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

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Abstract

One-third of Thailand's workers are in agriculture, but the country's agricultural GDP is still less than 10% of its total GDP. Most Thai farmers are smallholders with limited land and low incomes. To improve the agricultural GDP and the economic situation of smallholder farmers, the Thai Government has been trying for decades to encourage and support smallholder farmers to adopt modern farming methods and smart farming equipment, including digital technologies. However, the improvement is still sluggish due to a lack of an effective approach to delivering essential digital knowledge and skills, as well as investment support for smart farming equipment. These have hindered smallholder farmers' digital farming skill progress. To address this issue, the Broadcasting and Telecommunications Research and Development Fund for Public Interest has funded a project to develop the Digital Farmer Development Framework. This framework provides essential digital knowledge, training, coaching, and fundamental resources to upgrade

smallholder digital-farming literacy to become digital farmers using problem- or project-based learning approaches and collaborative blended learning theories. Bloom's taxonomy is used as a guideline for evaluating the framework's effectiveness. Implementation of the Digital Farmer Development Framework has shown that farmers can significantly improve their digital farming literacy and are capable of using digital technology to improve farm management and productivity. Based on Bloom classification guidelines, 100% of the farms in the project can apply digital skills and utilize fundamental smart farming equipment as well as able to evaluate and analyze data from IoT devices. Moreover, 66% can create their own smart-system solution from fundamental smart farming tools for their farm. The project has also created a digital farmer community that shares knowledge and resources with others.

Keywords: Smart farmer, digital farmer, project-based learning, problem-based learning, collaborative learning, blended learning, IoT technology, 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].

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
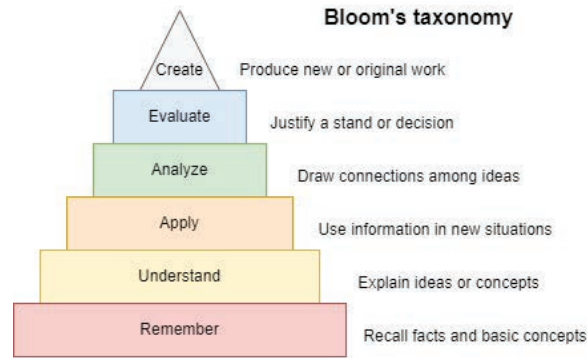
**Figure 1** Bloom's learning taxonomy [17].
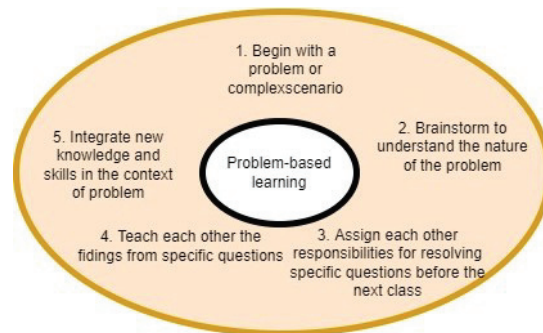
Figure 2 The PBL concept.

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 3   Cooperative learning.

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].

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,
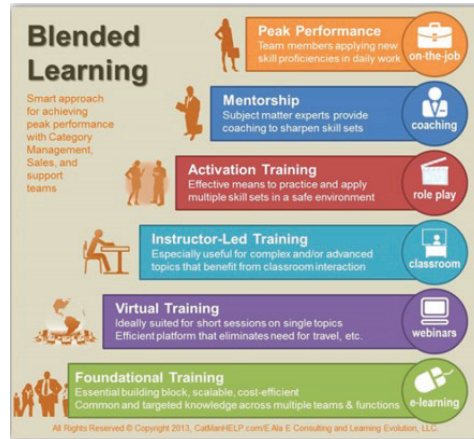
Figure 4   Sources: Learning Evolution, LLC and CatManHelp.com.

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].

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].

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

Figure 5   Digital Agricultural Development Plan of the Ministry of Agriculture and Cooperatives, year period (2017–2021).

Figure 6   Source: Smart Farm(Thailand) Co., Ltd.

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].

3 The Experimental Processes and The Proposed Upskilling Framework

Implementing a research digital-upskilling framework to provide smallholder 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 fundamental digital

farming technologies and a problem-based learning along with 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. This includes knowledge gathering plan, 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 northern Thailand: Chiang Rai, Phayao, Phrae, and Nan.

3. Organize a seminar for farmers participating in the project to establish a knowledge of the activities 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 conceptually design different tools and systems based on their need and 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 7.

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
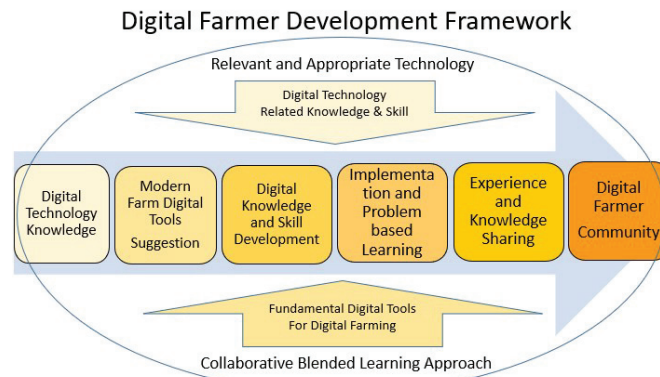
Figure 7 The proposed digital farmer development framework.

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 regarding the planting that is done, including the plants planted, how to water, fertilize, and care for them; problems in agriculture, including labour, 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. Figure 8 depicts the visiting and interviewing actions of farmers.

4.1 Farmer's Issues

Based on the interview, the farmer's issues can be summed up as follows: A labour shortage problem exists since some farms are family-owned and use local labour. 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

Figure 8 Interviewing farmers activities from Nan, Prae, and Chiang Rai provinces, Thailand.

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.

4.2 Fundamental Digital Tools and Knowledge Demands

We may summarize what farmers expect from smart agricultural equipment (fundamental digital tools) 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 labour 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.

4.3 Fundamental Digital Farming Equipment Design

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:

1. A Microclimate Sensor Node is a tool for measuring the weather on a farm or at home.

2. Water pump control system for drip irrigation systems, sprinkler system, pipeline fertilizer system, as well as the home ventilation system.
3. Weather Station.
4. Automated measurement and control system (monitoring and controlling system).
5. 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.
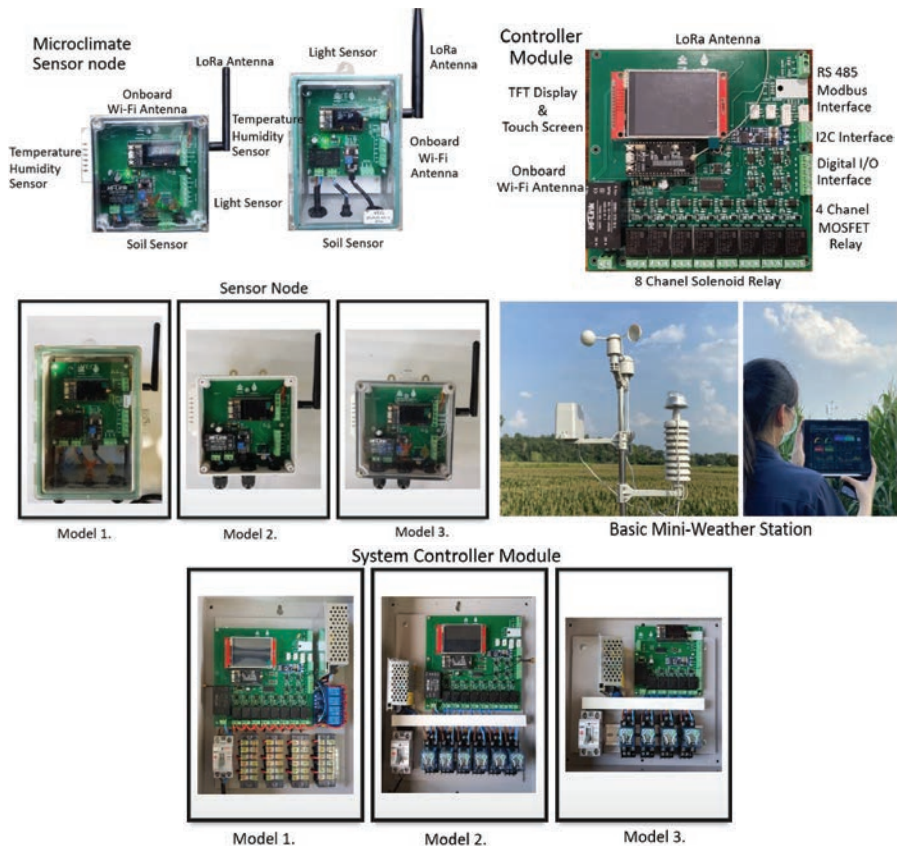
Figure 9 Some designed equipment and module for different farming conditions.
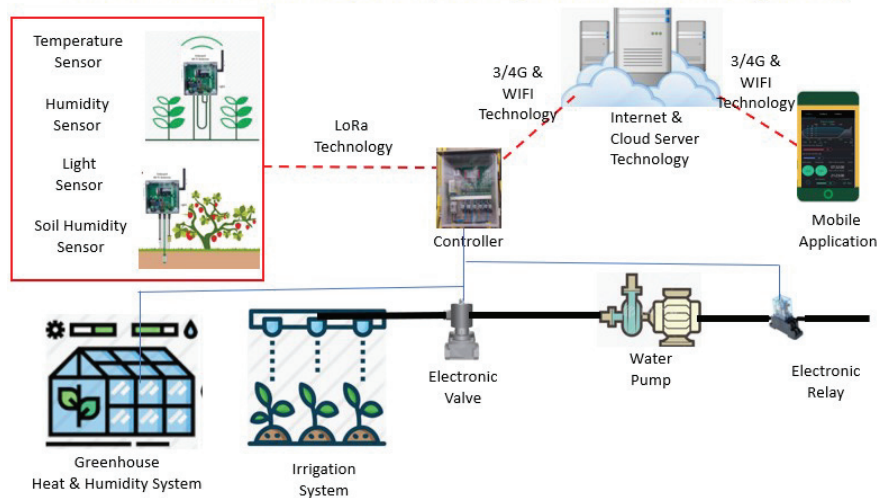
Figure 10   The conceptual designed system architecture.

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 9 displays the intended module, and Figure 10 displays the implementation system architecture.

4.4 Problem-Project Based and Collaborative Blended Learning Framework

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 11 and 12.

Figure 11   The training based on the proposed framework.

Figure 12   System installation at Cocoa farm, Thailand.

4.5 Digital Farmer Development Framework Evaluation

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 and researcher observation. Figures 13 and 14 summarizes the assessment outcomes from the twelve farms that completed the project.

The proposed Digital Farmer Development Framework has been assessed as an effective approach for transforming smallholder farmers into digital farmers in Thailand. A key challenge in this process is related to farmers' basic understanding of digital technology, which varies based on age and prior experience, and the design of development framework. This study evaluated the impact of the framework on farmers from twelve farms in the Northern Rural Area of Thailand. The training program focused on IoT technology and digital upskilling using problem-based approach, and Bloom's classification theory was used as the evaluation tool to measure the farmers' cognitive skills and knowledge before and after the training. The findings indicate significant improvement in the farmers' digital skills and knowledge across all levels of Bloom's classification theory. Prior to the implementation
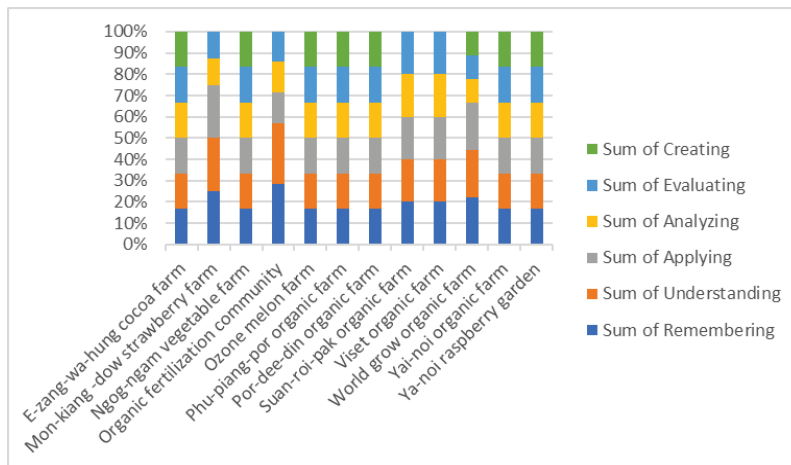
Figure 13   Development evaluation of twelve farms using Bloom's classification theory.
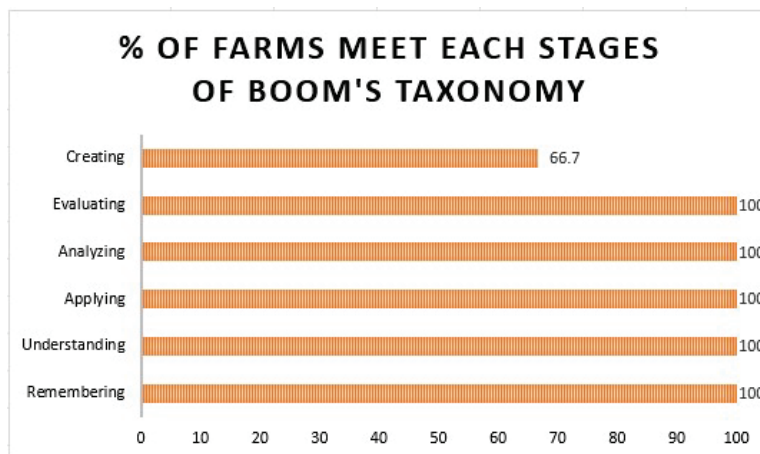

Figure 14   Bloom's theory-based average evaluation results.

of the Digital Farmer Development Framework, the farmers had limited understanding of IoT technology and digital skills related to farming. Only 25% of the farmers could recall the basic concepts of IoT technology, 16% used basic digital devices in their farms, while only 12.5% of the farmers could explain the benefits of using IoT technology in agriculture. Moreover, none of the farmers could apply their digital skills to analyze data related to their farming practices, nor could they analyze and interpret data from

IoT devices used in their farms or evaluate the effectiveness of their farming practices using IoT data. Additionally, none of the farmers could create new solutions using IoT technology to improve their farming practices.

However, after receiving training in IoT technology and digital upskilling using the proposed framework, all farmers demonstrated significant improvement in their digital skills and knowledge. Based on Bloom's taxonomy, all twelve farms in the project (100%) were able to comprehend the basic concepts and benefits of IoT technology and able to utilize digital tools along with applying their digital skills to analyze, interpret, and evaluate data from IoT devices related to their farming practices. Furthermore, 66% of the farms can create new solutions using IoT technology to enhance their farming practices as illustrated in Figures 13 and 14. These results highlight the efficacy of the Digital Farmer Development Framework in bridging the gap in digital skills among farmers and driving digital transformation in the agricultural sector and equipping smallholder farmers with the necessary digital skills to thrive in today's technological landscape.

5 Conclusion

The research results obtained after two years of study have enabled researchers to identify the challenges and requirements of digital farmer development in different aspects. A collaborative blended learning framework has been developed for digital farmer development, which incorporates rules for operation, essential fundamental digital farming-tools, and a learning model, capable of rapidly and practically developing farmers' digital-skills. The framework provides farmers with a deep understanding of their challenges and requirements then equips them with vital technological skills in various domains, such as digital communication and IoT technology, which they can apply practically. The collaboration of a group of experts from agriculture and technology fields facilitates learning and enhances productivity. The farmers' attention and willingness to learn and be receptive to new information are critical elements of the learning process that both researchers and farmers must undertake in a short period. This approach can be adapted to train employees in various industries who aspire to enhance their technological skills and system development to meet the demands of other businesses. To further enhance and develop the learning model, it is imperative to incorporate sustainable and continuous learning, taking into account several critical factors that can accommodate the growth and learning of farmers and business groups.

Acknowledgment

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