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Empowering Islamic Science Literacy Through IoT Hydroponics Based Project Learning

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ABSTRACT

This community service program was implemented at MTs Muhammadiyah 1 Taman, Sidoarjo, to transform simple hydroponic practices into a data-based science learning medium that integrates technology, Islamic ecological values, and green edupreneurship. The partner school had introduced hydroponics, but the activity was still manual, had not used pH, TDS, and water temperature data as learning evidence, and had not been supported by modules, worksheets, standard operating procedures, or a sustainability team. This program aimed to strengthen students' science literacy, Islamic character, life skills, and entrepreneurial awareness through Technology Project-Based Learning (TPjBL) supported by Internet of Things (IoT)-based hydroponics. The program used a participatory-collaborative method involving needs assessment, TPjBL and Islamic entrepreneurship training, IoT hydroponic implementation, learning assistance and evaluation, and sustainability strengthening. Participants consisted of 22 people, including science teachers, seventh-grade students, and life-skills program managers. Data were collected through pre-test and post-test, observation sheets, project rubrics, pH/TDS/water temperature logs, product documentation, and teacher-student reflections. The results showed a 70% increase in students' science literacy achievement, improved engagement in observing, measuring, recording, analyzing, and communicating plant growth data, and the formation of an initial school-based green edupreneurship initiative. The program produced an IoT hydroponic TPjBL model, learning modules, sensor data logs, SOPs, and a follow-up management plan. This activity demonstrates that hydroponics can function as a contextual living laboratory for sustainable science learning in madrasah environments.

Keywords: IoT hydroponics, science literacy, Islamic values, TPjBL, green edupreneurship

1. Introduction

Science learning at the junior secondary level should provide students with meaningful opportunities to observe phenomena, ask questions, measure variables, analyze evidence, communicate findings, and draw conclusions from real-life contexts. However, science teaching in many schools still tends to focus on the delivery of concepts rather than the development of scientific practices, inquiry skills, and contextual problem-solving. As a result, students often understand scientific concepts in a theoretical manner but are less able to connect them with environmental issues, technological applications, and practical problems in their daily lives. This condition may weaken students' science literacy, particularly their ability to use scientific knowledge as evidence for decision-making and problem-solving. Therefore, authentic, technology-supported, and socially meaningful learning is needed to increase students' cognitive engagement, scientific reasoning, and awareness of their role in solving local problems (Farrokhnia et al. 2025); (Fahyuni, Hariastuti, and Taurusta 2023); (Moges et al. 2025)empirical evidence on the relationships between the learning environment and student engagement remains scant in the context of higher education in Ethiopia. This article examined the association between student perception of the learning environment and student engagement (affective, agentic, behavioural, and cognitive engagement. The integration of Islamic ecological values is also a distinctive and important element of this program. In the madrasah context, science learning needs to be connected to values that guide students' behaviortowardnature,technology,andsociety. The values of khalifah fil ardh, amanah, ihsan, cooperation, and honesty can be practiced through caring for plants, maintaining tools, recording data truthfully, using water and nutrients wisely, and improving cultivation practices responsibly. This integration helps students understand that scientific activities are not separated from moral responsibility. Previous studies have shown that integrating Islamic values and science can strengthen both learning meaning andstudent character formation (Fahyuni. et al. 2020)gathering and analyzing what is needed to develop spiritual potential, self-control, personality, intelligence, noble character, by using seamless mobile media to get the required help in his life. Integration with guided inquiry learning the values of Islam and science in the phenomenon of natural at millennial students utilize information technology of learning resources available environment. The concurrent triangulation strategy is done by collecting quantitative and qualitative data concurrently, then comparing the two databases related to the presence or absence of convergence, differences, or combination. Based on this multivariate statistic analysis, there are differences in learning outcomes between millennial students who use seamless mobile media and non-seamless mobile media. Efforts to integrate Islamic values and science are realized learning outcomes that are; 1;M(Baihaqi, Sulistiyana, and Fadholi 2021); (Khamaj and Ali 2024); (Wahid 2024)

MTs Muhammadiyah 1 Taman, Sidoarjo, as the partner madrasah, is located in a semi-urban area with limited green open space. This condition restricts students' access to natural learning environments that can be used for direct observation and practical science activities. Nevertheless, this limitation also provides an opportunity for the school to develop small-scale agricultural learning through hydroponics. The partner school has strong institutional potential because it promotes Islamic value implementation and life-skills education as part of its educational identity. These two strengths are important social capital for developing science learning that does not only emphasize knowledge acquisition but also nurtures responsibility, discipline, environmental awareness, collaboration, and productive skills among students. Initial observations indicated that hydroponic activities had already been introduced at the partner school through simple installations and student planting practices. However, these activities had not yet been optimally developed as a structured science learning ecosystem. Several partner problems were identified (Firoozi and Firoozi 2025); (Olanrewaju 2025)the value added of sustainable construction is not meeting the requirements of stakeholder's value systems. Despite the urgency, there is a lack of comprehensive framework addressing how to manage these elements effectively. This predicament is primarily attributable to the inadequacies in the practices, processes, tools, and strategies employed across all the phases of the sustainable construction projects. This research fills this gap by developing an international framework for sustainable construction management through clustering of its critical success factors (CSFs. First, hydroponic practices were still conducted manually and were mainly based on visual observation, so students were not yet accustomed to reading, recording, and interpreting scientific data such as pH, nutrient concentration or TDS, water temperature, and plant growth indicators. Second, hydroponics had not been systematically integrated into project-based science learning, which limited its potential to develop inquiry, collaboration, and problem-solving skills. Third, teachers did not yet have adequate learning tools, such as modules, student worksheets, sensor data logs, project assessment rubrics, and standard operating procedures to guide hydroponic-based learning. Fourth, the harvest had not yet been developed as an educational product that could support green edupreneurship. These conditions show a clear gap between the partner's potential and the actual use of hydroponics as a living laboratory for science learning.

The urgency of this mentoring program lies in the need to transform hydroponic activities from routine planting practices into a data-based, technology-supported, and value-oriented learning medium. Without systematic assistance, hydroponics may remain a complementary extracurricular activity rather than becoming an integrated learning resource that strengthens students' science literacy and life skills. The partner school also requires guidance to strengthen teacher capacity, prepare learning instruments, establish data-recording habits, develop simple operational standards, and build a sustainable management system. Therefore, mentoring is essential to ensure that the available hydroponic facilities can be used more effectively, not only for cultivation but also for scientific inquiry, character formation, and school-based productive learning. Technology Project-Based Learning (TPjBL) is relevant to address these partner problems because it connects learning projects, technology use, collaboration, and real problem-solving. Through TPjBL, students do not only learn about plant growth theoretically; they are guided to identify problems, design projects, operate simple technological tools, collect data, analyze findings, and present evidence-based solutions. Research on technology-integrated project-based learning shows that learning outcomes become stronger when project design, assessment criteria, and teacher scaffolding are prepared systematically (Rachmawatietal. 2022);(Z. Sunetal. 2025);(de Jong et al. 2024)2023. In hydroponic learning, Internet of Things (IoT) sensors can strengthen this process by providing real-time or periodic data that students can use as evidence for decision-making (Usmany et al. 2024); (Ma et al. 2024)the current implementation of the pipeline requires more than 6.5 hours to process a single MRI scan, making it expensive for large-scale neuroimaging studies. In this paper, we propose a fast deep learning (DL.

In addition to strengthening science literacy and Islamic character, hydroponics also has strong potential to develop green edupreneurship. Students can learn that science and technology are not only used to understand natural phenomena but can also produce useful, healthy, and economically valuable products. This orientationis important because life-skills programs in schools are expected to develop practical competencies, creativity, collaboration, environmental responsibility, and entrepreneurial awareness. Hydroponic products can be used for internal school needs, exhibitions, and simple product simulations, while still being grounded in ethical and Islamic values. Thus, hydroponics can become a strategic medium for integrating science learning, character education, life skills, and sustainable entrepreneurship (Ashraf et al. 2025); (Z. Sun et al. 2025); (Forni et al. 2025). Based on these conditions, this community service program aimed to strengthen students' science literacy, Islamic ecological character, life skills, and green edupreneurship through IoT-based hydroponics using the TPjBL approach. The program was designed to solve partner problems through a gradual and participatory strategy consisting of needs assessment, teacher and student training, implementation of IoT-based hydroponics, learning assistance and evaluation, and sustainability strengthening. The expected benefits of this program include increased student engagement in scientific practices, improved teacher capacity in facilitating project-based science learning, the availability of learning tools and sensor data logs, and the establishment of a school-based hydroponic management plan that can be continued independently after the service activity ends.

2. Method

This community service activity employed a participatory-collaborative approach. This approach positioned the implementation team, school leaders, science teachers, students, and life-skills program managers as active partners who jointly identified problems, formulated solutions, implemented activities, evaluated achievements, and prepared follow-up actions. The approach was selected because the main objective of the program was not merely to introduce IoT-based hydroponic technology, but also to strengthen the partner's capacity to manage hydroponics as a sustainable learning medium, a living laboratory, and an initial green edupreneurship program.The activity was conducted at MTs Muhammadiyah 1 Taman, Sidoarjo, from May to June 2026. The participants consisted of 22 people, including science teachers, seventh-grade students involved in hydroponic activities, and school life-skills program managers (Smith et al. 2025); (Kim et al. 2022). The participants were selected based on their direct involvement in science learning, hydroponic practice, and school program sustainability. The implementation team was responsible for facilitating training, technical assistance, learning tool preparation, evaluation, and follow-up planning. Meanwhile, the partner school provided the activity site, teacher facilitators, student participants, hydroponic facilities, equipment support, and institutional commitment to continue the program after the mentoring process ended. The implementation of the program was organized into five measurable stages: needs assessment, TPjBL training, IoT-based hydroponic implementation, learning assistance and evaluation, and sustainability strengthening. Each stage was designed with clear activities, participants, instruments, outputs, and achievement indicators (Afzal, Khan, and Lee 2024); (X. Sun, Lee, and Lim 2025), as presented in Table 1.

Table 1. Stages and Measurable Indicators of the Community Service Program

Stage	Main Activity	Participants	Instrument/Evidence	Output	Achievement Indicator
Needs Assessment	Observation of existing hydroponic practices, interviews with school leaders and teachers, and identification of learning needs.	Head of madrasah, science teachers, students, and life-skills managers.	Observation sheets, interview notes, documentation, and facility checklist.	Map of partner problems, potentials, and needs.	Partner problems and program priorities were clearly identified.
TPjBL Training	Training on hydroponic concepts, project-based learning flow, sensor data reading, Islamic ecological values, and green edupreneurship.	Teachers and students.	Training materials, attendance list, worksheets, and practice notes.	Teachers and students understood the TPjBL project cycle.	Participants were able to explain project stages, group roles, and basic sensor data use.
IoT-Based Hydroponic Implementation	Installation and practice of hydroponic monitoring using pH, TDS, and water temperature data.	Implementation team, teachers, and students.	Equipment documentation, sensor logs, field notes, and plant growth records.	Hydroponics functioned as a data-based science learning medium.	Students recorded pH, TDS, water temperature, and plant growth data weekly.
Assistance, Evaluation, and Reflection	Mentoring during project implementation, pre-post assessment, observation, project assessment, and reflection.	Teachers and students.	Pre-test and post-test sheets, observation sheets, project rubrics, student reflections, and product documentation.	Evidence of improved science literacy, responsibility, collaboration, and environmental awareness.	Improvement in science literacy scores and visible student engagement in observing, measuring, recording, analyzing, and presenting findings.
Sustainability Strengthening	Preparation of SOPs, task distribution, hydroponic maintenance schedule, and follow-up management plan.	School team and implementation team.	SOP documents, task distribution sheet, monitoring schedule, and follow-up notes.	The program could be continued independently by the school.	A small hydroponic management team and routine monitoring plan were established.

The first stage was socialization and needs assessment. At this stage, the implementation team coordinated with the head of the madrasah and science teachers to explain the objectives, flow, and expected outcomes of the program. The team then observed the existing hydroponic site, identified available facilities, mapped teacher readiness, and discussed students' learning needs. The needs assessment focused on five aspects: the current condition of hydroponic practices, teacher capacity in facilitating project-based learning, student involvement in scientific activities, the availability of learning tools, and the potential development of hydroponic products as part of green edupreneurship.

The second stage was TPjBL and Islamic green edupreneurship training. Teachers and students were introduced to the project cycle, hydroponic principles, sensor-based measurement, data recording techniques, Islamic ecological values, and simple entrepreneurship practices. The training emphasized hands-on activities so that participants could formulate project questions, divide group tasks, read pH, TDS, and water temperature data, prepare simple reports, and connect scientific practices with the values of amanah, ihsan, khalifah fil ardh, cooperation, honesty, and environmental responsibility. This stage was intended to ensure that participants understood hydroponics not only as a cultivation activity, but also as a medium for science learning, character education, and productive life skills.

The third stage was the implementation of IoT-based hydroponics. The implementation team assisted the school in organizing hydroponic installations, introducing pH, TDS, and water temperature monitoring, and preparing sensor data logs. Students worked in groups to conduct sowing, planting, nutrient monitoring, plant care, data recording, and basic interpretation of plant growth conditions. The plants observed in this activity included water spinach, Brazilian spinach, watercress, and pok choy. Monitoring was conducted from the first week of planting until the fourth week of harvesting. The variables recorded included pH, TDS/PPM, water temperature, plant height, number of leaves, root length, survival rate, and follow-up actions based on IoT monitoring results.

The fourth stage was learning assistance, evaluation, and reflection. During this stage, teachers were accompanied in facilitating the TPjBL process and assessing student activities. Students were guided to observe, measure, record, compare, analyze, present, and reflect on their findings. The evaluation instruments included science literacy pre-test and post-test, student activity observation sheets, project rubrics, sensor data logs, activity documentation, product analysis, and teacher-student reflections. The assessment focused on four science literacy indicators: identifying problems and formulating questions, designing simple investigations, interpreting data and drawing conclusions, and communicating findings. In addition, the reflection process was used to identify students' understanding of Islamic ecological values, especially responsibility, honesty in data recording, discipline in plant care, cooperation, and environmental awareness.

Data analysis was carried out descriptively and reflectively. The pre-test and post-test results were compared to identify changes in students' science literacy achievement. Observation sheets, project rubrics, sensorlogs, and product documentation were analyzed to describe students' scientific practices during the project. Teacher and student reflections were reviewed to identify changes in learning engagement, responsibility, cooperation, and understanding of Islamic ecological values.

The use of multiple instruments allowed the implementation team to triangulate the findings, so that program achievements were not interpreted solely from test scores, but also from behavioral evidence, project artifacts, and partner outputs.

The fifth stage was sustainability strengthening. The implementation team and the partner school formulated follow-up actions through the preparation of SOPs for sensor calibration, water and nutrient monitoring, plantmaintenance, harvesting, and student task distribution. A small hydroponic management team was proposed, consisting of teachers and student representatives, to ensure that the program could continue as a living laboratory, a life-skills activity, and an initial school-based green edupreneurship program. The follow-up plan also included weekly monitoring, periodic evaluation, product documentation, and integration of hydroponic activities into science learning and school life-skills programs.

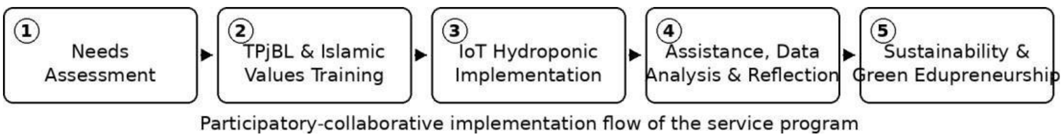

Figure 1. Implementation flow of IoT-based hydroponic TPjBL assistance

3. Results and Discussion

Initial Condition and Partner Problem Mapping

The needs assessment showed that MTs Muhammadiyah 1 Taman had strong potential for developing hydroponic learning. The school already had simple hydroponic facilities and a culture of life-skills education. Students also showed interest in planting and caring for vegetables. However, the activity had not yet functioned optimally as a data-based science learning medium. Students were involved in planting but had limited opportunities to formulate scientific questions, measure variables, interpret data, and communicate evidence-based conclusions. The main problem was the gap between available hydroponic facilities and their use as a structured learning ecosystem. Before the program, hydroponics was mostly understood as a cultivation activity (Ebbes et al. 2026); (Golledge et al. 2025). After the needs assessment, it was repositioned as a living laboratory that integrates science literacy, IoT technology, Islamic ecological values, and green edupreneurship. This repositioning was important because a community service program should provide solutions to partner problems, not merely conduct ceremonial activities. The mapping results are summarized in Table 2.

Table 2. Plant Growth Data in IoT-Based Hydroponic System

Plant	Week	pH	TDS/PPM	Water Temperature (°C)	Plant Height (cm)	Number of Leaves	Root Length (cm)	Survival Rate	IoT Status/Action
Water Spinach	1	6.1	620	26.4	7.2	4	3.5	100%	Sensor worked normally; pump operated 15 minutes
Water Spinach	2	6.0	760	26.8	15.6	8	7.8	100%	Light AB Mix nutrient adjustment was added
Water Spinach	3	5.9	890	27.1	25.4	14	12.6	98%	Daily TDS monitoring; pH remained stable
Water Spinach	4	6.0	940	27.0	34.8	21	17.2	98%	Selective harvesting was carried out; pH was rechecked
Brazilian Spinach	1	6.2	650	26.5	5.8	5	3.2	100%	Sensor worked normally; surrounding maintained
Brazilian Spinach	2	6.1	780	26.7	11.4	9	6.5	100%	Low nutrient; water flow was checked
Brazilian Spinach	3	6.0	910	27.0	18.7	16	10.4	98%	TDS sensor calibration was conducted
Brazilian Spinach	4	6.1	980	26.9	25.3	25	14.8	98%	Gradual leaf harvesting was carried out
Watercress	1	6.4	560	25.8	4.9	6	3.8	100%	Sensor worked normally; water discharge maintained
Watercress	2	6.3	680	26.0	10.6	13	8.1	100%	Moderate nutrient; water temperature was checked
Watercress	3	6.2	760	26.2	16.8	24	12.4	96%	TDS stable; light algae cleaning was conducted
Watercress	4	6.2	820	26.3	23.1	36	16.7	96%	Shoot harvesting; nutrient sanitation was conducted
Pok Choy	1	6.0	720	26.2	4.6	4	3.1	100%	Sensor worked normally; pump operated stably
Pok Choy	2	5.9	900	26.5	9.8	7	6.9	100%	AB Mix nutrient was added; pH was controlled
Pok Choy	3	5.8	1080	26.7	16.5	11	11.5	98%	Low TDS alert appeared once; nutrient solution adjusted
Pok Choy	4	5.9	1220	26.8	23.7	16	15.9	98%	Harvesting conducted; pH, net pot cleanliness checked

Table 3. Harvest Summary Hydroponic

Plant	Harvesting Period	Average Weight	Category	Plant
Water Spinach	Week 4	38 g	Very good	Water Spinach
Brazilian Spinach	Week 4	30 g	Good	Brazilian Spinach
Watercress	Week 4	28 g	Good	Watercress
Pok Choy	Week 4	65 g	Very good	Pok Choy

The mapping stage also clarified the partner's readiness and constraints. The school had strong motivation, teacher support, and student enthusiasm, but still needed simple guidance that could be applied within a regular school schedule. For this reason, the mentoring design did not place the school in a difficult technological position. The technological component was simplified into essential measurements that students could understand: acidity level, nutrient concentration, water temperature, and plant growth observation (Ibrahim et al. 2024). This design choice made the program realistic, because empowerment activities must match the partner's resources, learning culture, and maintenance capacity.

Transformation Toward IoT-Based Hydroponic TPjBL

The implementation of IoT-based hydroponic TPjBL transformed the partner's learning process from manual planting activities into a more systematic learning cycle. Students were guided to begin with real problems, such as limited green space, the need for healthy vegetables, and the importance of efficient water and nutrient use. These problems became the entry point for project planning and group task division. Students then learned to prepare planting media, observe seedlings, maintain hydroponic installations, and record the condition of plants using sensor-based data. The use of pH, TDS, and water temperature data helped students understand that plant growth is influenced by measurable environmental variables. Students were not only asked whether plants grew well, but also encouraged to ask why certain plants grew better, how water quality changed, and what corrective actions could be taken (Jalilpour and Müller-Putz 2025); (Hagenaars et al. 2025); (Sipe et al. 2024). This process strengthened inquiry skills because students practiced observing, measuring, comparing, analyzing, and drawing conclusions. The installation activity is shown in Figure 2 and 3.

Figure 2. IoT hydroponic tower installation as a living laboratory

Figure 3. Seedling activity facilitated by teachers and the community service team

Teacher capacity also improved through the mentoring process. Teachers gained practical experience in designing project questions, facilitating group work, using sensor data logs, applying rubrics, and connecting the project with Islamic values. The availability of modules, worksheets, rubrics, and SOPs made the activity more systematic and easier to continue. This finding supports the view that technology in project-based learning becomes effective when it is integrated with learning scenarios and clear assessment criteria (Ieva et al. 2025). The main output of this stage was the emergence of a complete learning package. The module explained the project flow, the worksheets guided students to identify problems and record data, the rubrics helped teachers assess process and product quality, and the SOP described simple procedures for monitoring, calibration, maintenance, and harvesting. These outputs are important because many school-based innovations fail to continue when they depend only on individual enthusiasm. By preparing written tools, the activity became more institutionalized and easier for teachers to repeat in the next learning cycle.

Strengthening Science Literacy and Islamic Ecological Values

The evaluation showed that students' science literacy achievement increased by 70% from the initial condition. The improvement was visible not only in test results but also in the quality of student activities and project artifacts. Students became more active in asking questions, recording data, discussing plant conditions, and presenting findings. The sensor log encouraged students to use evidence when explaining plant growth rather than relying only on visual impressions.The strongest improvement appeared in students' ability to communicate findings and interpret simple data. Student groups were able to explain that pH, TDS, and water temperature need to be monitored because they influence nutrient absorption and plant health. They also learned that inaccurate data must be rechecked, and that maintenance decisions should be based on observations and measurements. These outcomes are consistent with studies showing that project-based learning can strengthen science literacy and collaborative skills when students are engaged in meaningful artifacts, discussion, and evidence-based reporting (Hindumathi et al. 2023)these photos are pre-processed. To determine whether the signature is fake or not, the characteristics that were extracted are compared, and the difference in error values between them is examined. The key advantages of signature verification systems (SVS; (Husamah et al. 2025).

The integration of Islamic ecological values made the project more meaningful for students. The value of amanah was practiced through responsibility in caring for plants, maintaining equipment, and completing group tasks. Ihsan was practiced through accuracy, discipline, and willingness to improve maintenance procedures when problems occurred. Khalifah fil ardh was strengthened through awareness that humans are responsible for caring for the environment and using technology wisely. Honesty was emphasized through accurate data recording. These values were not presented as separate religious messages, but were embedded in the scientific and practical activities of the project. The program also strengthened the affective dimension of learning. Students were encouraged to understand that data accuracy is part of honesty, tool maintenance is part of amanah, and environmental care is part of the human responsibility as khalifah. This integration helped avoid a separation between science and religious values. Science became a means to understand and care for Allah's creation, while Islamic values became an ethical framework for using technology responsibly. This is a significant contribution for madrasah-based science learning because it provides an applied example of how scientific inquiry and character education can be implemented simultaneously.

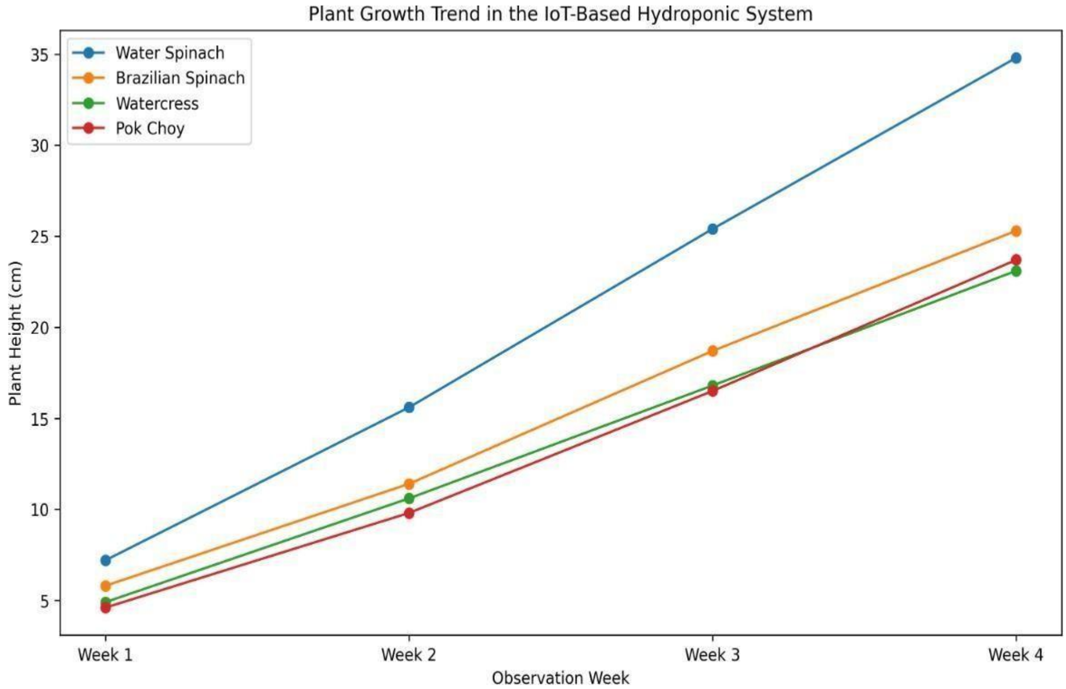

Figure 4 The weekly growth trend of four hydroponic

Figure 4 illustrates the weekly growthtrend of four hydroponic crops cultivated during the program. All plants showed consistent growth from Week 1 to Week 4, indicating that the IoT-based monitoring system supported stable hydroponic management. Water spinach showed the highest growth rate, followed by Brazilian spinach, pok choy, and watercress. These findings demonstrate that the hydroponic system functioned effectively as a data-based living laboratory for science learning.The contribution of this activity lies in the development of an integrated school empowerment model. Hydroponics is not treated merely as a planting activity, IoT is not treated merely as a device demonstration, and Islamic values are not treated as an additional moral message. Instead, the three elements are combined into a single learning ecosystem: students learn science from data, practice Islamic ecological values through responsibility and honesty, and develop green entrepreneurial awareness through real products. This model can be replicated in other madrasahs or schools that have limited green space but want to strengthen contextual science learning and life-skills education.

Green Edupreneurship and Program Sustainability

The hydroponic project also introduced students to green edupreneurship. Harvesting and product presentation activities encouraged students to see hydroponics as an educational product that has environmental and economic value. Students discussed the possibility of using vegetables for internal school needs, exhibitions, and simple product simulations. This activity strengthened the connection between science, life skills, and entrepreneurship (Delgado-Guerrero et al. 2025); (Wang and Huang 2025). The harvest and product presentation are shown in Figure 4.

Figure 4. Harvest presentation and green edupreneurship simulation

Program sustainability was strengthened through the preparation of SOPs, task distribution, sensor data logs, and a follow-up management plan. The school was encouraged to establish a small hydroponic team consisting of teachers and students. The team is responsible for monitoring water quality, scheduling plant maintenance, recording data, preparing harvest activities, and integrating hydroponics into science and life-skills learning. This sustainability strategy is essential because partner empowerment should result in institutional capacity, not only short-term activity outputs. The main obstacles found during implementation were sensor stability, the need for routine calibration, the dependence on internet access, and the need to strengthen student discipline in data recording. These obstacles were addressed by preparing calibration SOPs, simplifying the data log format, assigning group responsibilities, and scheduling periodic monitoring. Overall, the program produced tangible outputs: an IoT-based hydroponic TPjBL model, learning modules, student worksheets, project rubrics, sensor data logs, activity documentation, harvest products, and a sustainability plan (Wang and Huang 2025); (Russell, Wang, and Cain 2024).

Compared with conventional hydroponic training, this program has a stronger educational impact because it provides learning instruments, assessment evidence, and sustainability mechanisms. Compared with technology demonstration programs, this activity has a stronger empowerment orientation because the technology is adapted to the school's capacity and is connected to learning, character, and entrepreneurship outcomes. The program therefore contributes to community service practice by showing that school empowerment can be designed as an integrated pedagogical, technological, spiritual, and productive intervention. Nevertheless, the program still requires continuous mentoring to ensure that the school can independently maintain sensor accuracy and data recording habits. Future activities should provide more structured teacher training in data visualization, develop simple dashboards that can be accessed by students, and prepare a more detailed business plan for hydroponic products. In addition, future evaluation should include more complete quantitative data, such as average pre-test and post-test scores, normalized gain, student attendance, and product sales simulation, so that program impact can be reported more rigorously (Shepherd, Wilson, and Gaudette 2026); (Chan et al. 2025).

4. Conclusion

The community service program at MTs Muhammadiyah 1 Taman shows that simple hydroponic practices can be transformed into a contextual and sustainable science learning medium through IoT-based Technology Project-Based Learning. The partner's main problems, namely manual hydroponic practice, limited data-based measurement, lack of learning tools, and underdeveloped hydroponic entrepreneurship, were addressed through needs assessment, training, implementation assistance, evaluation, and sustainability strengthening. The program increased students' science literacy achievement by 70% and strengthened their engagement in observing, measuring, recording, analyzing, and communicating plant growth data. The integration of Islamic ecological values strengthened students' responsibility, honesty, discipline, cooperation, and environmental awareness. The program also produced practical outputs, including learning modules, student worksheets, project rubrics, sensor data logs, SOPs, harvest products, and a follow-up management plan. The impact of the program was reflected in the increased capacity of teachers and students to use hydroponics as a living laboratory and in the emergence of an initial school-based green edupreneurship initiative. Program sustainability requires routine sensor calibration, consistent data recording, teacher supervision, and integration into science and life-skills learning. This model can be replicated in other madrasahs or schools that seek to integrate science, technology, Islamic values, and sustainable entrepreneurship in limited land contexts.

5. Allowance

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AI Disclosure Statement

The authors acknowledge the use of artificial intelligence (AI) tools, specifically ChatGPT, to assist with language refinement, paraphrasing, and improving manuscript clarity. The use of AI was limited to editorial support and did not involve the generation of core research ideas, data analysis, original findings. All content has been carefully reviewed, revised, and validated by the authors to ensure its accuracy, originality, and academic integrity.

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