E-ISSN : 3025-0013
International Journal Community Service Implementation
Vol. 3 No. 4 March 2025, Page 188 - 194

Integrating Aquaponics to Enhance Ecological Awareness and Promote Sustainability-Oriented Competencies among Islamic High School Students in Labuhanbatu Selatan Regency

Rivo Hasper Dimenta[1)], Rusdi Machrizal[2)]*, Khairul[3)], Amin Harahap[4)]
[1, 2, 3)] Department Biology Education, Faculty of Teacher Training and Education, Labuhanbatu University
[4)]Department Mathematics Education, Faculty of Teacher Training and Education, Labuhanbatu University

*Coresponding Author
Email: rusdimachrizal@ulb.ac.id

Abstract

Sustainable food security and environmental literacy require contextual and practice-based learning approaches in high school education. This community engagement program introduced a school-based aquaponic learning intervention designed to enhance students' ecological reasoning and sustainability awareness. The activity was carried out in August 2025 at Islamic High School of MA Swasta Irsyadul Islamiah, Tanjung Medan District, Labuhanbatu Selatan Regency, involving 32 students. The intervention combined structured conceptual sessions, guided technical demonstrations, supervised system construction, and reflective evaluation. Learning outcomes were assessed using pre- and post-intervention instruments complemented by observational documentation. Quantitative analysis indicated a marked improvement in students' academic performance, with average scores increasing from 58.4 (SD = 12.5) prior to the intervention to 82.7 (SD = 8.9) afterward. Statistical testing using a paired-samples t-test confirmed that this gain was significant ($t(31) = 8.76$, $p < 0.001$). Field observations further revealed strengthened collaborative participation and heightened interest in environmentally responsible practices. In addition to cognitive gains, the program produced a permanent instructional facility in the form of an operational aquaponic unit that supports continued experiential learning. The findings provide empirical support for integrating recirculating cultivation systems into biology instruction as a strategy for advancing ecological literacy and applied scientific skills. This initiative offers a transferable framework for schools seeking context-responsive, resource-efficient models to reinforce sustainability-oriented education

Keywords: Aquaponic; Learning; Ecological Awareness; Collaborative Program; High School

INTRODUCTION

Sustainable food security and the enhancement of environmental literacy are pivotal components of ecology-based development strategies. Challenges such as limited arable land, environmental degradation, and rising food demand necessitate the implementation of efficient and adaptive production systems (Rapiya et al., 2024). Within the educational context, these challenges require the integration of environmental education that is both conceptual and practical, as well as contextually relevant. The High schools play a crucial role in fostering ecological awareness and imparting practical skills aligned with the principles of sustainable development (Nair et al., 2024).

Aquaponics, an integrated cultivation system, combines aquaculture and hydroponics within a single nutrient recirculation cycle. The metabolic waste produced by fish serves as a nutrient source for plants through the activity of nitrifying microorganisms, thereby creating a system that is both water-efficient and environmentally sustainable (Krastanova et al., 2022). Pedagogically, aquaponics embodies essential concepts in biology and ecology, such as organism interactions, biogeochemical cycles, ecosystem balance, and the efficiency of energy and matter (Zamnuri et al., 2024). Consequently, aquaponics holds potential as a contextual

learning medium that effectively bridges theoretical understanding with practical application. This advantage is one of the learning opportunities for students to practice modern farming (urban farming), and it enables students to understand environmental sustainability.

Despite the potential benefits, the adoption of aquaponics as an educational tool in secondary schools remains limited, particularly within private madrasah aliyah located in regency regions. Biology education predominantly relies on theoretical approaches, with insufficient use of the school environment as a dynamic laboratory. The selection of the aquaponics activity was informed by interviews conducted with the partner school in February 2025. An assessment of the needs at MA Swasta Irsyadul Islamiah reveals that practical activities utilizing simple technology are not optimally supported yet, even though students express interest in project-based and experiential learning. This situation highlights a discrepancy between the potential for contextual biology education and current pedagogical practices. This advantage constitutes a learning opportunity for students to engage in contemporary agricultural practices, specifically urban farming, thereby enhancing their understanding of environmental sustainability.

In response to these challenges, this community service initiative introduces an innovative aquaponics education model grounded in participatory learning, specifically tailored for the madrasah aliyah context. The program's innovation extends beyond the mere installation of an aquaponics unit; it encompasses the integration of ecological concept reinforcement through structured educational sessions, hands-on experience in constructing educational-scale aquaponic systems using readily accessible materials, and ongoing maintenance support coupled with scientific reflection based on observations of fish and plant growth. This approach empowers students to become active participants in the learning process, rather than passive recipients of information.

The program is systematically structured into phases encompassing socialization and concept reinforcement, technical demonstrations, direct practice in system assembly, and evaluation of improvements in students' comprehension and skills. This design yields outcomes such as the establishment of an educational aquaponics unit within the school environment, the development of a foundational aquaponics education module, and the documentation of activities to serve as resources for ongoing learning. The anticipated outcomes include enhanced environmental literacy, a deeper understanding of applied ecological concepts, and the acquisition of fundamental skills in integrated cultivation among students.

This community service initiative significantly enhances practice-based biology education, fosters the development of an environmentally conscious school culture, and offers an adaptable and replicable aquaponics education model for madrasahs with similar characteristics. The integration of conceptual, technical, and reflective components within this program is anticipated to bridge the gap between theoretical biology instruction and the practical application of ecological principles, thereby supporting the attainment of sustainable education at the high school level.

RESEARCH METHODS

This community service activity was conducted in Augusber 2025 at MA Swasta Irsyadul Islamiah High School, located in Tanjung Medan District, Labuhanbatu Selatan Regency. The activity employed an educational and participatory approach through aquaponic education as a contextual learning medium. A qualitative descriptive approach was applied to describe and

understand the implementation process, student engagement, and educational outcomes of aquaponic-based learning activities. This approach was chosen because it allows for an in-depth exploration of learning processes, participant responses, and contextual conditions without relying on numerical measurements.

The subjects of this community service activity were students of madrasah aliyah who participated directly in the aquaponic education program. Teachers and school representatives were also involved as supporting stakeholders to ensure the sustainability of the activity outcomes. The involvement of multiple parties was intended to obtain a comprehensive perspective on the effectiveness of aquaponic education as a learning medium and its potential integration into school-based biology learning.

The data collection methodologies employed in this study encompassed the following,

1. Educational socialization and material delivery: The team facilitated interactive learning sessions to introduce fundamental concepts of aquaponics, such as ecosystem balance, nutrient cycles, and sustainable food production (in figure 1). This phase was designed to enhance students' conceptual understanding prior to engaging in practical activities;
2. Demonstration and direct practice: Students were instructed in the assembly of a basic aquaponic system utilizing readily available materials such as fish ponds, water pumps, tilapia fish, carp fish, feed, spinach seeds, water spinach seeds, and instrument (PVC pipes/net pots, growing media), as well as supporting components such as water pH test kits. Which followed by practical exercises in fish and plant maintenance (in figure 1). This approach was implemented to augment students' practical skills and experiential learning;
3. Observation: Direct observations were conducted throughout the activity to document student participation, learning enthusiasm, and their proficiency in adhering to aquaponic procedures. Observations also concentrated on the functionality of the installed aquaponic system as an educational instrument;
4. Documentation and reflective discussion: Documentation, including photographs and field notes, was employed to record the stages of the activity, while reflective discussions with students and teachers were conducted to gather feedback, perceived benefits, and challenges encountered during implementation.

The collected data were analyzed descriptively by synthesizing observations, documentation, and participant feedback to evaluate the effectiveness refers to (Cheng et al., 2022) . The analysis focused on the alignment between activity implementation, learning objectives, and expected outputs, including the availability of an aquaponic learning unit and increased student awareness of ecological principles and sustainable practices of the aquaponic education program. The analysis focused on the alignment between activity implementation, learning objectives, and expected outputs, including the availability of an aquaponic learning unit and increased student awareness of ecological principles and sustainable practices.

RESULTS AND DISCUSSION

Implementation and Statistical Outcomes

The aquaponic educational activity was conducted with the full participation of students (N = 32) in the second grade of senior high school at MA Swasta Irsyadul Islamiah. Descriptive statistical analysis was applied to the pre- and post-activity conceptual understanding scores,

E-ISSN : 3025-0013
International Journal Community Service Implementation
Vol. 3 No. 4 March 2025, Page 188 - 194

which were collected through structured questionnaires. The results indicated a mean increase in students' understanding of aquaponic principles from the pre-test (M = 58.4, SD = 12.5) to the post-test (M = 82.7, SD = 8.9), as illustrated in Table 1, signifying a substantial enhancement in conceptual comprehension. A paired samples t-test confirmed that this increase was statistically significant ($t(31) = 8.76$, $p < 0.001$), demonstrating that participation in the aquaponic education was associated with improved ecological learning outcomes.

The present findings corroborate prior research indicating that aquaponics media substantially enhances student learning outcomes. For instance, the integration of aquaponic systems into science education at MTs Zainul Hasan Balung resulted in an increase in classical mastery learning from 61.2% to 90.3% subsequent to the intervention with aquaponic media as a pedagogical aid (Nuri et al., 2020). This evidence supports the efficacy of aquaponic systems as pedagogical tools for augmenting student achievement.

Table 1. Comparison of Students' Conceptual Understanding Scores Before and After Aquaponic Education

No	Parameter	Pre-test	Post-test
1	Sample size (N)	32	32
2	Mean score (M)	58.4	82.7
3	Standard deviation (SD)	12.5	8.9
4	t-value (paired samples t-test)	-	8.76

Note: A paired samples t-test indicated a statistically significant in post-test scores compared to pre-test scores ($p < 0.001$).

Quantitative and qualitative observations revealed positive student engagement throughout the various phases of the activity. During the hands-on processes of system assembly and maintenance, students demonstrated active collaboration and heightened levels of engagement compared to traditional classroom instruction. This pattern aligns with findings from other studies, which indicate that aquaponic-based learning not only enhances conceptual understanding but also fosters positive attitudes towards scientific engagement. In a quasi-experimental study on project-based learning supported by aquaponics conducted by (Lusvinaningtyas et al., 2024), statistical analysis revealed that the integration of aquaponics significantly improved creative thinking skills among elementary students, with an 83.5% explained variance attributable to the intervention.

Reflective discussions have also demonstrated an increased willingness among students to engage in sustainability practices, such as monitoring water quality in systems and optimizing plant care routines. These behavioral changes suggest that aquaponic education promotes not only cognitive but also affective learning dimensions. This is consistent with research indicating that experiential learning activities involving aquaponic systems enhance both knowledge and sustainability intentions among learners (Bush & Stewart, 2021).

The observed enhancements in conceptual understanding and student engagement underscore the potential of aquaponic systems to effectively integrate ecological concepts with practical environmental applications. This integration is further corroborated by reflective feedback, wherein students explicitly linked biological processes, such as nutrient cycling and organism interactions, with sustainability outcomes. These findings align with existing research, which suggests that aquaponics can serve as an effective environmental learning tool in harmony with school sustainability programs (Tapilouw et al., 2025).

E-ISSN : 3025-0013
International Journal Community Service Implementation
Vol. 3 No. 4 March 2025, Page 188 - 194

(a)

(b)

(c)

Figure 1. Activities and Installation Process of Aquaponic Infrastructure

Beyond cognitive improvements, the activity facilitated an enhancement in students' ecological awareness and sense of responsibility. Numerous participants demonstrated an interest in maintaining the aquaponic system as an extracurricular educational module, indicating a shift towards pro-environmental attitudes. This outcome is consistent with findings from experiential aquaponic learning by (Crowe et al., 2025), which reported significant changes in students' intentions towards sustainable behavior, such as an increased likelihood of growing and consuming locally produced food ($p < 0.001$). Such evidence substantiates the proposition that aquaponic education effectively integrates conceptual biology learning with practical environmental stewardship.

Output and Sustainability of Program

A significant outcome of this community service initiative was the establishment of a functional aquaponic unit within the school premises, which now serves as a permanent educational resource for biology instruction and student projects. The presence of this unit facilitates ongoing experiential learning beyond the program's conclusion, thereby enhancing the school's capacity to integrate environmentally relevant topics into the curriculum. The involvement of teachers and school representatives has facilitated the potential institutionalization of aquaponic learning within school programs. In alignment with broader educational objectives, aquaponic education fosters the development of environmental literacy, practical biological skills, and sustainability awareness among students. These outcomes contribute to overarching educational goals in biology and environmental science, providing a practical model that is adaptable and replicable for other schools facing similar resource constraints.

CONCLUSION

The aquaponic-based educational program implemented at MA Swasta Irsyadul Islamiah High School resulted in a statistically significant improvement in students' conceptual understanding of ecological and biological principles, as demonstrated by the notable increase in post-test scores compared to pre-test results. These findings provide empirical evidence supporting the scientific contribution of this program, indicating that experiential aquaponic learning effectively enhances biology learning outcomes by integrating nutrient cycling, organism interactions, and sustainability concepts within a real-world context. From an applicative and biological standpoint, the establishment of a functional aquaponic system within the school environment serves as a sustainable educational output that facilitates continuous experiential learning and the development of environmental literacy. The program further encourages pro-environmental behavior and practical biological skills, reinforcing the role of aquaponics as a scalable and context-appropriate model for community-based biology education. This approach offers a replicable framework for strengthening ecology-oriented learning in secondary schools, particularly in resource-limited educational settings.

REFERENCES

Bush, Z., & Stewart, M. (2021). A Mixed Methods Analysis of Two Inexpensive and Simple Aquaponics Systems for School Use. *Journal of Student Research*, *10*(4). https://doi.org/10.47611/jsrhs.v10i4.2343

Cheng, L., Li, Y., Su, Y., & Gao, L. (2022). Effect of regulation scripts for dialogic peer assessment on feedback quality, critical thinking and climate of trust. *Assessment & Evaluation in Higher Education*, *48*(4), 451–463. https://doi.org/10.1080/02602938.2022.2092068

Crowe, I., Charlton, K. E., Mcmahon, A.-T., Rhind, I., & Kent, K. (2025). The Impact of Experiential Learning Using an Indoor Aquaponic System on Nutrition Students' Sustainable Food Knowledge and Behaviour. *Journal of Human Nutrition and Dietetics : The Official Journal of the British Dietetic Association*, *38*(4). https://doi.org/10.1111/jhn.70103

Krastanova, M., Sirakov, I., Ivanova-Kirilova, S., Yarkov, D., & Orozova, P. (2022). Aquaponic systems: biological and technological parameters. *Biotechnology & Biotechnological Equipment*, *36*(1), 305–316. https://doi.org/10.1080/13102818.2022.2074892

Lusvinaningtyas , L., Nuraeni, F., & Hikmatunisa , N. P. (2024). Pengaruh Model Project Based Learning Berbantuan Aquaponik Terhadap Keterampilan Berpikir Kreatif Siswa Pada Pembelajaran IPA di SD . *Jurnal Kajian Pendidikan,* 6(3), 385–397.

Nair, C. S., Manoharan, R., Nishanth, D., Subramanian, R., Neumann, E., & Jaleel, A. (2024). Recent advancements in aquaponics with special emphasis on its sustainability. *Journal of the World Aquaculture Society*, *56*(1), e13116. https://doi.org/10.1111/jwas.13116

Nuri, N. L., Nurjanah, U., & Hakim, M. (2020). Implementasi Sistem Akuaponik Sebagai Media Pembelajaran Untuk Meningkatkan Hasil Belajar Siswa MTS Zainul Hasan Balung. *Jurnal Bioshell,* 9(1), 16–20. https://doi.org/10.36835/bio.v9i1.759

Rapiya, M., Truter, W., & Ramoelo, A. (2024). The Integration of Land Restoration and Biodiversity Conservation Practices in Sustainable Food Systems of Africa: A Systematic Review. *Sustainability*, *16*(20), 8951. https://doi.org/10.3390/su16208951

Tapilouw, M. C., Djohan, D., Sucahyo, S., Hartadji, E. W., & Zega, Y. T. (2025). Akuaponik sebagai Pembelajaran Lingkungan Hidup Siswa SMA yang Selaras Misi Sekolah Adiwiyata. *Jurnal SOLMA*, *14*(1), 1312-1321. https://doi.org/10.22236/solma.v14i1.17497

Zamnuri, M. A. H. B., Qiu, S., Rizalmy, M. A. A. B., He, W., Yusoff, S., Roeroe, K. A., Du, J., & Loh, K.-H. (2024). Integration of IoT in Small-Scale Aquaponics to Enhance Efficiency and Profitability: A Systematic Review. *Animals : An Open Access Journal from MDPI*, *14*(17), 2555. https://doi.org/10.3390/ani14172555