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Research

Edufarming communication strategy for the diffusion of smart farming innovation: A qualitative case study of SGH hydroponic

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ABSTRACT
This study analyzes Edufarming as a communication strategy for diffusing AIoT-based smart farming innovation at SGH Hydroponic in Gowa Regency, South Sulawesi, Indonesia. The study employed a qualitative approach with a descriptive single-case study design. Data were collected through semi-structured interviews, participant observation, and documentation. The informants consisted of the founder, co-founder, two technical staff members of SGH Hydroponic, and one Edufarming program participant. The researcher also participated directly in the Edufarming program to observe the learning process, interaction patterns, and technology demonstration. Data were analyzed using an interactive qualitative model consisting of data collection, data condensation, data display, and conclusion drawing. The analysis also applied thematic categorization based on Rogers' diffusion of innovation attributes and was strengthened through source triangulation and technique triangulation. The findings show that Edufarming functions not only as an agricultural education activity but also as a participatory communication mechanism that connects technology, agribusiness actors, training participants, and market partners within a learning ecosystem. The diffusion process occurs through technology demonstration, hands-on practice, interpersonal communication, group learning, and direct observation of production outcomes. AIoT-based hydroponics provides relative advantage through production stability, faster harvesting, product consistency, and stronger market trust. Edufarming also improves compatibility, reduces perceived complexity, facilitates trialability, and strengthens observability through visible plant growth, dashboard-based monitoring, and practical learning activities. The study implies that smart farming diffusion requires technological readiness, structured communication, mentoring, digital literacy support, and participatory learning.

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INTRODUCTION

The global agricultural sector is undergoing a structural transformation toward Agriculture 4.0, driven by the simultaneous pressures of food insecurity, climate change, resource scarcity, and the need for more efficient production systems. The urgency of this transformation is reflected in recent global statistics: around 733 million people experienced hunger in 2023, while approximately 2.33 billion people faced moderate or severe food insecurity (FAO et al., 2024). At the same time, the world population is projected to reach about 9.7 billion by 2050, increasing pressure on agricultural systems to produce more food with limited land, water, and energy resources (United Nations Department of Economic and Social Affairs, 2022). FAO also reports that land and water systems for food and agriculture are under increasing stress, requiring production models that are more resource-efficient, climate-resilient, and knowledge-intensive (FAO, 2021). These conditions explain why digital agriculture, smart farming, and controlled-environment agriculture are increasingly viewed not merely as technological options, but as strategic responses to global food-system challenges.

Smart farming technologies, including the Internet of Things (IoT), Big Data, artificial intelligence, and AIoT-based automation, provide opportunities to improve agricultural efficiency through real-time monitoring, data-driven decision-making, and automated control of production variables (Thilakarathne et al., 2025; Wolfert et al., 2017). In hydroponic systems, digital technologies can support the monitoring of water quality, nutrient concentration, pH, temperature, humidity, and plant growth conditions, thereby reducing production uncertainty and improving resource use efficiency (Appicciutoli et al., 2025; Lakhiar et al., 2025; Raj & Prahadeeswaran, 2025). However, the adoption of smart farming is not determined solely by technological availability. Studies show that farmers' digital literacy, access to technical assistance, perceived usefulness, infrastructure readiness, and social networks strongly influence the acceptance of digital agricultural innovation (Al-Ammary & Ghanem, 2024; Bashiru et al., 2024; Liu et al., 2025; Strong et al., 2022).

In developing-country contexts, including Southeast Asia, digital agricultural innovation is increasingly recognized as an instrument for strengthening agribusiness competitiveness, sustainability, and youth participation in agriculture (Irawan et al., 2023; Mardiana & Kembauw, 2021). Nevertheless, technology adoption often faces a gap between innovation developers and end users. Innovations that are technically sophisticated may remain underutilized when farmers and community members do not fully understand their benefits, operational procedures, or relevance to local farming conditions. This condition highlights the importance of communication strategy in agricultural development. Communication is not simply a process of transmitting information; it is a mechanism through which users interpret, evaluate, test, and eventually decide whether an innovation is acceptable within their social and economic context (Melaku et al., 2024).

Rogers' diffusion of innovation theory provides an appropriate analytical lens to explain this process. According to Rogers (2003), innovation adoption is shaped by communication channels, time, the social system, and perceived attributes of innovation, namely relative advantage, compatibility, complexity, trialability, and observability. In the context of smart farming, these attributes are highly relevant. AIoT-based hydroponics may offer relative advantage through production efficiency, but potential adopters may also perceive it as complex due to its reliance on sensors, digital monitoring, and automated control systems. Therefore, adoption requires communication channels that can translate technological complexity into practical knowledge. Hands-on learning, field demonstration, mentoring, and peer interaction can reduce perceived complexity, increase observability, and allow potential adopters to experience trialability before making adoption decisions (Osumba et al., 2021; Timpanaro et al., 2024).

Within this framework, Edufarming can be understood as a practical communication mechanism for innovation diffusion. Edufarming does not merely deliver information about hydroponics or smart farming; it creates an experiential learning space where participants observe the technology, interact with practitioners, practice cultivation techniques, and evaluate the innovation's relevance to their own need. This model strengthens the analytical connection between Rogers' theory and the empirical phenomenon under study. Through workshops, internships, group discussions, and direct demonstration, Edufarming transforms smart farming from an abstract technological concept into a visible, testable, and socially communicable practice. In this sense, Edufarming functions simultaneously as an interpersonal communication channel, a group communication channel, and a social innovation platform.

Samata Green House (SGH) Hydroponic in Gowa Regency, South Sulawesi, provides a relevant case for examining this issue. Since its establishment in 2020, SGH Hydroponic has developed into a modern hydroponic agribusiness that applies AIoT-based systems to support production management. The greenhouse manages approximately 75,000 planting sites and uses digital monitoring to improve the efficiency of hydroponic cultivation. Beyond its production function, SGH Hydroponic also operates Edufarming activities through workshops, internships, and educational visits involving students, youth groups, and community participants. This dual role positions SGH Hydroponic not only as a producer of hydroponic vegetables, but also as a local innovation hub that facilitates the diffusion of smart farming literacy.

Previous studies on smart farming have largely emphasized technological performance, adoption barriers, digital literacy, and the role of digital platforms in agricultural transformation (Bashiru et al., 2024; Liu et al., 2025; Thilakarathne et al., 2025; Wolfert et al., 2017). Other studies have examined digital communication, social media, and farmer networks in supporting knowledge dissemination and technology adoption (Dilleen et al., 2023; Melaku et al., 2024; Purwanto et al., 2025). However, limited scholarly attention has been paid to how hands-on educational models such as Edufarming operate as structured communication strategies for diffusing smart farming innovations.This gap is important because smart farming adoption requires not only technological readiness, but also social learning, trust building, practical demonstration, and locally meaningful communication.

Based on this gap, this study aims to analyze the Edufarming communication strategy implemented by SGH Hydroponic for diffusing smart farming innovations. Specifically, the study examines the actors involved, the communication channels used, the messages delivered, and the way Edufarming facilitates the perceived attributes of innovation proposed by Rogers. Theoretically, this study contributes to agricultural development communication by explaining how group and interpersonal communication channels can operationalize innovation diffusion in the context of AIoT-based hydroponic farming. Practically, the study is expected to provide a reference for agribusiness actors, educational institutions, and local agricultural communities in designing inclusive, participatory, and community-based smart farming literacy programs.

METHOD

This study employed a qualitative approach with a descriptive single-case study design. A qualitative approach was considered appropriate because the study focused on understanding communication practices, actor interactions, and meaning-making processes in the diffusion of smart farming innovation. Rather than measuring adoption statistically, this study aimed to explain how Edufarming was designed, communicated, interpreted, and practiced within the social context of SGH Hydroponic. A case study design was selected because the phenomenon under investigation was bounded by a specific location, actors, program, and institutional context. In this study, SGH Hydroponic was treated as a bounded case because it integrates AIoT-based hydroponic production with Edufarming as a community education and innovation diffusion program.

The research was conducted at Samata Green House (SGH) Hydroponic, located in Gowa Regency, South Sulawesi Province, Indonesia. The study was conducted from November 2025 to March 2026. The site was selected purposively based on three empirical considerations. First, SGH Hydroponic applies AIoT-based technology in hydroponic cultivation. Second, the institution actively implements Edufarming activities through training, visits, and internship programs. Third, SGH Hydroponic represents a local agribusiness initiative that combines production, education, and social communication in introducing smart farming to wider audiences. These characteristics made SGH Hydroponic relevant for analyzing the relationship between communication strategy and innovation diffusion in a modern agribusiness context.

Informants were selected using purposive sampling. This technique was used because the study required information from actors who were directly involved in the management, communication, technical implementation, and learning process of Edufarming. The informants consisted of five people: the founder of SGH Hydroponic, the co-founder, two technical staff members, and one Edufarming participant who also joined the internship program. The founder was selected because of his role in initiating the hydroponic business, developing the Edufarming concept, and communicating the vision of smart farming. The co-founder was selected because of involvement in communication management and program coordination. The two technical staff members were selected because they understood the operational implementation of hydroponic cultivation and AIoT-based control systems. The Edufarming participant was selected to represent the perspective of program participants as potential adopters of smart farming knowledge.

Data were collected through three techniques: semi-structured interviews, participant observation, and documentation. Semi-structured interviews were used to obtain in-depth information while allowing flexibility for informants to explain their experiences and interpretations. The interview topics included the background of SGH Hydroponic, the role of AIoT in operational management, the design and implementation of Edufarming, communication channels, participant engagement, perceived barriers, and the role of Edufarming in introducing smart farming innovation. Participant observation was conducted by directly engaging in Edufarming activities. Through this technique, the researcher observed the interaction between facilitators and participants, the delivery of educational messages, the demonstration of hydroponic practices, and the way participants responded to smart farming technology. Documentation was used to complement interview and observation data by reviewing field notes, activity documentation, visual materials, and relevant institutional information related to SGH Hydroponic and Edufarming.

Data were analyzed using the interactive model (Miles et al., 2014), which consists of data collection, data condensation, data display, and conclusion drawing/verification. In the data collection stage, interview results, observation notes, and documentation were compiled as the primary data corpus. In the data condensation stage, the researcher selected, simplified, and focused the data based on the research objective, particularly data related to Edufarming communication strategy, actors, communication channels, innovation attributes, and adoption barriers. In the data display stage, the findings were organized into descriptive narratives, informant matrices, and thematic categories. These categories were interpreted using Rogers' diffusion of innovation framework, particularly relative advantage, compatibility, complexity, trialability, and observability. In the conclusion drawing and verification stage, patterns emerging from the data were interpreted and compared across informants and data sources

The scope of this study was limited to one case, namely SGH Hydroponic in Gowa Regency. Therefore, the findings are not intended to represent all smart farming or hydroponic agribusiness practices in Indonesia. Instead, the findings provide an in-depth understanding of how Edufarming functions as a communication strategy for diffusing smart farming innovation in a specific local agribusiness context.

RESULTS AND DISCUSSION

This study analyzes the Edufarming communication strategy implemented by SGH Hydroponic in diffusing AIoT-based smart farming innovations. Based on interviews, observations, and documentation, the findings show that Edufarming functions not only as an agricultural education activity, but also as a participatory communication mechanism that brings together technology, agribusiness actors, training participants, and market partners within a learning ecosystem. The innovation diffusion process at SGH Hydroponic does not occur linearly through one-way information delivery, but through a combination of technology demonstration, hands-on practice, interpersonal communication, group learning, and the verification of production outcomes.

Operational Profile of SGH Hydroponic as a Smart Farming Agribusiness

SGH Hydroponic is a hydroponic enterprise operating in South Sulawesi, with business activities extending to Makassar City, Gowa Regency, and Bulukumba Regency. However, this study focuses specifically on the SGH Hydroponic greenhouse in Gowa Regency, where AIoT-based smart farming technology is implemented in hydroponic production and Edufarming activities. SGH Hydroponic manages a production area of approximately 16 × 50 m² with around 75,000 planting holes. The main commodities cultivated include lettuce, pakcoy, baby kailan, Brazilian spinach, and pagoda mustard.

The production data from January to March 2026 show a relatively stable and increasing harvest trend. These data strengthen the position of SGH Hydroponic as an urban hydroponic agribusiness that utilizes limited land for commercial production. This model is consistent with Lakhiar et al. (2025), who explain that soilless agricultural systems have significant potential in responding to land limitations, urbanization, and the need for more controlled horticultural production. In the case of SGH Hydroponic, hydroponics is not merely a technical alternative to soil-based farming, but also a commercial production model that requires continuous and reliable output. In terms of market segmentation, SGH Hydroponic does not rely on a single consumer group. Its market is divided into four main categories: HoReCa, resellers, local markets, and household customers.

Table 1. Harvest Production of SGH Hydroponic from January to March 2026

Month	Commodities	Monthly Harvest Volume	Average Weekly Harvest
January	Lettuce, Pakcoy, Baby kailan, Brazilian spinach, Pagoda mustard	±1,800 kg	±450 kg
February	Lettuce, Pakcoy, Baby kailan, Brazilian spinach, Pagoda mustard	±1,880 kg	±470 kg
March	Lettuce, Pakcoy, Baby kailan, Brazilian spinach, Pagoda mustard	±1,920 kg	±490 kg

Source: Field findings based on interviews with SGH Hydroponic informants, processed by the researcher, 2026

This composition shows that SGH Hydroponic has a strong orientation toward the B2B market, particularly hotels, restaurants, cafés, and catering services, while still maintaining community markets and individual consumers. Purchases across these categories are reported to occur routinely, making production stability a key requirement in SGH Hydroponic's business model. In this sense, smart farming innovation at SGH Hydroponic has both technical and economic value.

Table 2. Market Target Composition of SGH Hydroponic

Category	Market Target	Percentage
HoReCa	Hotels, restaurants, cafes, catering services	40%
Resellers	Traders/agents	30%
Local Markets	Community market	20%
Household customers	Individual consumers	10%

Source: Field findings based on interviews with SGH Hydroponic informants, processed by the researcher, 2026

Technology is used to maintain consistency in product quality, leaf size, taste, and supply continuity. In the HoReCa market, such consistency is essential because partners require scheduled supply and relatively stable quality standards. This aligns with Wolfert et al. (2017), who explain that big data and smart farming support agricultural supply chain coordination through data management, production monitoring, and more precise decision-making.

SGH Technology System and the Position of AIoT in Hydroponic Production

SGH Hydroponic uses several key technologies in its production system, namely the NFT hydroponic system, pH/EC/TDS sensors, circulation pumps, timers or pump automation, greenhouse structures, Skypian AIoT, and solar cells. The NFT system is used to distribute a thin and continuous flow of nutrient solution to plant roots. The nutrient solution is channeled through growing gutters with a slope of 1–5% and then returned to the reservoir. This system supports root growth, maintains dissolved oxygen, and reduces the risk of root rot. The pH/EC/TDS sensors are used to read acidity and nutrient concentration in real time, while circulation pumps ensure nutrient distribution across the entire installation. Timers and pump automation help reduce human error, while the greenhouse protects plants from external pests and extreme weather conditions.

The combination of these technologies reflects the main characteristics of smart farming because it integrates sensors, data, automation, and environmental control. In line with this Thilakarathne et al. (2025) explain that IoT-enabled smart agriculture includes the use of sensors, connectivity, real-time monitoring, control systems, and data-based decision-making to improve agricultural efficiency. At SGH Hydroponic, these technologies do more than support production. They also function as educational communication media because Edufarming participants can observe how sensor data, technical interventions, and plant conditions are connected.

Furthermore, Miller et al. (2025) emphasize that the integration of IoT and AI in agriculture is increasingly important because sensor technologies can provide environmental and plant data more rapidly. The case of SGH Hydroponic shows that the value of sensors is not limited to measurement accuracy. Sensors also make the cultivation process visible and explainable for Edufarming participants. Thus, the technology serves a dual role: supporting production management and functioning as a learning medium.

The introduction of Skypian AIoT, solar cells, and automation at SGH Hydroponic originated from a combination of managerial initiative and collaboration with technology providers. These technologies were introduced to address concrete operational and educational problems, including nutrient parameter instability caused by weather changes, the need to reduce electricity costs for pumps that operate almost continuously, and the need for data visualization so that Edufarming would not remain purely theoretical.

Table 3. Technologies Used by SGH Hydroponic

Technology/System	**Function**	**Working Mechanism**	**Operational Impact**
NFT hydroponic system	Distributes a thin and continuous nutrient flow to plant roots	Nutrients flow through growing gutters and return to the reservoir	Optimizes root growth and stabilizes nutrient distribution
pH/EC/TDS sensors	Measure pH and nutrient concentration	Sensors read ions in the water and send data to the controller	Reduces manual checking and prevents nutrient dosage errors
Circulation pumps	Distribute water from the reservoir to the installation	Electric pumps push water into the growing gutters	Nutrients are distributed to all planting holes
Timer/pump automation	Regulates the on/off operation of equipment	Digital switches operate based on time settings or sensor parameters	Improves electricity efficiency and reduces human error
Greenhouse	Protects plants from weather and pests	UV plastic and insect nets create a controlled growing environment	Stabilizes the microclimate and reduces the use of chemical pesticides
Skypian AIoT	Provides data-based monitoring and control	Sensor data are displayed on a dashboard and connected to control devices	Improves production precision and makes Edufarming easier to explain
Solar cell	Provides supporting energy	Solar panels support electricity needs for pumps and systems	Reduces dependence on conventional electricity

Source: Field findings based on interviews with SGH Hydroponic informants, processed by the researcher, 2026

This pattern indicates that technology adoption at SGH Hydroponic is problem-driven rather than trend-driven. Technology was not adopted simply to follow the trend of agricultural digitalization, but to respond to specific technical and educational challenges. This point is important because agricultural innovation is more likely to be accepted when users see a direct connection between the technology and the problems they face. In this regard Rizzo et al. (2024) show that sustainable innovation adoption is influenced by perceived benefits, socioeconomic conditions, user capacity, and institutional support.

Relative Advantage: Production Stability, Faster Harvesting, and Market Trust

Relative advantage refers to the extent to which an innovation is perceived as better than previous practices. At SGH Hydroponic, this attribute is most clearly reflected in the shift from manual hydroponics to monitoring and automation based hydroponic systems. Before AIoT was implemented, SGH Hydroponic managers measured pH and EC manually using handheld pH meters. Measurements were conducted once or twice a day. The main weakness of this system was the delayed detection of changes in nutrient parameters. For example, if pH increased during the day, the condition might only be identified in the afternoon, resulting in a delayed technical response.

After AIoT and automation were introduced, managers were able to monitor parameters in real time through a dashboard. This change contributed to more stable nutrient management, particularly for lettuce production. Interview findings indicate that before the technology was applied, the harvest age of green lettuce ranged from 35 to 40 days. After the use of AIoT, automation, and digital monitoring, the harvest age ranged from 21 to 25 days.

Table 4. Comparison of Harvest Age Before and After Technology Use

Cultivation Condition	System Used	Average Harvest Age	Commodity	Description
Before technology	Manual/conventional hydroponics	35–40 days	Green lettuce	Manual and fluctuating nutrient control
After technology	AIoT, automation, monitoring	21–25 days	Green lettuce	Nutrients are more stable at the optimal level

Source: Field findings based on interviews with SGH Hydroponic informants, processed by the researcher, 2026

This result illustrates relative advantage because the technology provides operational benefits that can be observed in daily production. However, faster harvesting should not be interpreted as the sole effect of AIoT. Other factors, such as seed quality, nutrient formulation, the experience of managers and technical staff, the NFT system, greenhouse conditions, and daily management practices, also contribute to the outcome. Therefore, AIoT should be understood as part of a broader socio technical production system that enhances control accuracy rather than as a single determinant of productivity improvement. Strong et al. (2022) examined barriers to IoT smart agriculture adoption and emphasized the importance of understanding stakeholder perceptions and interests before launching an innovation. This finding is relevant to SGH Hydroponic because the benefits of technology are assessed not only from the technical side, but also from the perceptions of managers/staff, Edufarming participants, and market partners. For managers, the advantage of technology lies in production stability. For participants, the advantage is reflected in the ease of understanding the process of agricultural digitalization. For HoReCa partners, the advantage lies in consistent product quality and supply continuity.

Interview findings also show that the relative advantage of SGH Hydroponic is reflected in business performance, particularly in more stable product quality and a reported reduction in crop failure risk to below 2%. In the HoReCa market, consistency in leaf size, non-bitter taste, and weekly supply is essential. Technology helps SGH Hydroponic managers maintain this consistency, thereby increasing B2B partner trust and enabling long-term contracts at premium prices above traditional market prices. Kendall et al. (2022) highlight that the adoption of precision agriculture is influenced by user readiness, perceived benefits, and supporting institutional mechanisms. This argument helps clarify that technology at SGH Hydroponic should not be viewed merely as equipment. It is part of an operational readiness system. Without managers and technical staff who are able to read dashboards, calibrate sensors, and respond to system alerts, the advantages of the technology cannot be fully realized.

Compatibility: The Fit between Technology, Production Needs, and Users' Social Capacity

Compatibility at SGH Hydroponic appears at two levels. First, the technology fits the needs of commercial-scale hydroponic production. The pH/EC/TDS sensors address the need for nutrient stability. Timers and pump automation help reduce human error. Solar cells respond to the need for electricity cost efficiency. The greenhouse protects plants from pests and external environmental condition. Second, the technology is adjusted to users' social capacity through Edufarming. Participants are not immediately introduced to AIoT as a complex technical system. Instead, they are first guided to understand the hydroponic workflow, including seedling, transplanting, nutrient mixing, dashboard reading, and harvesting. In this context, compatibility is not only technical but also communicative. Technology is adapted to participants' learning experiences.

This compatibility suggests that innovation communication should be directed toward users' information needs, rather than simply emphasizing technological sophistication. Anteneh & Melak (2024) argue that ICT-based agricultural extension and advisory services can help farmers obtain useful information when the information is relevant, accessible, and aligned with users' conditions. At SGH Hydroponic, this principle is reflected in the way Edufarming connects smart farming materials with participants' practical needs, such as understanding nutrient solutions, reading sensor data, recognizing dashboard functions, and assessing business opportunities in hydroponic vegetables. The role of Edufarming becomes clearer in comparison to the findings of Melaku et al. (2024), who identify weak communication between innovation providers and end users as a major barrier in agricultural innovation diffusion. Their study also shows that fear, knowledge gaps, and limited experience can generate negative perceptions of agricultural innovation. At SGH Hydroponic, this gap is addressed through face-to-face communication, hands-on practice, and technology demonstration, allowing participants to approach AIoT not as an abstract system but as a practical tool embedded in daily cultivation

Becerra-Encinales et al. (2024) reviewed barriers to agricultural extension in developing countries and emphasized the importance of relationships among extension agents, farmers, and the social context in adopting technological practices. In the case of SGH Hydroponic, this relationship is built through direct interaction between SGH managers and Edufarming participants. Innovation compatibility is strengthened because participants do not only receive technical instructions but also engage directly with practitioners who have implemented the innovation in real production settings. Compatibility is also reflected in SGH Hydroponic's communication strategy with market partners. Communication with HoReCa partners and resellers is carried out through an interpersonal approach, but the complexity of AIoT is not emphasized as the main message. The main messages are product quality, continuity, and consistency. In contrast, for Edufarming participants, AIoT becomes the main learning object. This differentiation shows that SGH Hydroponic adjusts its communication according to the needs of each audience.

Complexity AIoT Complexity and the Role of Edufarming in Simplifying Technology

The use of AIoT at SGH Hydroponic involves a relatively high level of complexity because it includes sensors, controllers, dashboards, notifications, nutrient parameters, automatic pumps, and data interpretation. For Edufarming participants without a technical background, this complexity can become an initial barrier. If not explained through accessible methods, such complexity may slow the adoption process. Liu et al. (2025) suggests that digital literacy positively influences farmers' adoption of green production technologies. Their study explains that digital literacy can strengthen risk perception, expand digital social capital, and improve the effectiveness of technology promotion. This argument is relevant to SGH Hydroponic because Edufarming serves as a space for improving agricultural digital literacy. Participants do not only learn how to grow plants. They also learn how to read data, understand dashboards, and connect numerical indicators in the system with actual plant conditions.

The Edufarming program at SGH Hydroponic already has written modules, including a basic hydroponic guide in e-book format, a weekly activity syllabus, AIoT materials, hydroponic practice, business materials, and participant evaluation. AIoT materials are delivered through practical activities such as dashboard reading and physical sensor calibration. Hydroponic practice includes seedling, transplanting, nutrient mixing, and harvesting. Business materials are delivered through sharing sessions on the HoReCa supply chain and ROI analysis. Osumba et al. (2021) explain that agribusiness-based farmer field schools can transform agricultural extension through participatory and practice-based learning. Edufarming at SGH Hydroponic shares several characteristics with this model because participants learn through direct involvement in production activities rather than through classroom-based instruction alone. However, SGH's Edufarming has an additional feature: the introduction of digital technology and AIoT as part of cultivation practice.

Nevertheless, the complexity of the Edufarming program has not been fully resolved. Field findings indicate that SGH Hydroponic still has a limited number of managers or mentors who master both hydroponic agronomy and AIoT technical aspects. Administrative limitations also emerge as participant interest increases. To address this issue, SGH Hydroponic plans to empower selected internship alumni as junior mentors and standardize digital modules so that knowledge transfer does not depend entirely on the founder. This situation shows that agricultural technology adoption is influenced not only by the readiness of tools, but also by interactions among actors within the innovation system. Addorisio et al. (2025) emphasize that sustainable agricultural technology adoption needs to be understood systemically because it involves knowledge, stakeholder relationships, governance, and institutional capacity. SGH's plan to prepare junior mentors and digital modules can therefore be understood as an effort to strengthen the supporting system for innovation diffusion.

As participant numbers increase while the number of available mentors remains limited, the quality of communication and mentoring may decline. Accordingly, module standardization, mentor training, and post-training evaluation emerge as critical components to ensure the sustainability of Edufarming as an innovation diffusion strategy.

Trialability: Hands-On Practice, Internships, and Gradual Adoption

Trialability refers to the extent to which an innovation can be tried on a limited scale before full adoption. At SGH Hydroponic, trialability is realized through Edufarming visits, training, and internship programs. Participants can observe the greenhouse system, try cultivation practices, read the dashboard, understand sensors, and follow the production process. For internship participants, trialability is stronger because they are involved in production activities over a longer period. Timpanaro et al. (2024) explain that living labs in agriculture function as spaces for technology diffusion because they bring together business actors, technology, users, and real practices within a learning environment. Edufarming at SGH Hydroponic has a similar character. Participants do not only receive knowledge; they also observe how technology operates in the context of commercial production.

However, trialability at SGH Hydroponic does not automatically lead to full adoption. High equipment costs remain a significant barrier for participants who wish to replicate the SGH system. The adoption of monitoring sensors, solar panels, automation, and hydroponic installations requires a large initial investment. SGH Hydroponic managers address this challenge through gradual investment, beginning with monitoring digitalization, moving toward control automation, and using reinvested profits from premium vegetable sales to HoReCa.

For Edufarming participants at the household or small-business scale, adoption also tends to occur gradually. Participants who have successfully built their own greenhouses generally do not immediately replicate the entire SGH Hydroponic technology package. They begin with basic hydroponic systems and physical greenhouses, then adopt digital monitoring through mobile phones, and gradually consider AIoT when their revenue increases. Forero et al. (2025) explain that agricultural innovation adoption often involves a paradox: technology may promise efficiency, but economic and institutional barriers can still hinder adoption. The SGH case reflects this paradox, where Edufarming enhances interest and understanding, yet actual adoption decisions are still constrained by capital availability, business scale, access to technology, and system maintenance capacity.

Observability: Visibility of Plants, Dashboards, and Business Outcomes

Observability at SGH Hydroponic appears in two forms: physical visibility and digital visibility. Physical visibility is reflected in plant conditions, NFT installations, greenhouse facilities, harvesting processes, and marketed products. Digital visibility is reflected in AIoT dashboards, pH/EC/TDS graphs, system notifications, sensor photos, and automatic activity logs. Observability is important because smart farming is often perceived as an abstract technology. Through the dashboard, participants can see that pH, EC, temperature, and humidity values are connected to plant conditions. Through the greenhouse, they can observe how environmental control contributes to production stability. Through the HoReCa market, they can understand that technology is also linked to quality standards and partner trust. Ibarra-Cabrera et al. (2024) show that IoT-based urban gardening systems can support technology adoption when users are able to directly observe how the system operates. This argument is relevant to SGH Hydroponic because system visibility becomes part of the persuasion process. Participants are not merely told that AIoT is useful; they can observe how data are displayed, how notifications operate, and how the system responds to specific parameters.

At the automation level, the AIoT system at SGH Hydroponic does not only function as a monitoring tool. It also includes alerts, recommendations, semi-automatic control, and automatic control. When sensors detect that the air temperature exceeds 32°C, the system automatically activates the mist sprayer. When the water volume in the reservoir falls below the minimum threshold, the solenoid valve automatically opens to refill raw water.

Table 5. AIoT Implementation Levels at SGH Hydroponic

System Level	Description
Monitoring	Displays pH, EC/TDS, temperature, and humidity
Alert/notification	Sends notifications when parameters exceed thresholds
Recommendation	Provides action recommendations to the operator
Semi-automatic control	The operator approves an action before the system operates
Automatic control	The system activates equipment based on sensor data

Source: SGH Hydroponic, 2026

Although AIoT adoption has influenced technical decision-making in the work process, it should be emphasized that not all production decisions are fully replaced by artificial intelligence. Some decisions still require human interpretation, especially those related to the visual condition of plants, installation maintenance, harvesting strategy, and market relations. SGH Hydroponic's system is therefore better understood as a combination of real-time monitoring, sensor-based automation, and human decision-making supported by data.

Edufarming as a Participatory Communication Strategy

Edufarming at SGH Hydroponic functions as an interpersonal and group communication channel. In this activity, participants do not only receive materials; they also interact with the founder, co-founder, technical staff, and other participants. This communication pattern enables questions, clarification, demonstration, and hands-on practice. Such interaction is important because innovation adoption is shaped not only by the availability of information but also by trust and experience.

In modern agricultural extension, information and communication technology plays an increasingly important role in expanding farmers' access to information, accelerating knowledge exchange, and strengthening relationships between information providers and end users. Mulungu et al. (2025) explain that ICT-based extension has strong potential to improve agricultural extension services, although challenges remain in terms of access gaps, digital skills, and user readiness. Edufarming at SGH reflects this point because digital communication through the AIoT dashboard does not stand alone. It is combined with face-to-face interaction, hands-on practice, and technical mentoring in the greenhouse.

Dilleen et al. (2023) show that farmer networks play an important role in disseminating knowledge about smart farming technology. Their study also found that farmers tend to trust information from fellow practitioners or peer networks more than information from technology vendors. This comparison is useful for understanding SGH Hydroponic. The managers do not present themselves as tool sellers but as practitioners who have used the technology in actual production. This position strengthens the credibility of the message delivered through Edufarming.

Steinke et al. (2021) emphasize that the digital revolution in agricultural extension should be directed toward a more participatory innovation agenda, rather than merely using communication technology as an information channel. Edufarming at SGH follows this direction because digital technology is embedded in the learning experience. Participants learn through observation, direct involvement, and interaction with both the technology and the people who operate it. In addition to functioning as a technical learning medium, Edufarming also has a persuasive communication dimension. It presents agriculture as a modern, technology-based activity with business opportunities. Wulandari et al. (2025) show that persuasive communication can attract young people's interest in agriculture when the messages delivered are close to their experiences, needs, and aspirations. This is consistent with the involvement of students and internship participants in Edufarming at SGH, where smart farming is introduced not only as production technology but also as a modern agribusiness entrepreneurship opportunity.

Compared with conventional agricultural extension, Edufarming at SGH Hydroponic has the advantage of combining technical learning, visual experience, and business context. However, this model also has limitations. Activities that depend heavily on direct interaction require an adequate number of mentors. If participant numbers continue to increase without additional mentors, the quality of the learning experience may decline. Therefore, SGH Hydroponic's plan to prepare junior mentors from internship alumni is an important strategy for maintaining the sustainability of the program.

CONCLUSION

This study concludes that Edufarming at SGH Hydroponic functions as a participatory communication strategy for diffusing AIoT-based smart farming innovation. Edufarming does not merely introduce hydroponic technology as a production tool, but also transforms it into a learning experience through technology demonstration, hands-on practice, interpersonal communication, group learning, and direct observation of production outcomes. In this context, the diffusion of innovation at SGH Hydroponic occurs through a socio-technical process in which participants are encouraged to understand, observe, try, and evaluate smart farming practices within a real agribusiness setting.

The findings show that the innovation attributes proposed in Rogers' diffusion of innovation theory are reflected in the Edufarming model. Relative advantage is demonstrated through production stability, faster harvesting of lettuce, improved product consistency, and stronger market trust. Compatibility is reflected in the alignment between technology, commercial hydroponic production needs, and participants' learning capacities. Complexity is reduced through modules, direct mentoring, dashboard demonstrations, and practical hydroponic activities. Trialability is facilitated through Edufarming visits, training, and internship programs, while observability is strengthened through visible plant growth, AIoT dashboards, sensor data, automated system responses, and market acceptance.

Practically, this study recommends that smart farming agribusiness actors develop educational programs that do not only promote technology but also provide structured learning experiences. Edufarming programs should include clear modules, practical demonstrations, participant mentoring, and post-training evaluation. Agribusiness actors who adopt AIoT-based farming systems also need to prepare human resources capable of explaining both the technical and business aspects of smart farming. The plan to involve internship alumni as junior mentors is relevant because it can reduce dependence on the founder and support the sustainability of knowledge transfer.

From a policy perspective, the findings suggest that local governments, agricultural extension institutions, and educational institutions should support smart farming diffusion through collaborative training programs, demonstration farms, and digital agricultural literacy initiatives. Policy support should not focus only on providing technological equipment, but also on strengthening communication capacity, mentoring systems, financing access, and evaluation mechanisms. For small-scale farmers or beginner adopters, policy programs should encourage gradual adoption pathways, starting from simple hydroponic systems, greenhouse management, digital monitoring, and then AIoT-based automation when the business scale and technical capacity are ready.

This study has limitations in its research scope. It uses a single-case study design focusing on SGH Hydroponic; therefore, the findings are not intended to be generalized to all Edufarming, hydroponic, or smart farming practices in Indonesia. The results should be understood as an in-depth description of Edufarming communication strategy in the context of AIoT-based hydroponic agribusiness at one research site. In addition, this study has not compared SGH Hydroponic with other greenhouses, either those using conventional hydroponic systems or those that have not adopted AIoT. As a result, this study cannot yet provide a comparative explanation of performance differences between AIoT-based and non-AIoT hydroponic systems.

Future research is recommended to conduct cross-case comparisons involving several greenhouses with different levels of technology adoption. Further studies should also use long-term production data and analyze Edufarming evaluation results more quantitatively, such as changes in participants' knowledge, digital literacy, adoption intention, and post-training implementation. These steps are important to explain the contribution of Edufarming to smart farming innovation diffusion in a more comprehensive, measurable, and comparable manner across different contexts.

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Nur Annisa Putri Nazaruddin contributed to the development of the research idea, field observation, data collection, interviews, data analysis, and writing of the complete initial manuscript draft. **Moehammad Iqbal Sultan** contributed to the refinement of the research framework, methodological direction, academic supervision, and critical review of the manuscript. **Andi Subhan Amir** contributed to strengthening the analysis, evaluating the manuscript, and reviewing the academic structure and coherence of the article. All authors have read and approved the final version of the manuscript for publication.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest related to the research, authorship, or publication of this article.

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