, or individual activity. The instructional activity package mainly consists of a teacher manual, assignment sheets, content sheets, pre-/post-tests, and learning outcome assessment. The instructional activity package must be designed in accordance with the content focusing on student-centered approach including evaluation form and outcome assessment with clear noting criteria. This research has designed and developed the package with diverse activities and instructional media according to students' level of knowledge. The instructional activity package accompanies the students in their research and self-learning efficiently, as shown in Figure 2.

Smart farm applies new technology under the principle of Good Agricultural Practices (GAP). Nowadays, farmers are more interested in farming and applying technology in farm that helps them take care of the plants throughout the cultivation process. Electrical, electronic and information technologies are implemented to manage the growth of plants, estimate the period to apply fertilizer or watering, and predict the harvest period more precisely. The learning from data can also be used to predict harvests' outcomes. These technologies are controlled by application in smart phones related automatic control system. The farm system is controlled by internet network connected and accessed to objects with IP address. The data are exchanged and processed to control the operation of devices. This is generally known as the Internet of Things or IoT. The integration of IoT to get the data for learning to control the farm with good agricultural practices are called smart farm, as shown in Figure 3.

2. Materials and Methods

The development of an instructional activity package based on STEM education: a case study of smart farm has a detail of this research as follows.

2.1 Materials

2.2.1 A teacher manual concerns learning activity plan, behavioral objectives, practice schedule,

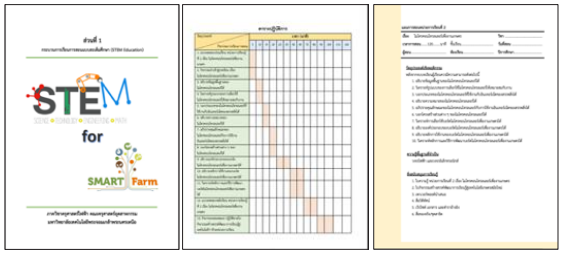

Figure 4 Teacher manual.

Figure 5 Student manual.

content sheets, laboratory sheets, presentation visual media, and test sheets, as shown in Figure 4.

2.2.2 A student manual consists of content sheets for five lessons, ten assignment and test sheets, pre-test and post-test, and learning outcome evaluation form, as shown in Figure 5.

2.2.3 As for the smart farm practice set, Arduino Uno and ESP8266 microcontrollers were applied together with other electrical equipment, electronic equipment, and other equipment in relation with smart farm. The application and the operation were set by C++ programming language that was written into the hardware. The electronic circuit of the smart farm practice set was designed for effective implementation, as shown in Figure 6.

Figure 6, the researchers have determined two main patterns of circuit connection including 1) general crop smart farm circuit, and 2) mushroom

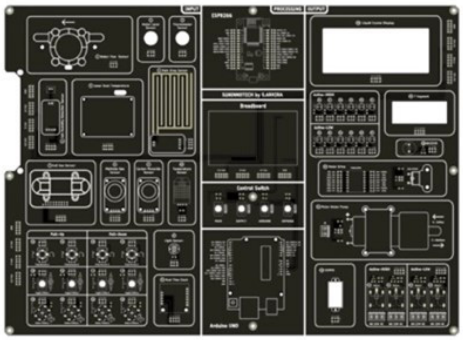

Figure 6 Circuit in the smart farm practice set.

Figure 7 Model of the smart farm practice set.

smart farm circuit. The circuit components for smart farm practice set consists of an Arduino Uno R3 board, an ESP8266 board, a relay module, an LCD screen, sensor modules, and direct current electrical motor modules. The smart farm practice set can control the farm with both the automatic system and IoT. The model of the smart farm practice set is shown in Figure 7.

2.2.4 Virtual instructional media consist of two main parts including a software and farm models.

1) The software part of virtual instructional media is about the Arduino IDE that was applied to write instruction programs and simulate the operation of smart farm control system. An applied circuit was designed to control smart farm with

```ino
//Temperature_Sensor
#include "DHT.h"
#define DHTPIN 10 //ประกาศขาสัญญาณ
#define DHTTYPE DHT22 //ประกาศชนิดของเซ็นเซอร์
DHT dht(DHTPIN, DHTTYPE);
void setup() {
  Serial.begin(9600);
  Serial.println(F("DHTxx test!"));
  dht.begin();
}
void loop() {
  delay(2000);
  float h = dht.readHumidity(); //ทำหนดค่าตัวแปลความชื้น h
  float t = dht.readTemperature(); //ทำหนดค่าตัวแปลอุณหภูมิแบบฟาเรนไฮต์ t
  float f = dht.readTemperature(true); //ทำหนดค่าตัวแปลอุณหภูมิแบบองศาเซลเซียส f
  if (isnan(h) || isnan(t) || isnan(f)) {
    Serial.println(F("Failed to read from DHT sensor!"));
    return;
  } //แสดงผลว่าเซ็นเซอร์อ่านค่าไม่ได้
  float hif = dht.computeHeatIndex(f, h); //แสดงค่าของความชื้นและอุณหภูมิแบบฟาเรนไฮต์
  float hic = dht.computeHeatIndex(t, h, false); //แสดงค่าของความชื้นและอุณหภูมิแบบองศาเซลเซียส

  Serial.print(F("Humidity: ")); //อ่านค่าความชื้น
  Serial.print(h); //แสดงค่าของค่าความชื้นด้วย "h"
  Serial.print(F("%  Temperature: ")); //หน่วยของค่าความชื้น
  Serial.print(t); //แสดงค่าของค่าอุณหภูมิแบบองศาเซลเซียส "t"
  Serial.print(F(" C ")); //หน่วยของอุณหภูมิแบบองศาเซลเซียส
  Serial.print(f); //แสดงค่าของค่าอุณหภูมิแบบฟาเรนไฮต์ด้วย "f"
  Serial.print(F(" F  Heat index: ")); //อ่านค่าดัชนีความร้อน
  Serial.print(hic); //ตัวแปลการคำนวนอุณหภูมิแบบองศาเซลเซียส
  Serial.print(F(" C ")); //หน่วยอุณหภูมิแบบองศาเซลเซียส
  Serial.print(hif); //ตัวแปลการคำนวนอุณหภูมิแบบฟาเรนไฮต์
  Serial.println(F(" F")); //อุณหภูมิแบบฟาเรนไฮต์
}
```

(a) The programming for Arduino Uno microcontroller

```ino
//mixed ESP8266
#include <ESP8266WiFi.h>
const char* ssid     = "555";          //อย่าลืมแก้เป็นชื่อ SSID  ของตัวเอง
const char* password = "5555555555"; //อย่าลืมแก้เป็นชื่อ password ของตัวเอง
void setup()
{
  Serial.begin(115200);   //ตั้งค่าใช้งาน serial ที่ baudrate 115200
  delay(10);
  Serial.println();
  Serial.println();
  Serial.print("Connecting to "); //แสดงข้อความ  "Connecting to"
  Serial.println(ssid);       //แสดงข้อความ ชื่อ SSID
  WiFi.begin(ssid, password); // เชื่อมต่อไปยัง AP

  while (WiFi.status() != WL_CONNECTED)   //รอจนกว่าจะเชื่อมต่อสำเร็จ
  {
    delay(500);
    Serial.print(".");
  }

  IPAddress local_ip = {192, 168, 1, 1}; //ตั้งค่า IP
  IPAddress gateway = {192, 168, 1, 1}; //ตั้งค่า IP Gateway
  IPAddress subnet = {255, 255, 255, 0}; //ตั้งค่า Subnet
  WiFi.config(local_ip, gateway, subnet); //setค่าไปยังโมดูล

  Serial.println("");
  Serial.println("WiFi connected");   //แสดงข้อความเชื่อมต่อสำเร็จ
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP()); //แสดงหมายเลข IP ของ ESP8266
}
void loop() {

}
```

(b) The programming for ESP8266 microcontroller

Figure 8 Programming of Arduino IDE to write instruction programs for smart farm practice set.

Figure 9 The farm models.

the microcontroller in the smart farm practice set. The code programming for controlling the system of the smart farm with the Arduino Uno and ESP8266 microcontroller board that were configured differently, and connect the control signal to the smart farm system, as shown in Figure 8.

2) As for the farm models, two models of farm were developed, 1) general crop farm model for vegetable. It was developed from Plastwood sheet or PVC foam sheet and aluminum materials which were easy to used and suitable for water system [10]. 2) Mushroom farm model was developed from PVC materials which were easy to used and suitable for water system. The wall was made of insulating polycarbonate sheet with UV protective coating [7], as shown in Figure 9.

2.2 Research Methodology

The methodology of the development of the instructional activity package based on STEM education for smart farm has a detail as follows.

2.2.1 Surveying problems and collecting data. The survey was carried out in the Microcontroller Application course with 12 undergraduate students of the Electricity and Electronics program. The objective of the survey is to identify problems encountered in the course as well as students' needs of learning activities. The result of the survey indicates that 1) the instructional media is not

appropriate and cannot be applied to improve learning, 2) the course put focus on theory rather than practice, and 3) the learning management format does not create students' learning. According to the collected information, the researchers agreed to prepare appropriate content and instructional media for learning management emphasizing on self-learning and real practice. The development of an instructional activity package consists of learning management, instructional media, learning activity designing, assignment and content sheet designing, and learning outcome evaluation designing.

2.2.2 Analyzing the course, the research was conducted in Microcontroller Application that is a course of the Bachelor of Industrial program, Nakhon Sawan Rajabhat University. Course description and course content were analyzed before applying STEM education to two lessons about smart farm including 1) Arduino microcontroller and connection ports and 2) microcontroller application. The content was redesigned to correspond to outcome indicators. The total learning period was 32 hours; 12 hours for theoretical lessons and 20 hours for practice sessions. After that, the students were allowed to self-study independently. During the students' self-study period, the researchers also provided additional knowledge concerning the development of automatic control system technology and smart control system with microcontroller.

2.2.3 An instructional activity package was developed for smart farm lessons. It consists of a guideline of learning activities based on STEM education, a teacher manual, a student manual, a smart farm practice set, virtual instructional media, pre- and post-tests, and learning outcome evaluation

Figure 10 Learning instructional activity package with sample group.

form. The smart control system technology was also applied efficiently and advantageously.

2.2.4 Testing and collecting data. The developed instructional activity package for smart farm was applied with a sample group of 12 undergraduate students enrolling in the Microcontroller Application course in Bachelor of Industrial program, Nakhon Sawan Rajabhat University. The students were selected with purposive sampling method. STEM education was also applied. To start, the teacher provided information about the instructional activity package that consisted of a teacher manual, a student manual, content sheets, test laboratory sheets, presentation visual media, test sheets. Then, the teacher explained the details, discussed content of each lesson, and introduced the smart farm practice set and STEM education. Throughout the second semester of the academic year 2021 and after completing of lessons, the students' outcomes were evaluated. All data from this semester were collected to analyze to find out statistic data including mean and standard deviation (S.D), as shown in Figure 10.

3. Results

To evaluate students' satisfaction towards the instructional activity package based on STEM education: a case study of smart farm, the questions are grouped in six aspects including teaching method, content sheets, PowerPoint presentation, smart farm practice set, virtual model, and outcome evaluation. Five-point scale questionnaire was submitted to 12 students, the result was, after that, analyzed to find out the mean ($\bar{X}$) and the standard deviation (S.D.) accordingly. Table 1 below shows the result of student's satisfaction evaluation.

Table 1 Result of students' satisfaction evaluation

Item	$\bar{X}$	S.D.	Result
Teaching method			
1. Activity plan is integrated in teaching	4.50	0.52	High
2. Learning activity duration is appropriate.	4.42	0.51	High
3. The teacher applies STEM education approach.	4.58	0.51	Very high
4. Learning activities are appropriate.	4.25	0.75	High
5. The evaluation method is appropriate.	4.17	0.83	High
Overall mean	4.38	0.62	High
Content sheets			
6. Contents correspond to the objectives of the program.	4.17	0.72	High
7. The content is accurate and up to date.	4.42	0.51	High
8. The amount of the content is appropriate.	4.33	0.65	High
9. The order of the content is appropriate.	4.25	0.87	High
10. Language and pictures used are appropriate.	4.17	0.58	High
Overall mean	4.27	0.67	High
PowerPoint presentation			
11. Font size and pictures are appropriate.	4.25	0.75	High
12. Presentation covers the content of the course.	4.42	0.51	High
13. The order of the content is appropriate.	4.33	0.65	High
14. The amount of the content facilitates learning.	4.50	0.52	High
15. It promotes students' self-learning.	4.17	0.58	High
Overall mean	4.33	0.60	High
Smart farm practice set			
16. The practice set is appropriate for students' level of knowledge.	4.50	0.52	High
17. The content corresponds to learning objectives.	4.42	0.51	High
18. Structure and design are easy to use.	4.67	0.49	Very high
19. It promotes students' systematic learning.	4.33	0.65	High
20. It can be used accurately and effectively.	4.25	0.75	High
Overall mean	4.43	0.58	High
Virtual model			
21. It corresponds to learning objectives.	4.50	0.52	High
22. Structure and design are appropriate.	4.25	0.87	High
23. It is precise and accurate.	4.17	0.72	High
24. It is easy to use, maintain, and carry.	4.33	0.65	High
25. It promotes students' learning skills.	4.25	0.62	High
Overall mean	4.30	0.68	High

Table 1 Result of students' satisfaction evaluation (*Continued*)

Item	$\bar{X}$	S.D.	Result
Outcome evaluation			
26. Questions corresponds to behavioral objectives.	4.50	0.52	High
27. The number of questions is appropriate.	4.42	0.51	High
28. Questions and answers are clear and appropriate.	4.25	0.45	High
29. The exam duration is appropriate.	4.33	0.78	High
30. The exam difficulty level is appropriate.	4.25	0.45	High
Overall mean	4.35	0.54	High
Overall mean (Every aspect)	4.34	0.62	High

From Table 1, the result of teaching method aspect indicates that the satisfaction level is very high at $\bar{X}$ = 4.58, S.D. = 0.51 concerning STEM education application in this course followed by the integration of activity plan in teaching at $\bar{X}$ = 4.50, S.D. = 0.52. In general, the students are highly satisfied with teaching method at $\bar{X}$ = 4.38, S.D. = 0.62

As for the content sheet aspect, the result reveals that the students are highly satisfied with the accurate and up to date content at $\bar{X}$ = 4.42, S.D. = 0.51 followed by the appropriateness of the content at $\bar{X}$ = 4.33, S.D. = 0.65. In general, the students are highly satisfied with content sheets at $\bar{X}$ = 4.27, S.D. = 0.67.

Concerning the PowerPoint presentation aspect, the result indicates that the students are highly satisfied with the amount of the content that facilitates learning at $\bar{X}$ = 4.50, S.D. = 0.52 followed by the presentation that covers all the content of the course at $\bar{X}$ = 4.33, S.D. = 0.65. In general, the students are highly satisfied with PowerPoint presentation at $\bar{X}$ = 4.33, S.D. = 0.60.

As for the smart farm practice set, the result shows that the students are very highly satisfied with the structure and design are easy to use at $\bar{X}$ = 4.67, S.D. = 0.49 followed by the appropriateness of the smart farm practice set for students' level of knowledge at $\bar{X}$ = 4.50, S.D. = 0.52. In general, the students are highly satisfied with the smart farm practice set at $\bar{X}$ = 4.43, S.D. = 0.58.

As for the virtual model, the result demonstrates that the students' satisfaction level is high concerning the accordance of the virtual model with learning objectives of the course at $\bar{X}$ = 4.50, S.D. = 0.52 followed by the fact that it is easy to use, maintain, and carry at $\bar{X}$ = 4.33, S.D. = 0.65. In general, the students are highly satisfied with the virtual model at $\bar{X}$ = 4.30, S.D. = 0.68.

And finally concerning the outcome evaluation aspect, the result indicates that the student's satisfaction level is high concerning the accordance of the questions with behavioral objectives at $\bar{X}$ = 4.50, S.D. = 0.52 followed by the appropriateness of the number of questions at $\bar{X}$ = 4.42, S.D. = 0.51. In general, the students are highly satisfied with the outcome evaluation at $\bar{X}$ = 4.35, S.D. = 0.54.

According to the result, the students' satisfaction level in every aspect is high. They are satisfied with the smart farm practice set the most due to the fact that it was designed to be in accordance with the content of the Microcontroller Application course and allow the students to learn from experience in real practice. The students are also satisfied with the teaching method that was designed with the consideration of problems encountered by the

students. STEM-based education was thus applied to enhance students' self-learning skills, understanding from practicing, and ability to transmit what they have learned in class. They can also practice with the smart farm practice set that help them understand complex content more easily. The content sheets were designed to cover all content and correspond to learning objectives with appropriate and easy-to-understand language that stimulate students' ability to think systematically. The students are also satisfied with PowerPoint presentation due to appropriate, easy and stimulating pictures. This develops students' interest and attention in the lessons. As for the outcome evaluation aspect, the tests were designed to be in accordance with behavioral objectives. The students obtained higher notes and better outcome. Finally, the students are satisfied with teaching method that integrates four disciplines to enhance problem solving skills. The students were trained to analyze, work in team, brainstorm, conclude, and present the results efficiently. In addition, the developed instructional activity package also focuses on the above-mentioned interdisciplinary approach with diverse instructional media to improve students' learning outcome and allow them to apply knowledge and skills in real situation.

4. Discussion and Conclusion

This research aims to developing an instructional activity package based on STEM education: A case study of smart farm. The researchers have applied collaborative learning approach as a guideline to organize teaching and learning together with STEM education approach that put students at the center and enhance students' knowledge, skills, and attitude according to the 21st century skills. The package was then developed for five lessons about smart farm. The package contains a guideline of learning activities based on STEM education, a teacher manual, a student manual, a smart farm practice set, virtual instructional media, pre- and post-tests, and learning outcome evaluation form. Then, during the second semester of the academic year 2021, the package was applied with a sample group of 12 undergraduate students enrolling in the Microcontroller Application course of the Bachelor of Technology program in Industrial Electricity and Electronics, Faculty of Agricultural and Industrial Technology, Nakhon Sawan Rajabhat University to test and conclude following the research hypothesis. The result from the evaluation of students' satisfaction towards the developed instructional activity package reveals that they are highly satisfied with the instructional activity package ($\overline{X}$ = 4.34 and S.D = 0.62)

Therefore, it is not exaggerating to conclude that the developed instructional activity package for smart farm can effectively be applied to organize microcontroller application teaching and learning. It also accelerates students' learning progress. In Figure 11, the students who had already passed the course with the instructional activity package based on STEM education applied their knowledge and skills to develop an automatic control system of oyster mushroom smart farm and develop a dual control system of organic vegetable smart farm for farmer groups in Nakhon Sawan province. The systems developed by the students help the farmers solve the problems relating to farm and yield monitoring. They students conducted field

Figure 11 Students presented the research on smart farm in ECTI-CARD 2022.

study to survey, collect data, create, and install the systems.

After that, they presented their work in a national conference and obtained best paper award from ECTI-CARD 2022 (International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology) held at Thepsatri Rajabhat University, Lopburi province between 17–19 February, 2022.

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