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Implementation of IoT-based smart farming and a price platform for farmer capacity building and productivity support

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ABSTRACT

Bumiaji Sejahtera Agricultural and Rural Self-Help Training Center (P4S) plays a strategic role as an agricultural training center in Batu City but still faces limited smart farming facilities and access to agricultural commodity price information. This community service program aimed to improve young farmers' knowledge, operational skills, and readiness to adopt technology through Internet of Things devices, a greenhouse monitoring application, and an agricultural commodity price information and forecasting platform. The program involved needs assessment, module development, device installation and demonstration, training, field practice, mentoring, and evaluation. Fifteen young farmers participated in the program. Evaluation was conducted through pre- and post-activity questionnaires, practical assessments, and pre-test and post-test instruments. The participants' average score increased from 58 to 74, representing a 16-point improvement. Furthermore, 93.3 percent of participants considered the system easy to understand, 80 percent intended to use it within one month, and 73.3 percent were able to operate it independently. The program produced reusable IoT-based monitoring devices, training modules, and digital platforms that strengthened participants' initial capacity and technology adoption readiness.

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1. INTRODUCTION

Digital transformation in agriculture offers significant opportunities to utilize sensors, the Internet of Things (IoT), applications, and data analytics. These technologies assist farmers in monitoring cultivation conditions and making more precise, data-driven decisions. However, the benefits of technology depend not only on hardware availability but also on the users' capacity to interpret data and align it with field demands. In community service projects, appropriate technology should serve as a tool for empowerment, complemented by demonstrations, practical exercises, and ongoing mentoring

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to ensure effective adoption by community partners. Lessons from IoT implementation with farming groups indicate that device installation, training, and post-implementation support must function as an integrated process (Darto et al., 2021). Similarly, smart irrigation training highlights the critical role of field practice in building farmers' knowledge and operational skills (Herdiana et al., 2025). Furthermore, IoT-based mentoring for precision agriculture demonstrates that field demonstrations and continuous guidance are essential components of successful technology transfer (Fadli et al., 2025).

The target partners of this program are a group of young farmers active in the Self-Help Agricultural and Rural Training Center (P4S) Bumiaji Sejahtera in Bumiaji Village, Batu City. In this activity, the group of young farmers is positioned as the primary beneficiary partners, while P4S serves as the location and program execution facilitator. This group has access to farmland and greenhouses and is involved in horticulture, hydroponics, livestock farming, and processed agricultural products. Based on field observations, interviews, and focus group discussions, two main problems faced by the young farmer group were identified. First, the use of sensors and monitoring applications has not become a routine part of cultivation activities. Greenhouse monitoring is still largely conducted through direct observation, while data on temperature, air humidity, soil moisture, pH, light intensity, and other parameters are not consistently used to guide irrigation, fertilization, and crop care. Second, commodity price information is still obtained from fragmented sources and is not presented in a format that allows participants to easily compare prices across commodities, markets, and time periods. Consequently, the utilization of cultivation data and market information to support agricultural decision-making remains sub-optimal.

These issues indicate that effective intervention requires more than mere equipment handover. Farmers need direct experience reading environmental parameters, operating applications, understanding recommendations, and linking market information to farm management. Klerkx et al. (2019) emphasized that digital agriculture adoption depends not only on technology availability but also on user capacity and the social-organizational context of its deployment. In Indonesian agricultural extension, Sirajuddin & Kamba (2021) demonstrated that perceived usefulness and ease of use shape ICT acceptance among farmers. Li et al. (2023) found that perceived benefits, technological ease of use, self-efficacy, and information channels influence farmers' willingness to adopt smart farming technology. Meanwhile, Setiawan et al. (2024) highlighted that farmer perceptions and mentoring roles contribute significantly to agricultural digitalization. For smallholders, training participation, organization membership, and interaction with extension workers also correlate with digital technology use (Gabriel & Gandorfer, 2023). Studies on smart farming adoption confirm that technology usage decisions depend on technological attributes, user conditions, and the implementation context (Osrof et al., 2023). Based on these considerations, the technology in this program is designed as both a learning tool and operational support, not a replacement for farmers' agronomical decisions. Initial measurable achievements focus on knowledge, system ease of understanding, usage intention, and independent system operation, while impacts on productivity, water and fertilizer efficiency, and income require further longitudinal measurement.

To address the partner's challenges, the program implements appropriate technology (*teknologi tepat guna*/TTG) consisting of two complementary components. The first component is a smart farming system for greenhouses that integrates environmental sensors, IoT box, database, dashboard, care recommendations, and irrigation control. This technology aims to reduce reliance on direct observation and assist farmers in using environmental data for monitoring and cultivation practices. The second component is a commodity price information platform presenting historical data, trends, and price forecasting features sourced from East Java's SISKAPERBAPO (Dinas Perindustrian dan Perdagangan Provinsi Jawa Timur, 2025). This platform helps participants access structured price information to guide farm management decisions. Integrating these two components enables participants to learn both cultivation monitoring and market information literacy within a unified empowerment program.

The execution approach positions farmers as active users from initial needs identification to evaluation. Rose et al. (2021) emphasize the importance of tailoring digital agricultural technology to user context and field workflows. Regarding mentoring, Eastwood et al. (2019) demonstrate that mentors play a crucial role in helping farmers comprehend digital information and translate data into relevant farming decisions. Meanwhile, Nurida et al. (2024) highlight that mentoring young farmers requires facilitators to serve as mediators, communicators, and consultants. Therefore, activities are designed through needs analysis, technology integration, module preparation, demonstrations, hands-on practice, discussions, and ongoing mentoring. Modules are prepared for reusability by partners, ensuring that knowledge transfer continues beyond the core program.

Based on the partner's challenges and needs, this community engagement initiative aims to enhance young farmers' capacity to understand and operate smart farming technology, interpret greenhouse monitoring data, and utilize commodity price information for farm management. Specifically, the program is directed at improving participants' knowledge, perceived ease of use, intention to use technology, and ability to operate the system independently through a combination of technology, practice-based training, and mentoring. Beyond building participant capacity, the program fosters early operational shifts in cultivation practices, encouraging the adoption of sensor data for environmental monitoring and decision-making in irrigation and crop care, alongside digital price information to support market tracking. Evaluations of productivity, resource efficiency, and economic impact are designated as follow-up agendas, as these indicators require longer observation periods.

2. METHODS

Partners, Participants, and Event Schedule

The program was conducted from March to November 2025 at the Self-Help Agricultural and Rural Training Center (P4S) Bumiaji Sejahtera, Bumiaji Village, Batu City, East Java. The target partners were a group of young farmers active within P4S and the local young farming community. A total of 15 young farmers participated in the program evaluation, representing diverse business backgrounds including horticulture, hydroponics, livestock farming, and processed agricultural products. In this initiative, the young farmer group served as the primary beneficiaries, while P4S functioned as the event location and program execution facilitator. This diversity in participant backgrounds was taken into account during curriculum design to ensure applicability across various commodities.

P4S provided the venue, greenhouse facility, and logistical coordination support, whereas the young farmer group offered insights into field requirements and participated actively from needs identification through user testing, hands-on practice, monitoring, and feedback provision. The academic team developed the appropriate technology, software applications, modules, training materials, mentoring framework, and evaluation tools. The young farmer group engaged continuously from initial needs assessment through usability testing, practice, monitoring, and feedback sessions. This division of roles ensured that technological interventions aligned with user needs, extended beyond hardware installation, and fostered operational competence and system management among partners after project completion.

Implementation Stage

The implementation method employed a participatory approach that actively involved the young farmer group from needs identification through evaluation. The program was executed across five stages: needs analysis, technology integration, module preparation, training and practice, as well as monitoring

and evaluation. Each stage connected the community service team's activities, partner engagement, and generated outputs, ensuring the technology adoption process could be systematically tracked. Details of these implementation stages are presented in Table 1.

Table 1. Implementation stages, partner involvement, and activity outputs

Stage	Activity	Partner Involvement	Output
Need analysis	Greenhouse observation, interviews, FGDs, baseline skills mapping, and technology and curriculum needs identification	Explaining cultivation practices, challenges, commodity priorities, and information needs	Technology requirements map and training curriculum needs
Technology integration	Installation and testing of IoT devices, monitoring application integration, price platform development, and functional testing	Providing test locations and giving feedback on system features and interfaces	Demonstrable smart farming system and price information platform
Module preparation	Drafting materials on IoT, monitoring and automation, crop care, and commodity price information	Assessing readability of materials and relevance of field examples	Three reusable training modules for P4S
Training and practice	Interactive lectures, system demonstrations, hands-on practice with hardware and apps, discussions, and troubleshooting	Participating in practice, testing features, and sharing experiences and technical issues	Improvement in knowledge and initial operational skills
Monitoring and evaluation	Field visits, pre-and-post questionnaires, knowledge tests, practical assessments, and follow-up planning	Operating the system, completing evaluation instruments, and providing inputs for improvement	Capacity-building data and continuous mentoring agenda

Technology Components and Training Materials

The smart farming appropriate technology consists of environmental sensors, an IoT box, a database, a dashboard, care recommendations, and irrigation control. Parameters available in the system design include air temperature and humidity, soil moisture and temperature, pH, electrical conductivity, N, P, and K elements, as well as light intensity. Sensor data are transmitted to the database and displayed via web or mobile applications as real-time values, historical logs, recommendations, fertilization schedules, and crop batch management. The system is designed as a monitoring and learning support tool in the greenhouse, leaving agronomical decisions to the farmers and mentors.

The price information platform was developed using a three-tier architecture. Commodity price data are periodically retrieved from East Java's SISKAPERBAPO (Dinas Perindustrian dan Perdagangan Provinsi Jawa Timur, 2025) through Python and BeautifulSoup web scraping, then validated and stored using a MongoDB database management system. The backend utilizes Node.js and Express with REST API, while the user interface employs React.js and Chart.js. Users can select specific commodities, markets, and timeframes to view historical data and trends. ARIMA, Exponential Smoothing, and Long Short-Term Memory were evaluated as potential forecasting models. The evaluation in this program focuses on participant utilization of the platform, whereas performance comparison of models based on MAE, RMSE, and MAPE requires further validation.

The training materials were structured into three modules: fundamentals of IoT; monitoring, automation, recommendations, and crop care management; and agricultural commodity price forecasting. The delivery of these materials was grouped into four primary domains: an introduction

to smart farming and sustainable cultivation practices; the utilization of price information and digital marketing strategies; sensor introduction and data interpretation; and the operation of monitoring applications, recommendations, irrigation, fertilization, and general troubleshooting. The learning methodology combined concise explanations, demonstrations, hands-on practice, group discussions, and continuous mentoring.

Evaluation of Program Success

Evaluation was conducted descriptively involving 15 participants using pre- and post-activity questionnaires, pre-test and post-test knowledge assessments, practical performance evaluations, and field monitoring of system usage. Program success indicators encompassed not only changes in participant capacity but also early operational shifts in cultivation practices following the appropriate technology intervention. Capacity indicators included knowledge, system ease of understanding, technology usage intention, and independent system operation skills. Meanwhile, changes in cultivation practices were observed through the adoption of sensor data for environmental monitoring, irrigation, and crop care, as well as the utilization of digital price information for market tracking. Knowledge scores were calculated on a 0–100 scale. Quantitative data were analyzed using participant counts, percentages, means, percentage point differences, and relative test score gains, whereas field monitoring results were analyzed descriptively.

Specific items regarding perceived ease of use and usage intention were available only in the final questionnaire. Therefore, baseline values for these two indicators were established using a baseline proxy, where participants were categorized positively if they responded “sometimes” or “often” to at least one item on technology usage frequency or price information access. The use of this baseline proxy is explicitly stated, as initial measurement indicators were not identical to the post-assessment items. Evaluation results serve to describe changes in participant capacity and early shifts in data adoption within cultivation processes. Productivity, water and fertilizer efficiency, crop yields, and economic impacts were not used as primary success indicators due to the lack of adequate longitudinal measurement. Consequently, these metrics are designated for follow-up evaluation to quantitatively assess the technology’s effectiveness on the partner’s agricultural performance.

3. RESULTS AND DISCUSSION

Results

Partner needs and direction of intervention

Observations revealed that the activity site possessed a supportive greenhouse facility and learning environment, alongside a group of young farmers receptive to technology adoption. However, participants’ experience in operating sensors and applications remained uneven. While some participants were accustomed to using smartphones for communication and information retrieval, they had not yet linked sensor data to irrigation, fertilization, and crop care practices. These baseline conditions formed the foundation for designing training materials ranging from hardware orientation and parameter reading to practical system operation.

Interviews and focus group discussions identified four primary requirements: practical cultivation information, access to market prices and trends, technical skills in device operation and data interpretation, and post-training support. The mapping results informed the intervention strategy, which comprised a smart farming system, a price information platform, training modules, and practical

mentoring. Consequently, the technology implementation directly addressed the needs identified within the partner group.

Implementation of Appropriate Technology (TTG), modules, and price information platforms

The smart farming system was installed and configured as a demonstration and practice facility in the greenhouse. The implementation phase included sensor connection testing, data transmission checks, dashboard interface adjustments, and application usability testing around the field. Participants could view environmental data on their smartphones and compare it with directly observed crop conditions. Documentation of device configuration and smartphone data monitoring is presented in Figure 1.



Figure 1. Smart farming hardware and application implementation at the partner site:
(a) IoT device configuration in the greenhouse; (b) Data monitoring via smartphone

During practical sessions, participants read parameter values displayed on the application and compared them with actual soil, crop, and environmental conditions in the greenhouse. This hands-on activity provided direct experience in using sensor data as an initial basis for monitoring and crop care, rather than treating them merely as numbers on a dashboard.

The three compiled modules served as a bridge between live demonstrations and post-training adoption. The IoT fundamentals module explains components, connectivity, and data flows. The monitoring and automation module covers parameter reading, recommendation usage, schedule management, and basic troubleshooting. The commodity price module details data sources, chart interpretation, and forecasting limitations. Materials were structured incrementally to allow reuse in subsequent mentoring activities. Training materials and IoT modules can be accessed at https://shorturl.at/nIYYp.



Figure 2. Smart farming system and price information platform interfaces:
(a) Environmental conditions dashboard and recommendations; (b) Commodity price trend visualization

The price information platform complemented the cultivation dashboard by adding a market perspective. The platform displays price history and trends by commodity and market. Forecast results are provided as supporting information rather than absolute price guarantees. This distinction is critical because market prices are influenced by broader factors beyond historical patterns, including supply, demand, seasonality, weather, and policy. In practical sessions, participants practiced selecting commodities and markets, reading historical charts, and observing price fluctuations across different periods. Figure 2 shows the environmental monitoring dashboard and price trend interface introduced to participants.

During the usability testing phase, the integration of sensors, databases, applications, and visual interfaces successfully displayed environmental conditions and market price information through two complementary functions. The monitoring system assisted participants in interpreting cultivation conditions, while the price platform supported market information literacy. Results at this stage demonstrate that the implemented appropriate technology yields outputs suitable for learning and practical application by the partner group.

Implementation of practice-based training

Training activities were conducted from September to October 2025, scheduled to align with the routines of the farming group and the implementation team. Materials were delivered incrementally, covering smart farming concepts, application examples, sensor usage, monitoring applications, automation, and price information utilization. Each explanation was followed by demonstrations or hands-on practice, allowing participants to log in, view charts, interpret recommendations, select commodities, and observe price trends. Discussions served to connect system features with participants' existing cultivation and farm management practices. The execution of practice-based training with young farmers at P4S Bumiaji Sejahtera is shown in Figure 3.



Figure 3. Training session with young farmers from P4S Bumiaji Sejahtera

The training sessions also yielded feedback for future development. Participants expressed a need for more precise fertilizer mixing support and technological assistance for early pest or disease risk detection. These suggestions are not fully addressed in the current system version or training modules. This highlights that the training served not only to deliver technology but also as a collaborative space to uncover evolving user requirements.

Achievement of program success indicators

Program achievements were measured using indicators provided in the evaluation instruments. The summary in Table 2 illustrates changes in system ease of understanding, intention to adopt technology

within a maximum timeframe of one month, and the capacity to operate the system independently. The pre-intervention values for ease of understanding and usage intention represent baseline proxies as elaborated in the Methods section; thus, comparisons serve as an indication of initial shifts.

Table 2. Comparison in participant capacity indicators post-activity

Indicator	Pre-Activity (n)	Pre-Activity (%)	Post-Activity (n)	Post-Activity (%)	Gap
Ease of system understanding*	4	26.7	14	93.3	+66.7 percentage points
Intention to adopt within ≤ 1 month*	4	26.7	12	80.0	+53.3 percentage points
Capable of independent operation	1	6.7	11	73.3	+66.6 percentage points

*Baseline values were derived using proxies of technology usage frequency or price information access, as specific items were available only in the post-activity questionnaire.

Following the activity, 14 out of 15 participants (93.3 percent) reported that the system was easy or very easy to understand. Intention to adopt the system within a maximum timeframe of one month reached 80.0 percent. These results indicate strong initial acceptance of the appropriate technology, although usage intention cannot yet be treated as evidence of long-term actual adoption.

A total of 11 out of 15 participants (73.3 percent) were able to operate the system independently after the training. This indicator demonstrates the early operational effectiveness of the program, as the majority of participants successfully transitioned from passive demonstration recipients to active early users. Four participants still required assistance, underscoring the ongoing need for concise user guides, step-by-step instructional videos, and troubleshooting support.

Knowledge gain was evidenced by test scores. The mean pre-test score of 58.0 increased to 74.0 on the post-test, representing an average increase of 16 points or a 27.6 percent relative improvement over baseline values. A summary is presented in Table 3. This increase indicates that improvements occurred not only in subjective perceptions but also in objective content mastery. Within the project framework, knowledge gains helped participants comprehend system parameters, while practical exercises facilitated the translation of understanding into practical skills.

Table 3. Summary of pre-test and post-test results

Matrix	Value
Mean pre-test score	58.0
Mean post-test score	74.0
Mean score gain	16.0 point
Relative gain from pre-test	27.6%

Initial changes in the cultivation process and information utilization

During field monitoring, participants began utilizing air temperature, soil moisture, and light intensity data to inform decision-making regarding irrigation timing and crop maintenance for strawberries, melons, kabocha pumpkins, and kale. Several participants noted that the system simplified environmental monitoring and had the potential to enhance labor, water, and fertilizer efficiency. However, these findings represent perceived user benefits and are not yet supported by quantitative

measurements of resource consumption. Consequently, the outcomes at this stage primarily demonstrate initial participant capacity building and system usability, whereas long-term impacts on crop yield, resource efficiency, and economic performance require further evaluation.

The evaluation was conducted with 15 participants without a control group, and two indicators utilized baseline proxies due to non-identical pre- and post-intervention questionnaire items. Therefore, the quantitative achievements at this stage serve to illustrate changes in participant capacity and initial operational effectiveness rather than establishing causal relationships or enabling generalization to all farmers in Batu City. Regarding the price information platform, the program evaluation focused on its utility as an informational tool for market trend literacy, while the predictive performance of the algorithms warrants further validation using appropriate metrics.

Program sustainability was reinforced through the formal handover of hardware, applications, and training modules to the partner, alongside the active involvement of local administrators and supporting partners. To ensure the continued functionality of the appropriate technology post-project, key operational measures are required, including designated local caretakers, regular sensor inspection schedules, calibration procedures, data backups, and dedicated communication channels for technical support. The provided infrastructure and educational modules can also be repurposed for subsequent training initiatives.

Discussion

The increase in knowledge scores from 58.0 to 74.0, high perceived ease of use (93.3 percent), and independent operational capability (73.3 percent) demonstrate that combining demonstrations, hands-on practice, training modules, and mentoring effectively enhances the initial capacity of young farmers. These findings align with Darto et al. (2021), who framed device installation and IoT training as an integrated mentoring pipeline, as well as Herdiana et al. (2025), who reported improvements in farmer understanding through practice-based smart irrigation training. Similar outcomes were documented by Setyawan et al. (2023), showing that training coupled with direct IoT smart farming implementation in farmer groups enhances both technical knowledge and practical skills. Furthermore, these results accord with Arnita et al. (2025), who observed increased technological comprehension following IoT-based smart farming adoption through outreach, training, and ongoing guidance. Other capacity-building initiatives for IoT-based farmer groups similarly emphasize training, technology implementation, mentoring, evaluation, and sustainability planning as a unified series of activities (Ciptadi et al., 2025).

From the perspective of appropriate technology implementation, achieving independent operational capability serves as a critical indicator, given that community service success relies not only on functional hardware but also on the partner group's ability to operate the technology autonomously once direct support ends. In a smart greenhouse empowerment initiative with another farming group, dashboard operation competency was similarly used as an outcome metric, with connectivity constraints and digital literacy remaining key factors requiring continued guidance (Hernawati et al., 2025). This corroborates the project's strategy to provide reusable training modules and embed mentoring as a core component of long-term sustainability.

Integrating cultivation data with a price information platform expands the program's scope from basic environmental monitoring to data literacy enhancement. Information system-based agricultural digitalization programs in farmer groups have likewise shown that structured data provision enables better management of production and farm operational records (Fardani et al., 2024). In this project, the price platform was not utilized to claim immediate income gains; rather, it functioned as an educational medium to familiarize participants with reading historical price trends to support decision-making processes.

Other community service initiatives demonstrate that sensor-based smart irrigation systems can be directed toward enhancing water use efficiency, rendering this indicator highly relevant for longitudinal evaluation in future program iterations (Kurniasih et al., 2025). In contrast to programs that have already quantified crop yield increases and cost efficiencies post-implementation of smart irrigation (Waluyo et al., 2025), the present project is situated at the stage of capacity building and initial technology adoption. This distinction primarily stems from the current absence of a longitudinal baseline for crop yields, water consumption, fertilizer usage, and operational costs. Consequently, measuring productivity and resource efficiency impacts represents an essential next phase to evaluate the benefits of this appropriate technology not only through user competence, but also through quantifiable shifts in farm operational performance.

4. CONCLUSION AND RECOMMENDATIONS

The community service program successfully integrated a smart farming system, training modules, and a commodity price information platform into a unified appropriate technology package for empowering 15 young farmers. Following the intervention, 93.3 percent of participants evaluated the system as easy or very easy to understand, 80.0 percent expressed intention to adopt it within one month, and 73.3 percent demonstrated the ability to operate the system independently. The mean knowledge score increased from 58.0 to 74.0. These achievements reflect enhanced theoretical understanding, adoption readiness, and early operational effectiveness of the technology among the partner group. Furthermore, the program created an educational framework connecting cultivation monitoring with market intelligence. However, the findings cannot yet confirm improvements in crop productivity, resource efficiency, or farmer income, as these indicators lack baseline data and longitudinal evaluation. Future evaluations should systematically measure water and fertilizer usage, treatment accuracy, crop yields, operational expenditures, and the performance of price prediction algorithms using standard metrics.

For subsequent project iterations, post-training evaluation should extend over a one- to three-month period to track system usage frequency, feature utilization, operational challenges, and ongoing support requirements. System enhancements should target more precise fertilizer mixing, early pest and disease detection, and the integration of local weather and production data. Evaluation of the price prediction functionality needs to incorporate MAE, RMSE, and MAPE metrics across various commodities, timeframes, and markets, benchmarked against appropriate baseline models. To establish a comprehensive assessment of program impact, future research must incorporate long-term observations encompassing water and fertilizer efficiency, treatment precision, crop yields, and farm economic indicators over an adequate observation timeline.

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