Smart Farming for Sustainable Agriculture: A Case Study through Korean Public TVET

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Article Info

Abstract

This study aims to present implications for sustainable education and training of the agricultural workforce. It introduces the case of a smart farm learning factory as an educational facility at Korea Polytechnics. Learning factory refers to the practical experience gained using the knowledge acquired in engineering education to solve problems in the actual work field. For this study, we analyzed the smart farm case of Hongseong Campus of Korea Polytechnics, a government-funded vocational education institution in Korea. The research questions are as follows. First, what is the purpose of establishing a smart farm education and training facility? Secondly, what is the performance of the facility? Thirdly, what are the implications of the Korean smart farm for sustainable TEVT? As a result of analyzing the case, the purpose of establishing the facility was to improve the practical capabilities of convergence technologies used in machinery, automation, industrial facilities, and electrical departments. Additionally, the performance has been found to serve as the foundation for project-based learning subjects that incorporate convergence education, and companies have been able to reduce training costs and contribute to sales profits by using this facility to train employees. Finally, the implication of sustainable TVET through smart farm cases is that it has provided a way to enhance the effectiveness of teaching and learning guidance at agricultural sites, create educational resources that can utilize advanced agricultural technologies for sustainable development, and actively cooperate and collaborate with educational institutions, governments, and local companies.

1. Introduction

Agriculture has significantly contributed to the accumulation of capital, and it has been instrumental in achieving economic growth, particularly in nations without any other industrial base. The development of the agriculture industry for national growth was conventionally focused on biochemical technologies, such as crop varieties, pesticides, and fertilizers. Recently it has expanded to incorporate intelligent information and communication technology (ICT) such as modern facilities, equipment, and devices. Combining agriculture with ICT to achieve digital and intelligent agriculture, smart agriculture is emerging as a significant factor in economic development. The growth strategy of the European Union for agriculture highlights the shift from a productivity-oriented

approach to a sustainability-oriented one as a method to maximize production while minimizing resources (EU, 2022).

Developing smart agriculture is essential for sustainability and profitability. Investing in educated and trained agricultural professionals is a key to reducing national poverty, improving industrial structure, and maintaining a sustainable agricultural industry. The primary approach to foster a smart farm workforce in smart agriculture is technical and vocational education and training (TVET). At the international level, there is a close relationship between sustainable development and TVET (Ahn et al., 2018; UNESCO, 2015, 2016). In 2015, the international community established the Sustainable Development Goals (SDGs) to achieve sustainable national development. The "international countries" mentioned in this study represent a common goal that the United Nations and the international community seek to achieve from 2016 to 2030, adopted by the United nations general assembly for sustainable development. It includes 17 goals and 169 detailed tasks for sustainable development in all countries around the world, addressing poverty and inequality, responding to climate change, economic growth, and education, and they refer to countries that are participating in it. These goals provide detailed strategies to be implemented at the global, national, and local levels in various areas, such as the environment, energy, socioeconomic infrastructure, security, and global partnerships (United Nations, 2015). The SDGs focus on promoting the systematic development of relevant enabling factors for active and decent employment through an integrated approach to education and training (Ahn et al., 2018).

During this era of rapid industrial changes brought on by events such as the prolonged Covid-19 crisis and the fourth industrial revolution, the focus on industrial development through TVET has become increasingly critical in achieving SDGs. Developing smart farms is essential for the productivity and profitability of agriculture. In particular, TVET plays an important role because acquiring new skills, understanding equipment and devices, and training professionals are crucial for the development of smart farms. Given the rapidly evolving technology demands of the fourth industrial revolution, there is an increasing need for technicians skilled in convergent technologies, rather than those with expertise in a single function or task (Bender, B. et al., 2015; KOPO, 2021). For this, TVET methods must become more demand-oriented. Learners need to acquire essential skills and knowledge by participating in the production process at the industrial site level and by building practice equipment similar to the manufacturing infrastructure of the industrial site (IALF, 2021).

In particular, the reasons why this study focused on the case of smart farms through Korean TVET are as follows: First, Korea's TVET system has achieved rapid economic development over the past 50 years through technical education and training to provide an efficient supply of industrial labor. These examples will be helpful in setting strategies and directions for sustainable TVET that are different from other countries and regions. Korea has experienced a tremendous growth in per capita national income, surpassing $30,000 as of 2023, compared to only $67 in the 1960s (KOSIS, 2022). TVET has been playing a vital role in the economic growth and development of Korea. The Ministry of Employment and Labor (MOEL) in Korea has established an employment and labor policy that promotes the development of high-quality human resources through public TVET. As part of this, Korea Polytechnics plays a pivotal role in the government's growth model by contributing to the development and supply of industrial skills. Examining Korea's TVET operation can provide valuable insights for sustainable strategies to foster human resources in agriculture.

Secondly, this research aims to examine how strategies for sustainable TVET have been implemented and how they have impacted local industries through the case of a smart farm for economic development in a rapidly changing industrial environment, including digital transformation and the fourth industrial revolution. This examination is necessary in a rapidly changing industrial environment such as the fourth industrial revolution and digital transformation. Considering that the smart agriculture industry in the U.S. grows at a remarkable 12.4% per year and is estimated to reach $6.2 billion by 2023, it is paramount that TVET plays an important role in sustaining its growth for future generations (New York Branch of Korea Agro-Fisheries & Food, 2019; Piwowar-Sulej et al., 2023; Russ-Eft, 2014). Understanding the implications of TVET in the context of smart farms will aid in crafting effective TVET strategies for the agricultural industry in developing countries and contribute to enhancing the quality of TVET for achieving SDGs at the local and national levels (Ahn et al., 2018; UNESCO, 2015, 2016).

The Korean government is committed to implementing the SDGs adopted at the 2015 United Nations Development Summit. To promote these goals, Korea established the Second Basic Plan for international development cooperation covering the period from 2016 to 2020. The Korea Council for International Development Cooperation launched this plan (Ahn et al., 2018). This plan is currently being implemented through the Third Basic Plan for international development cooperation, which spans from 2021 to 2025. The main content of the plan proposes a new direction for changing the development cooperation environment through four goals and 12 key issues, including inclusion, win-win cooperation, and innovation. The vision is to realize global values and mutually beneficial national interests through cooperation and solidarity. The plan aims to enhance higher education and vocational and technical education in partner countries by collaborating with universities. This includes providing support for training high-level human resources, strengthening research

capacities, and promoting continuing education-level curricula related to the SDGs, such as global citizenship education (Joint Ministry, 2021).

Lastly, over the past decade, research in smart agriculture has focused on minimizing costs and resources by utilizing data collection technologies for optimal growing conditions. Although the role of human resources in utilizing technology and data is crucial to improving the quality of smart agriculture, there is limited research on exploring the types of education and facilities that are effectively used and disseminated in TVET. A case study on a Korean smart farm can provide insights into how the knowledge acquired by trainees can be applied to address real workplace problems through the integration of construction steps and examples in educational environment facilities and equipment.

Therefore, this research aims to explore the ramifications of sustainable TVET by examining the case of a smart farm at Korea Polytechnics (KOPO), an educational training facility. Over the past decade, research on smart agriculture has focused on minimizing costs and resources (Jang & Kim, 2019; Lee, 2021, April 5; MAFRA, 2024). While TVET plays a critical role in enhancing smart agriculture, research on training processes and outcomes using facilities and equipment remains limited.. The smart farm case study at KOPO can show how to use facilities and equipment to deal with workplace problems. This study aims to contribute to the efficiency of smart farms and the development of agricultural human resources by exploring the process from intentions to outcomes through activities within the context of smart farming. The research questions are as follows. First, what is the purpose of establishing a smart farm education and training facility? Secondly, what is the performance of this facility? Thirdly, what are the implications of the Korean smart farm for sustainable TEVT?

2. Literature Review

2.1 The Meaning of Smart Farming

Since 7,000 B.C., agriculture has played a vital role in human survival. Nevertheless, it is vulnerable to price and quality fluctuations that rely heavily on changes in the external and internal environment. The problem has been addressed by the introduction of 'smart farming,' which integrates fourth industrial technology with agriculture (EU, 2022; Jang & Kim, 2019). This transformation is not confined to developed countries, as developing countries are also experiencing it, due to the rapid increase in ICT adoption such as mobile phone usage and internet access. Farmers are using smart farming to manage their farms, utilizing modern ICT to enhance product quality and quantity while minimizing human labor requirements (Anonymous, 2022). This technological innovation is driving what is referred to as the Third Green Revolution.

Smart farming is a revolutionary technology that is transforming agriculture. It has the potential to overcome the limitations of traditional farming and address future food insecurity by leveraging artificial intelligence (AI) and big data to improve production efficiency and quality. The first generation focused on increasing the convenience of farming. Its main function was to control remote facilities with communication technology serving as the core technology. This approach promoted human decision-making and control based on environmental information, exemplified by the "smartphone greenhouse control system." The second generation focused on precise growth management functions to improve productivity. Utilizing communication mirage, big data and AI technologies, it leveraged environmental and growth information for human-made decisions, but with computer-executed control. An example of this generation is the "data-based growth management software." The third generation aims to automate and roboticize agriculture, paving the way for a more sustainable and efficient future. It employs environmental, growth and production information, with computers and robots taking over decision-making and control. This evolution is represented by the "intelligent robot farm" (Jang & Kim, 2019; MAFRA, 2024).

It is noteworthy that smart farming in the United States is expanding at an impressive annual rate of 12.4%. The market size of smart farming in the United States is projected to grow to $6.2 billion by 2023 (New York Branch of Korea Agro   -Fisheries & Food, 2019). Morever, investment in smart agriculture has markedly risen in the United States. The investment amount rose from $230 million in 2018 to $929 million in 2020, according to Lee (2021, April 5). The European Union has a budget allocation of 560 million euros for research related to smart farming in its Horizon 2020 research program. Meanwhile, Australia is set to invest a substantial amount of AUD 4 billion in rural development with the goal of promoting smart farming practices (Suebsombut et al., 2017).

Over the past decade in Korea, the research trends in smart farming have focused on second-generation smart agriculture. The aim of this type of agriculture is to minimize costs and resources by using data collection technology to create optimal growth environments (Jang & Kim, 2019). According to the language network analysis, 'environment,' 'technology,' 'system,' 'agriculture,' 'cultivation,' 'utilization,' 'influence,' 'results,' and 'growth' are among the most frequently used terms in smart farming research. The topic modeling analysis reveals that the bulk of research on smart farming can be grouped into five primary topics, which include introductory studies (16%), eco-friendly methods (12%), and economic efficiency (12%). The areas in which smart farming in Korea focuses on include 17% on smart farm platform design, 12% on smart farm ecosystem, and 7% on smart

farm implementation. The findings imply that smart farming research in Korea emphasizes enhancing agriculture's efficiency and convenience through sustainable practices and advanced technologies.

2.2 Facility and Equipment of TVET Through Learning Factory

The Consortium of Pennsylvania State University, sponsored by the National Science Foundation, created the term 'Learning Factory' (LF) in 1994, and ever since then, significant funding has been allocated for its progress. The fourth industrial revolution has enabled the expansion of multiple establishments, striving to improve learning in one or multiple domains (Abele et al., 2015). The essential concept lies in prioritizing the practical knowledge acquired through engineering education to tackle real-world issues.

The LF adopts a holistic approach, characterized by six essential elements: purpose, process, setting, product (i.e., output), teaching method, and operating model. These elements are defined as follows: The purpose of the LF encompasses education, research, and training. The process is authentic, multi-stage, technical and organizational. The setting is adaptable and oriented towards real or virtual environments. The products of LF can be either physical goods or services. The teaching method leverages the concept of combining the formal and informal learning, includes trainers' own activities, and accommodates both on-site and distance learning. The operating model represents a sustainable plan that ensures continuous operations (IALF, 2021). This approach is commonly applied in education, training, and research, following a technical and organizational process to produce tangible outcomes in the settings of the changing real world and virtual reality. The outcomes include physical products or services. The LF utilizes various teaching methods such as conceptual, formal, and informal learning, voluntary actions of the trainer, and practical or distance learning. It is crucial to note that the operation model is sustainably managed to ensure its long-term viability.

The LF operates in diverse scenarios depending on factors, such as operator characteristics, purpose, product, financial source, learning environment, and learning channel. The purpose and strategy differ based on the LF's type, as stated by IALF in 2021. For example, the LF established at Ruhr-Universität Bochum in Germany was created to fulfil the learning requirements in dynamic situations where various factors change, including products, production technology, procedures, organizations, ICT, and employee relations (Bender, B. et al., 2015). The fourth industrial revolution necessitates that employees and learners acquire new skills urgently, and an appropriate learning place and method are crucial to fulfilling this requirement. To address this issue, the LF employed facilities and equipment to create a genuine manufacturing environment connected to training and products. This approach enabled an understanding of the flow of material and information, and helped in analyzing the product value chain by tracking the production process and including all operational procedures of the factory.

The University of Vienna in Austria has an outstanding LF that is divided into four main areas: training, education, research, and industrial service offerings. This impressive platform offers unparalleled training and educational opportunities for the industry, research, and practice regarding cutting-edge technologies and methodologies. The LF is an essential link between research and industries. It streamlines communication and provides test-bed sites to assess students' learning outcomes. The curriculum at the University of Vienna is carefully designed by module for each level of introductory, advanced, customized, and innovative courses. This curriculum thoroughly covers the entire process-from design to product completion and service delivery-ensuring an all-encompassing and immersive learning experience (KOPO, 2021).

The KOPO LF in Korea is an impressive facility. It aims to integrate practical training with communication in the field where physical products are created using field-based technology. It is designed to support project-based interactions that can solve problems in convergent and complex situations caused by rapid industrial changes. In contrast to the previous lab that only operated large equipment for single tasks and single process practice, the learning factory offers an integrated approach. It provides convergence project-based practice, new product development, and technology support for small to medium-sized enterprises (KOPO, 2022). Table 1 highlights the unique characteristics of the LF that distinguish it from the previous lab.

Project-based learning(PBL) is a form of problem-solving education that involves teamwork to enhance problem-solving skills through steps such as identifying a problem, generating alternatives, implementing a solution, and analysing the results (Kokotsaki et al, 2016). At KOPO, PBL is facilitated through the LF. Students form a project team in class, focusing on real-world projects from companies, and engage in the problem-solving process through practical tasks. The results of the project are assessed by company representatives, offering students the potential for employment within the company. Furthermore, the learning achievements and the process of working on the project can be documented to provide evidence of the learner's experience or work history (KOPO, 2022).

Table 1 *Difference between previous lab and learning factory*

Category	Previous Lab		Learning Factory
Type	Large equipment centered		Integrated operation of educational equipment throughout all processes
Purpose	Vocational education practice	→	Converged project-based practice, research projects, new product development, technical support for SMEs,
Training task	Single task		Convergent task
Practice	Single practice (Department lab)		Pre-production process integration practice (Campus lab)
Prototype production	N/A		Possible

The KOPO LF covers a broad range of fields, such as machining, automation, IT, design, medical engineering, robot welding, smart logistics, smart convergence software, semiconductors, ICT convergence, plant facilities, and aviation electronics. They develop commercial products using big data analysis, implement a rigorous product design process, and manufacture products with automated high-tech production equipment. After a comprehensive review and verification stage, the finished prototype offers a modern system that enables trainees to gain hands-on experience in the production of robot-controlled devices using Internet of Things (IoTs) and network equipment, both of which are vital technologies for the fourth industrial revolution. The comprehensive process of product planning to promotion is executed by devising a marketing strategy for the final product and advertising it through various media channels. In December 2018, KOPO launched a project to construct the LFs, starting with the Incheon campus. Its goal is to drive the convergence of vocational education in the rapidly-evolving technology industry. As of 2021, KOPO has equipped all 59 campuses with LFs, including 17 in 2019, 22 in 2020, and 19 in 2021.

Recently, Europe has established a network association of learning factories that shares operational cases, development products, achievements, and development plans annually through conferences (IALF, 2021). As a result, information exchange has been created, shared, and activated. The checklist for the operating model, purpose, environment, and scale of the learning factory, product, teaching method, and management system helps to facilitate information exchange. Moreover, learning factories are under examination in diverse consultations depending on fields or distant education methods, construction environments such as actual sites or virtual reality, services, and products (Bender, B. et al., 2015).

In the United States, considerable research has been carried out on educational space innovation to promote creative manufacturing cultures. The maker movement has been promoted as part of the People's Innovation Strategy to revise the U.S. Innovation Strategy and solve national challenges while promoting economic growth. To bolster these initiatives, there has been a reinforcing of ICT-based Manufacturing Innovation (IMI) and national networking. Furthermore, computer education has been focused on public schools, museums, and libraries, which were furnished with maker spaces and workshops to foster public engagement (KFASC, 2014, 2016).

In Korea, there has been a government- or local government-led maker movement related to the field of learning factories. Infinite imagination, prototype manufacturing, self-manufacturing, creative economy innovation center, startup workshop, and maker space were disseminated throughout the nation to serve as a hub space for ideas, start-ups, and local networking (KOPO, 2021). Information is primarily shared online at the private level, and various private maker spaces like Fab Lab and Hackerspace are emerging. However, they are small in terms of both size and quantity, and developers' involvement, community activation, and crowd-funding activities are comparatively lower than those overseas (KFASC, 2014; Lee, S, 2017).

The KOPO LF is an excellent environment for both students and prospective start-ups alike. It is a space for generating ideas, solving problems, and promoting innovation through education and training, prototype production, crafting, and the convergence and collaboration of different departments. This open space has transformed the region by rapidly becoming a hub for innovative startups, attracting significant attention. Furthermore, it has contributed significantly to the employment rates of graduates through its close partnerships with neighboring industries and regions. Moreover, it has established itself as a trustworthy training area in the region by earning accreditation from specialized organizations such as Samsung Electronics and the Korea Welding Industry Cooperative. Several corporations also employ it as a hub for communication and collaboration.

After reviewing several studies and examples, it is evident that the LF in TVET is an innovative educational system that integrates educational and training equipment to create a comprehensive learning experience of the entire product development process, from design to completion. The LF incorporates elements such as converting traditional education, enhancing practical training, integrating practice and education, and providing a

collaborative and convergent space. This innovative educational approach has the potential to bridge the gap between theoretical knowledge and practical skills. A Korean smart farm case through LF can offer insight into how knowledge acquired by trainees can be utilized to solve real workplace problems through integrated construction steps and examples in educational environment facilities and equipment.

3. Research Methodology

This study employed the case analysis method, which involved developing a logical model for LF operations at KOPO smart farm, a representative institution of public TVET. The logic model visualizes a performance-oriented program, its impact theory, and the intervention process theory (McLaughlin & Jordan, 1999; Noh & Lee, 2012). The foundational structure of the model is composed of inputs, activities, outputs, and outcomes (Rosi et al., 2004). This study aims to enhance the performance of smart farms and the development of agricultural human resources by examining the process from intentions to outcomes within the context of smart farming

The rationale for focusing on the smart farm case study through KOPO is to inform future TVET strategy planning in other countries. Over the past 50 years, Korea's TVET system has contributed to rapid economic development by providing technical education and training, thus ensuring an efficient supply of industrial labor. As a public TVET institution in Korea, KOPO's case analysis through a logic model is believed to systematically elucidate the inputs, processes, and outcomes of TVET operations. Specifically, the smart farm case at the Hongseong campus offers insights into the necessary inputs for establishing the LF, such as budget and purpose, the training operation process, and the training outcomes and performance's impact on rural industries. This case is expected to enhance the quality of TVET at the local level.

3.1 Selection of the Case

This study conducted a case analysis of the Hongseong Campus of KOPO, a government-funded vocational education institution in Korea. The criteria for selecting KOPO's Hongseong campus as a case for examination are clear. The selection focused on the presence of a specific feature, the smart farm LF facility. Exploring the rationale behind this selection reveals:

- **Uniqueness**: Among the 40 campuses of KOPO, only the Hongseong Campus features a smart farm LF facility.
- **Research Relevance**: The presence of a smart farm LF facility is directly aligned with the research objectives. It indicates that this campus may have innovative agricultural and technological practices that are of interest to the study.
- **Ideal Case Study**: Given that the Hongseong Campus is the only one with a smart farm LF facility, it can be considered an ideal case study. This allows for a focused examination of this specific technology and its application within the context of KOPO.

This study concentrates on the Hongseong Campus of KOPO, distinguished as the only campus among 40 with a smart farm LF facility, for the following reasons. First, TVET is closely related to economic development in Korea. During the period of economic growth, the Korean government implemented a five-year master plan in 1962 to promote the development of the national economy and rebuild the country after the destruction caused by the 1950 Korean War. In the 1960s, the Korean economy manufactured and exported labor-intensive products by mobilizing a large number of workers. TVET concentrated on providing the workforce necessary for labor-intensive industries. During this period, the MOEL established 13 vocational training centers and enacted critical legislation such as the Vocational Training Promotion Act and the National Technical Qualifications Act to guarantee that the workforce received suitable training. The role and performance of TVET in Korea are closely associated with economic development and growth. This relationship can have significant implications on developing and achieving the goals of the SDGs beyond the organization, at the local or national level (Ahn, 2018; UNESCO, 2016). Moreover, it can be helpful in setting strategies and directions for sustainable TVET.

Secondly, KOPO has been a key player in providing technical human resources to the industry over the past 55 years. The example of KOPO illustrates the profound effect that investments in TVET can have on sustainable economic growth and the development of human resources. KOPO, which began as a National Vocational Training Center with foreign funding and assistance in 1968, has evolved into one of the most prominent state-run technical training and educational establishments under the MOEL. KOPO, with 39 campuses in eight regions throughout the country, is devoted to training technical manpower according to the demands of the local industries. KOPO's programs include industrial-associate degree programs, non-degree vocational training programs, and vocational training programs for the unemployed in the national, strategic, and new-growth industries. Public TVET, including KOPO and other institutions, has contributed significantly to Korea's rapid economic development and industrialization over the years (Lim et al, 2021).

Finally, located in a rural area where agriculture and livestock form the backbone of the industry, the Hongseong Campus serves a community where local farmers consistently seek new skills to enhance their techniques. There are 15 Agricultural Skill Centers nearby, focused on providing training and education to farmers. Recently, they turned to KOPO for help, and together they have been offering smart farming programs for two years now. The Hongseong campus is one of the facilities that provides this program. The campus combines agriculture with ICT solutions, making it an innovative and educational experience for the farmers. A smart farm case of the Hongseong Campus provides a good example of how AI technology can be adopted to improve productivity and promote sustainable agriculture. This example could provide important insights for public TVET through the smart farming in regions and enhancing sustainable human resource development (HRD). By carefully considering these implications, it is possible to design effective programs that benefit both individuals and communities in these areas.

3.2 Data Collection and Analysis

This study applies the logical model concept to analyze the KOPO smart farm LF case. The logical model displays a program that aims to improve performance along with its impact and intervention process theories (McLaughlin & Jordan, 1999; Noh & Lee, 2012). The model has a fundamental structure that contains inputs, activities, outputs, and outcomes (Rosi et al., 2004). This study utilized a mixed-method approach for data collection to analyze the KOPO smart farm LF case. Quantitative data were gathered on the number of participants engaged in various smart farm programs, as illustrated by the chart below (Figure 1), which reflects participation in the LF smart farm programs during the first and second halves of 2022. Additionally, qualitative data were collected through in-depth interviews and feedback sessions, which offered insights into the effectiveness of these programs. These interviews were conducted with professors, the director of academic affairs, and the director of the industry-academic collaboration department at the Hongseong Campus. We also reviewed internal reports that detailed the establishment process of KOPO's LF, budget allocations, and documentation regarding the establishment plan of the Hongseong Campus. This comprehensive dataset provided a robust foundation for our logical model, allowing us to assess the impact of ICT on agriculture and the outcomes of education and training in the context of the smart farm. The data enabled us to explore how HRD can be achieved and its influence on workforce education and training performance, particularly emphasized by the feedback from farmers and institutions like KOPO and agricultural technology centers.

We conducted an analysis of the smart farm construction strategy and infrastructure at Hongseong Campus, focusing on the 'inputs' dimension as defined by the logic model elements. The analysis of the deployment strategy focused on how campus departments approached the construction of the required facilities, taking into account factors such as the feasibility of building a smart farm, budget constraints, manpower availability, and role assignments. We identified the operation and content of education and training programs within the 'activities' dimension. It was presented the main practical tasks involved in the smart farm curriculum as well as how its educational contents are organized and delivered.

We assessed the impact of ICT on agriculture within the 'outputs and outcomes' dimension. Our study also presented the outcomes of utilizing education and training in the context of the smart farm. Additionally, we examined how HRD can be attained and its influence on the performance of workforce education and training. This was emphasized by feedback from both farmers and institutions like KOPO and agricultural technology centers.

The LF smart farm has also played a pivotal role in establishing PBL subjects that incorporate convergence education, uniting various fields like mechanics, automation, electricity, and industrial facilities. Furthermore, it has developed smart farm experience programs for middle and high school students, offering them practical exposure and the opportunity to explore the evolving landscape of convergence technology in the farming sector during the era of the 4.0 industrial revolution.

The chart below provides a visual representation of the number and categories of participants in the smart farm LF programs offered by the Hongseong campus in the first and second halves of 2022. It clearly illustrates the increased interest of trainees, which can be attributed to the effectiveness of the VET program.

We assessed the impact of ICT on agriculture within the 'outputs and outcomes' dimension, and presented the results of education and training utilized through the smart farm. Additionally, we explored its effects on workforce education and training performance, as highlighted by farmers and institutions such as KOPO and agricultural technology centers.
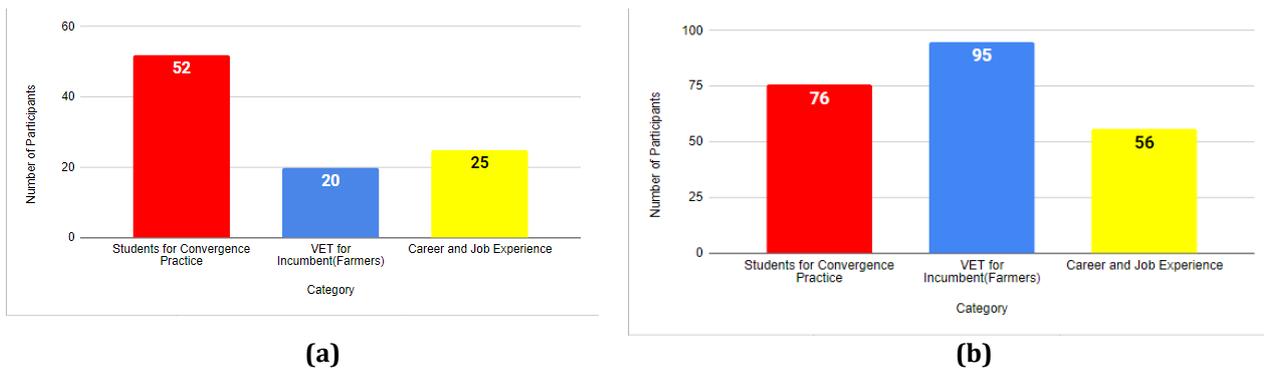
(a) **(b)**

Fig. 1 *Participation in the LF smart farm programs of 2022 (a) The first half of 2022 (b) The second half of 2022*

4. Findings

4.1 Inputs : Strategy, Purpose, and Infrastructure

The Hongseong campus recently established a new LF focused on smart farm technology, which aims to introduce the latest trends in utilizing ICT in agriculture. The smart farm LF focuses on improving practical capabilities of convergence technologies used in machinery, automation, industrial facilities, and electrical departments. The LF was constructed over a ten-month period from March to December 2021, covering an area of 680.4 square meters, and had an allocated budget of roughly $337,936.

The Hongseong Campus established a task force team to devise ideas and plans for the convergence practice field. The team comprised professors and facility managers from related departments such as mechanics, electricity, and automation. Their task was to review and benchmark the design plan. This approach was based on collaboration with universities or educational and training institutions. The subsequent step involved constructing the LF, which included integrating both new and existing equipment utilized by the department.
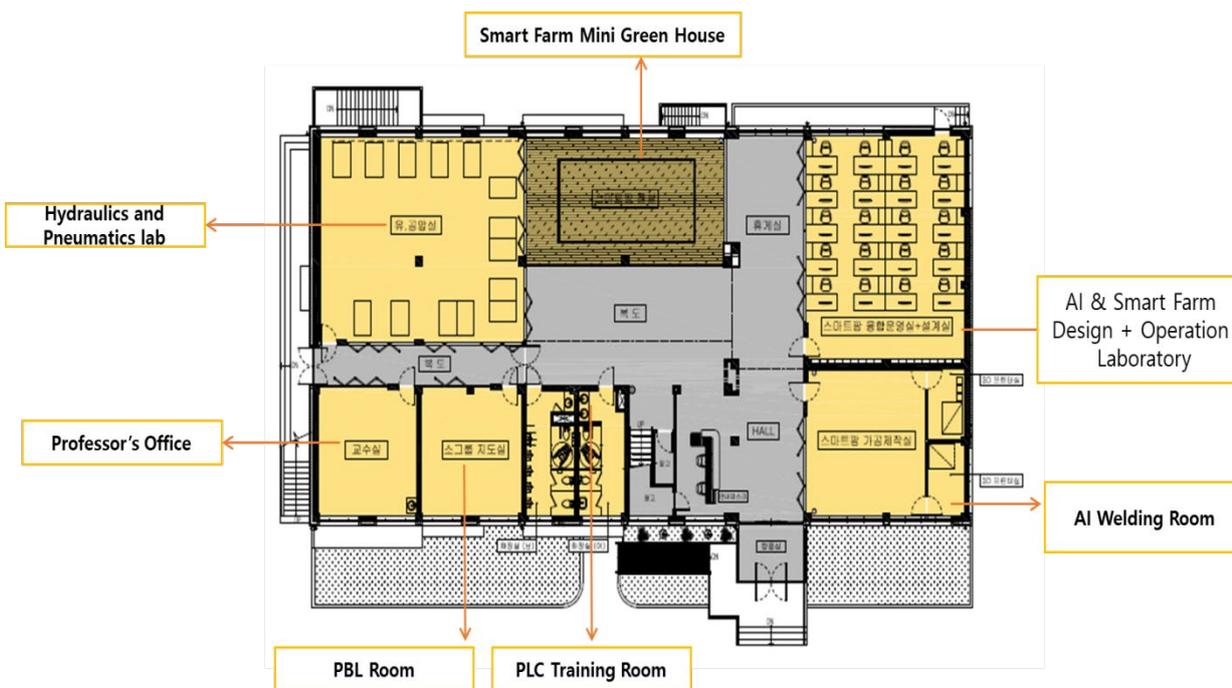

Fig. 2 *The smart farm LF layout of the Hongseong campus*

The LF organized a trial and convergence curriculum for the equipment, which involved conducting a pilot class on education and training. The local community also used the LF for career experience opportunities for teenagers and for education and training for small and medium-sized enterprise (SMEs) employees.

The smart farm LF has a mini indoor smart greenhouse that can automatically maintain and manage optimal crop-growing conditions via remote control of soil, water, light, humidity, and temperature from a computer or mobile phone.
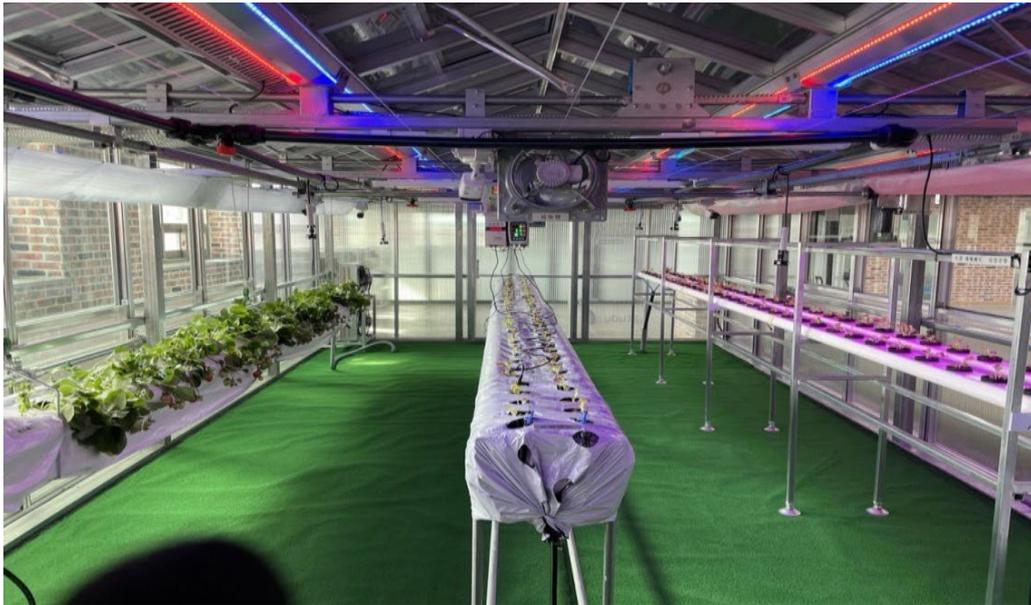
Fig. 3 The smart *farm LF of the Hongseong campus*

The facility is equipped with a cutting-edge information management system that guarantees optimal growth conditions for crops. The system continuously tracks the growth environment and analyzes a database of all the information pertinent to the growth conditions. The environmental center's duty is to monitor both internal and external conditions of the smart farm, such as temperature, humidity, CO2 levels, nutrient solutions, wind direction and velocity, rainfall, and daily solar radiation. The integrated control system includes ventilation, heating, shading, hot water, motor, nutrient solution, and LED lighting. Infra-red cameras and DVR (dynamic voltage restorer) video equipment are also installed to monitor crop growth conditions. A mobile robot, equipped with a vision camera and sensor, records crop status and sends the data to an integrated control and management system for farmers to monitor and make informed decisions. Figure 4 presents the facility equipment process, illustrating each step from the design of the LF of the smart farm to automatic control, processing, assembly, and start-up.

(a) Vision Camera and sensor & Moving Robot   (b) Repetitive moving to the appointed spot after the initial default setting   (c) Recording & sending data   (d) Confirmation of the detecting cod

Fig. 4 *Using educational equipment in the smart farm LF*

4.2 Activities: Education and Training Program

The Hongseong Campus has designed a curriculum aimed at assisting farmers in the nearby areas to learn about adopting new technology to increase productivity and profitability. The Center of Agricultural Skills conducted a survey to assess the demand for smart farming courses and the results indicated that while the attitudes towards smart farming were positive, there was a lack of knowledge about it. Farmers, many of whom are elderly and not familiar with cutting-edge technology, may view changes as a threat. Thus, the program should demonstrate

substantial obstacles, such as increasing supply expenses, workforce deficits, and evolving consumer demands for clarity and eco-friendliness, and how the relevant technologies can be advantageous.

Based on the survey results, the syllabus has been categorized into three main sections: the basics, the practical application under the supervision of an expert, and the operation of a smart farm. The initial session of the program provided farmer trainees with fundamental knowledge and competencies on smart farming, encompassing the principles of ICT and their practical applications in agriculture. Undoubtedly, this knowledge and competency will benefit the trainees as they continue to develop and progress in this field.

In the first session, farmers were informed about how different IoTs technologies can help them maximize their agricultural yields by using minimal resources such as water, fertilizer, and seeds. They learned about the vitality of placing sensors at accurate locations and gathering data regarding soil properties, such as compaction, structure, pH and nutrient levels, soil temperature at different depths, rainfall, and more. Additionally, they were taught about various wireless communication modules and topologies, such as bluetooth, wi-Fi, ethernet, and how they can be utilized in the agricultural field. Furthermore, they became acquainted with various devices that they can use in greenhouses, such as carbon dioxide, oxygen, and air temperature sensors. Furthermore, they were provided with precision agriculture tools, such as soil mapping, yield mapping, remote sensing, variable rate technology, integrated pest and weed management, and precision irrigation water management. The use of these tools can help achieve better results and enhance farming practices.

In the second session, they had the privilege of listening to an expert in the smart farming field. The expert recounted his journey from traditional farming to smart farming, which also included the challenges he faced along the way. He elucidated the numerous benefits of a smart farm and his impressive accomplishments. Furthermore, he discussed the necessary infrastructure to compete in today's markets. The ensuing Q&A session was highly informative and helpful. The Q&A session focused on practical experiences, enhancing the value of shared information.

In the third session, the farmers visited an indoor smart farm LF. The expert explained the mechanism and application of the technologies thoroughly. The trainees were able to manipulate the farm's functions with their phones, easily operating window blinds, irrigation systems, etc. with the touch of their phones, and adjusting the smart farm's humidity, temperature, nutrient solution, LED lights, and other environmental controls. The level of sophistication in smart farm technology allows it to detect changes in the environment and autonomously adjust windows' openings and nutrient supplies. This contributes greatly to farmers' overall efficiency, especially during abrupt weather conditions. The statistics show that these smart farms produce 20% more crops than their counterparts and also enhance the quality of food. Moreover, farmers can promptly and remotely respond to unexpected weather changes by receiving notifications on their phones.

4.3 Outputs and Outcomes: Performance

In order to achieve sustainable agricultural growth in TVET, it is important to understand the impact of ICT-enabled agriculture and the results of KOPO's LF of the smart farm. By making agriculture more connected and intelligent, ICT-enabled agriculture can help reduce overall costs and improve the quality and quantity of products, while promoting agricultural sustainability. Increased control over production leads to better cost management and waste reduction. In addition, automation increases efficiency because smart devices can activate multiple processes simultaneously, and automated services improve product quality and quantity by better controlling production processes. With these strategies in place, the agricultural industry can continue to grow in a sustainable and efficient manner.

The first-generation smart farm makes farming more convenient and efficient than ever before. By attaching sensors to the greenhouse, farmers can easily obtain all the information they need to monitor and control their crops. This remote control and monitoring system allows for automatic opening and closing of greenhouses, precise nutrient solution control, and accurate temperature and carbon dioxide concentration control. With these advancements, growers can now reduce labor and focus on producing high-quality crops.

The second-generation smart farm is truly a marvel of modern technology. With its ability to constantly monitor the atmosphere, soil and crops, it can automatically take appropriate action to optimize conditions for growth and productivity. The complex above-ground environmental control system and cloud computing service work seamlessly together to provide real-time data analysis and decision-making capabilities. The AI cloud service offers a suite of tools for farmers, including a cultivation history management system, a database of disease and insect occurrences, and data analysis for crops cultivation.

With the second-generation smart farm, managing a greenhouse has never been easier. The sensors attached to the greenhouse collect data on plant growth and growth status, which is then analyzed by an AI-powered system. This system creates an optimized greenhouse environment based on big data, ensuring that the crops grow well. Unlike the first-generation smart farm, which required some farming knowledge, the second-generation system is fully automated anyone can control and manage the greenhouse, regardless of their level of farming experience.

This means that even those without any knowledge of farming can successfully grow crops in their own greenhouse.

The third-generation smart farm is an incredible innovation that has completely automated farming through the use of advanced technologies like artificial intelligence and robots. This system provides farmers with a complex energy control system, robots, and intelligent machinery systems that make agricultural work much easier and more efficient. With the third generation of smart farm, farmers can now maximize their greenhouse and stock energy system and automate their processes using multiple robots. This has given farmers the power to control and manage the whole process of smart farming, making it easier and more profitable than ever before. Table 2 encapsulates the evolution of smart farming from its inception, focusing on convenience and efficiency, through to its current state where complete automation is possible.

Table 2 *Smart farm generations: key features and benefits*

Generation	Key Features	Benefits
1st	- Sensors for greenhouse monitoring - Remote control systems for climate and nutrient solution control	- Reducing labor - Enhancing crop quality
2nd	- Comprehensive monitoring (atmosphere, soil, crops) through AI and cloud computing - Data-driven cultivation advice - Automation for ease of management without prior farming knowledge	- Simplifying management regardless of farming experience - Optimizing conditions for growth and productivity
3rd	- Advanced AI, robots, and intelligent machinery for complete automation - Complex energy control system	- Maximizing efficiency and profitability - Completely automating farming process

Small farmers face a major challenge in setting up smart farms due to the high initial installation cost involved. Therefore, it is crucial to develop a small-scale smart farm model and an education and training program to support them, and KOPO is well-placed to lead this effort.

The results of the smart farm LF have been positive and have served as the foundation for PBL subjects that incorporate convergence education. This has enabled the establishment of convergence courses that combine various departments such as mechanics, automation, electricity, and industrial facilities, providing students with a chance to investigate and resolve issues through hands-on exercises and dialogues. Companies could really benefit from utilizing the LF facilities to train and educate their current employees. By improving their skills and knowledge, they could become more efficient and effective in their roles, which would be beneficial for both the company and the employees themselves. Additionally, if SMEs in rural areas had access to the expensive equipment needed for smart farm construction, it could significantly help them to take advantage of this technology and improve their operations. Finally, supporting the production or quality management of smart farm prototypes could be a great opportunity for rural areas and SMEs to get involved in this exciting new field.

In the Hongseong area, the local community has found a way to link the career experiences of middle and high school students to promote their campus. They have created smart farm experience programs for high school students, which are high-quality career advancement programs. These programs have played an important role in promoting the campus and attracting more students to visit. Providing students with practical experience and the opportunity to explore their passions is a meaningful way to help them gain valuable insight and develop their interests. Figure 4 illustrates the positive outcomes stemming from the KOPO's smart farm LF.

The LF at Hongseong campus has significantly advanced smart farm technology through interdisciplinary collaboration, resulting in the creation of a high-tech greenhouse with automated monitoring and data analysis. The comprehensive curriculum educates local farmers on smart farming practices, leading to improved crop production and quality. The facility also serves as a practical educational platform for students and a resource for SMEs, integrating multiple generations of smart farm technology to foster sustainable agricultural growth and community development.
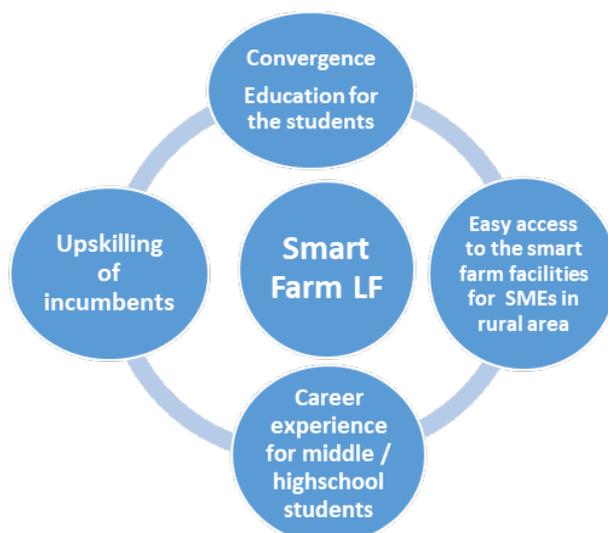
Fig. 5 *The positive outcomes of KOPO's smart farm LF*

5. Conclusion

The purpose of this study was to investigate the implications of sustainable TVET by examining the case of the smart farm LF at KOPO, an educational training center. As a result, smart farm LF at KOPO focuses on improving the practical skills of convergence technologies used in machinery, automation, industrial equipment, and electricity, and is equipped with a mini indoor smart greenhouse that can automatically maintain the optimal environment for crops through remote control of a computer or mobile phone. Additionally, the purpose of the training was to gain knowledge of how various IoT technologies can enhance agricultural productivity. The smart agriculture specialists shared the methods of the smart agriculture transformation, including the trial and error process as well as the critical success factors. Additionally, the attendees had the chance to witness equipment demonstrations and visit a mini indoor smart farm LF. Furthermore, by making agriculture more connected and intelligent, ICT-enabled agriculture can help reduce overall costs and improve the quality and quantity of products, while promoting agricultural sustainability. Utilizing this facility to train employees of SMEs and provide career experiences for middle and high school students has yielded positive results.

Based on these findings, the insights for farmers, learners, educators, companies, regions, along with implications for sustainable TVET, are multifaceted. First, students could engage in project-based learning through the smart farm LF gaining an understanding of basic skills and practicing operating system. The smart farm LF enabled learners to explore the integration of agriculture with automation, machinery, and ICT, including data analysis, wireless communication, and other technologies. Designed as a curriculum, smart farm LFs aim to assist farmers in nearby areas in adopting new technology to increase productivity and profitability. Educators could teach fundamental knowledge and competencies related to smart farming, including the principles of ICT and their practical applications in agriculture. Training professionals can thereby contribute to the productivity and sustainability of agriculture in their region.

The smart farm LF system continuously monitors the growth environment and analyzes a database, containing all information relevant to the growth conditions. This enables farmers to monitor both internal and external conditions of the smart farm, such as temperature, humidity, CO_2 levels, nutrient solutions, wind direction and velocity, rainfall, and daily solar radiation. This system has simplified the process for farmers to make informed decisions to control automated greenhouse systems based on data acquired from the smart farm LF. Companies utilized it as a training venue to enhance their employees' job capability. In particular, SMEs focusing on equipment or technology related to smart farms have been able to advance their equipment and technology through this initiative. Locally, LF has beefoudnn utilized as an exploration opportunity for middle and high school students, positively impacting campus promotion and student recruitment.

Based on these findings, the implications for sustainable TVET are as follows: First, it is crucial that governments, local authorities, and businesses acknowledge the significance of TVET capable of integrating farmers' knowledge and expertise with modern technologies. Furthermore, they need to invest in training programs that are timely and well-coordinated (Kim et al, 2020; Wee et al, 2018). TVET is pivotal in acquiring and disseminating smart farming skills. Farmers with higher education levels tend to adapt more quickly and efficiently to the digital agriculture era, leading to a positive impact on agricultural productivity. Conversely, farmers with lower education levels have faced challenges in keeping up with the latest smart farm technologies. Therefore, investing in farmer training can help bridge this gap and improve overall productivity in the agricultural industry.

Second, there is a need to enhance the effectiveness of practice-based instruction and guidance on learning while supporting the creation of comprehensive educational resources that integrate and take advantage of cutting-edge industrial technologies in agriculture. The smart farm LF has played a role in improving agricultural practices and boosting crop yields by giving farmers education and training on utilizing the most recent technologies. In particular, the smart farm LF hands-on training, access to experts, experiences and field trips have been utilized as various useful tools and strategies for the digital age. One of the key factors for the development of sustainable agriculture was on-farm, hands-on education and training. This has led to cost savings, improved quality and quantity of agricultural products. To spread these results, it is necessary to actively consider ways to improve the quality of education and training by providing guidebooks through teaching and learning centers in local universities or by presenting practice-based teaching and learning guidance to instructors. Specifically, the insights derived from the input, process, and output analysis of the smart farm case should be shared and disseminated as training expertise with other countries in the future.

Finally, active collaboration and cooperation among educational institutions, the government, and local businesses are necessary. The smart farm LF by KOPO has been serving as a hub for innovation, problem-solving, and idea generation through education and training, prototyping, production, development, and cross-departmental collaboration. The center has served as a work experience opportunity for young individuals seeking employment, as well as a facility for aspiring entrepreneurs to develop prototypes.

Its dedication to acting as a regional practice space is underscored by certifications from highly regarded organizations such as Samsung Electronics and the Korea Welding Industry Cooperative. The smart farm has highlighted the significance of its LF as a vital basis for sustainable TVET, by establishing strong connections with local and regional industries, and providing a platform for communication with businesses.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Author Youngah Kang, Author Youngeun Wee; **data collection:** Author Youngah Kang; **analysis and interpretation of results:** Author Youngeun Wee, Author Youngah Kang, Author Woocheol Kim; **draft manuscript preparation:** Author Youngeun Wee, Author Youngah Kang, Author Woocheol Kim. All authors reviewed the results and approved the final version of the manuscript.*

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