SIMPLE ECOLOGICALLY BASED AQUAPONIC SYSTEM DESIGN FOR VOCATIONAL HIGH SCHOOL STUDENTS

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Abstract. The Community Service program at *SMK Muhammadiyah* 3 Purwokerto introduced an ecologically based aquaponic system design as a learning method for 11th-grade students. Aquaponics, which combines aquaculture and hydroponics, offers a practical approach to understanding ecosystem relationships. Involving 29 vocational high school students, 4 Entrepreneurship teachers, 1 Master of Environmental Science postgraduate student, and 5 community service teams. The program aimed to enhance environmental understanding through learning simulations. Through a closed system, students observed the interactions between fish, plants, and microorganisms. Fish waste became nutrients for the plants, and the plants filtered water for the fish's survival. The activities consisted of socialization, counseling, and demonstration plot implementation, emphasizing the importance of theory and practice in environmental education. Students were tasked with designing, building, and maintaining an aquaponic system, then discussing the cultivation results and problems. As a result, students understood the concepts of ecology and sustainable agriculture, and developed critical thinking and teamwork skills. Their awareness of ecosystem balance and environmental impacts also increased. It was concluded that the implementation of the aquaponic system design was effective as a learning tool, inspiring students to care about the environment and motivating them to participate in maintaining the school's ecosystem. This activity recommends wider implementation in educational institutions to improve environmental literacy of the younger generation.

Keywords: Aquaponics, ecological concepts, environmental learning, students

1. Introduction

Environmental education is a crucial aspect of school learning, particularly at the Vocational High School (SMK) level, which focuses on practical application and skills development. *SMK Muhammadiyah* 3 in Purwokerto, as an educational institution committed to developing technology-based education without neglecting ecological knowledge, recognizes the importance of integrating a simple aquaponics system as a learning tool. The design of this aquaponics system aims not only to provide theoretical

understanding but also to foster students' environmental awareness through practical applications and simulations of ecosystem component interactions [1].

Aquaponics, as a sustainable agricultural system, combines aquaculture (fish farming) and hydroponics (soilless plant cultivation) in a single integrated system. This system fosters an interaction between fish and plants, where fish waste is used as nutrients for the plants, while the plants filter and purify the water to support fish life. Through this mechanism, students are expected to learn about nutrient cycling and the symbiotic relationship between ecosystem components in the aquaponics system [2].

The implementation of a simple aquaponics system design at *SMK Muhammadiyah* 3 aims to enhance students' understanding of ecological and sustainability principles. Through this approach, students are expected to develop analytical and problem-solving skills related to environmental issues, as well as raise their awareness of the importance of maintaining ecosystem balance. The use of the aquaponics system as a learning tool also supports the national education goal of developing students' critical and creative thinking skills [3].

As part of a community service activity, the implementation of this aquaponics system is expected to have a positive impact not only on students but also on the surrounding environment. By involving vocational high school students in the system design and maintenance process, it is hoped that they will experience firsthand the benefits of integrated, sustainable agricultural practices and apply their knowledge to improve environmental quality. Furthermore, this activity also serves as an interactive learning model that can enrich students' learning experiences [4].

The development of an ecologically based aquaponics system in the school environment also provides opportunities for participants, particularly vocational high school students, to understand the benefits of managing aquaponics cultivation within the field of environmental education, through entrepreneurship lessons. Furthermore, this activity can explore the effectiveness of contextual, nature-based learning methods through student involvement in managing aquaponics systems to enhance their understanding of ecological and environmental concepts. According to [5], this activity can also be used to identify factors influencing the successful implementation of student learning activities in formal educational contexts.

Globally, the implementation of aquaponics systems in schools is part of efforts to address environmental challenges such as climate change, soil degradation, and water resource shortages. By increasing students' understanding of sustainable integrated agricultural systems, it is hoped that the younger generation can actively contribute to environmental conservation efforts. Therefore, integrating a simple aquaponics system design into the vocational high school curriculum is a strategic step in building environmental awareness and preparing students for future challenges [6].

This community service activity, using the implementation of a simple, ecology-based aquaponics system for student learning at *SMK Muhammadiyah* 3 Purwokerto, is expected to serve not only as a learning tool but also to shape students' character and foster an entrepreneurial spirit among the younger generation. In addition, this activity is expected to create a learning environment that supports the development of students' knowledge and skills in the fields of ecology and entrepreneurship, as well as encouraging students to become agents of change in their communities [7].

2. Methods

In this modern era, environmental awareness and awareness are crucial aspects that must be instilled from an early age, especially in the younger generation. As an educational institution committed to developing students' technological skills and knowledge, *SMK Muhammadiyah* 3 Purwokerto strives to increase students' environmental awareness while

fostering entrepreneurial skills. This can be achieved, among other things, through ongoing collaboration between students, teachers, and stakeholders. One effective and innovative method for achieving this goal is through the implementation of contextual learning using a simple aquaponics system.

This Community Service activity was conducted at *SMK Muhammadiyah* 3 Purwokerto, Jalan Kyai H. Wahid Hasim No. 271, Windusara, Karangklesem, South Purwokerto District, Banyumas Regency, Central Java 53144. The activity ran from June to August 2025, with 11th-grade students participating. Overall, this community service activity was implemented in three stages, as shown in Figure 1.

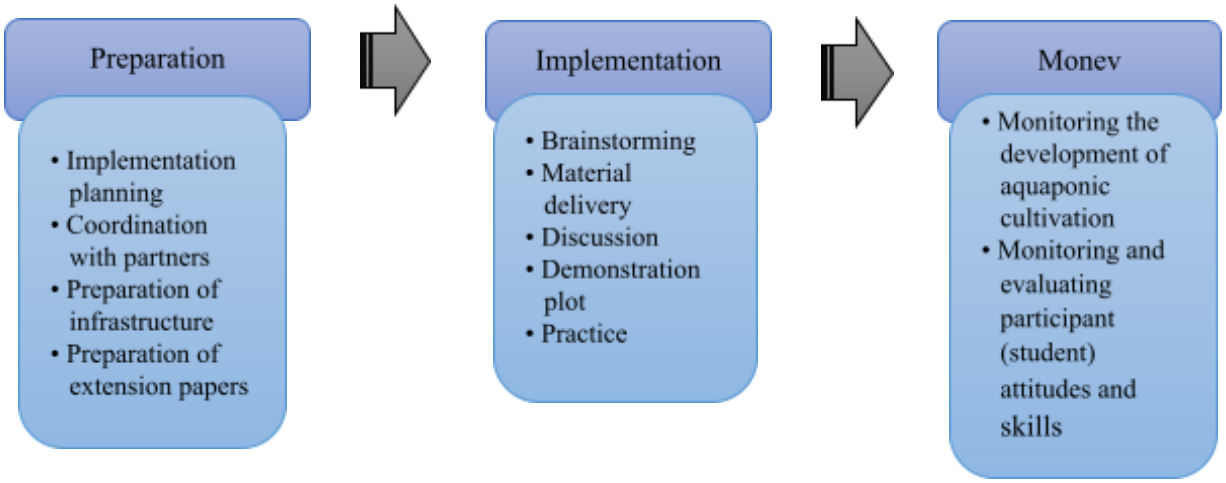

Figure 1. The Community Service program activity method approach flow

A. Preparation Stage

In this stage, the community service program team conducted preparations, including planning activities, establishing a schedule, creating a logbook, compiling a list of materials and tools used for the demonstration plot implementation and participant practice, and conducting pre- and post-tests. Questions in the pre-test covered students' ecological knowledge and environmental awareness; entrepreneurial knowledge; and aquaponic cultivation techniques. Questions to assess participants' prior knowledge are presented in Table 1. The next step was coordinating with partners to align with the entrepreneurship lesson schedule used for delivering materials and practice during the community service program activity. The next step was preparing the location for the demonstration plot implementation, including two sets of aquaponic cultivation tools, creating Power Point slides, and preparing the overall training materials.

Tabel 1. Questionnaire to determine the increase in participants' knowledge and skills

No	**1. Ecological knowledge and environmental awareness**
1	Definition of ecology and the interrelationships of components within an ecosystem
2	The role of society in environmental conservation
3	The importance of maintaining environmental balance
	2. Knowledge of entrepreneurship
1	Definition of entrepreneurship
2	Business opportunities that can be developed from a simple aquaponics system?
3	How to determine the target market for aquaponics products, such as fish and vegetables?
	3. Knowledge of aquaponic cultivation techniques
1	How does an aquaponics system work?
2	How to select suitable fish and plant species for an aquaponics system?
3	How to ensure optimal water quality in an aquaponics system?

This knowledge is categorized into 5 scales, namely: do not understand (1), do not understand (2), understand quite well (3), understand (4) and understand very well (5).

B. Implementation Phase

The implementation phase includes brainstorming, delivering aquaponics materials, discussions, demonstration plots, and practice. Brainstorming is conducted to foster engagement and explore participants' interest in the community service topic. The presentation of materials through counseling and discussions aims to determine participants' level of understanding and basic skills regarding the topic. During the presentation, new terms are introduced and the names of supporting infrastructure for aquaponic cultivation are introduced. Demonstration plots serve as direct examples of the application of new methods, technologies, or systems. This allows participants to see the results visually and concretely, not just theoretically. Demonstration plots also facilitate knowledge transfer because participants learn by observing and trying. It is hoped that by observing the success of the demonstration plots, participants will be encouraged to implement them on their own land or in their own environments. This is because demonstration plots serve as a starting point for the dissemination of innovations in a participatory manner. Next, practical activities are conducted to improve student skills, including preparing cultivation media, cultivating vegetable seedlings, preparing AB mix fertilizer as vegetable nutrients, and techniques for transferring plant seedlings from the seedling medium to the aquaponic framework. During the maintenance/cultivation process, routine monitoring and observation are carried out in the morning and evening during fish feeding. During the training, participants are also introduced to the integrated feeding mechanism for fish to be cultivated, ensuring that the amount of feed does not exceed the capacity of the fish growth medium (plastic box)

C. Monitoring and Evaluation Phase

Monitoring of the implementation of the aquaponic cultivation demonstration plot was conducted to observe the growth of vegetables and fish, observe the improvement in participants' (students') understanding and skills, and evaluate the results before and after the community service activity by assessing participants' understanding of the material and maintenance mechanisms of the demonstration plot. This was demonstrated by students' active participation in care, discussions, and the results of the

aquaponic cultivation at the end of the maintenance period, as well as participants' enthusiasm for independent practice.

To measure the achievement of the Community Service Program implementation, several questions were asked via a Google Form link sent to all participants. The resulting data were then analyzed descriptively. This aimed to identify shortcomings and obtain feedback from participants to improve the quality of the community service program implementation. This also reflected the success of the activity, including whether it had an impact on improving the understanding, motivation, and skills of participants, particularly 11th-grade students, regarding the community service program material.

3. Results and Discussion

The results of the pretest and posttest analysis of participants through Google Forms regarding ecological concept knowledge, environmental knowledge, and awareness showed an average increase of 91.6%. This means that the learning method using the implementation of the aquaponics system as a contextual learning method was able to improve students' understanding and knowledge. Basically, students already have a basic understanding of the reciprocal relationships of ecosystem components such as the interaction of plants with animals, and with direct practice involved in observing the relationship between fish and vegetables in the aquaponics cultivation mechanism, their understanding of ecological knowledge increased by 75%. There were 25% of participants who did not fully understand the components of the ecosystem, this was due to initial misconceptions, including considering an ecosystem only as a collection of living things without understanding the role of abiotic factors. Therefore, learning using the aquaponics cultivation system as a tool greatly helped improve understanding of ecology and environmental knowledge.

Furthermore, understanding of the role of society in environmental conservation and the importance of maintaining environmental balance was seen in 82.75% of participants (students of Muhammadiyah 3 Vocational School) in the understanding to very understanding category (Figure 2).

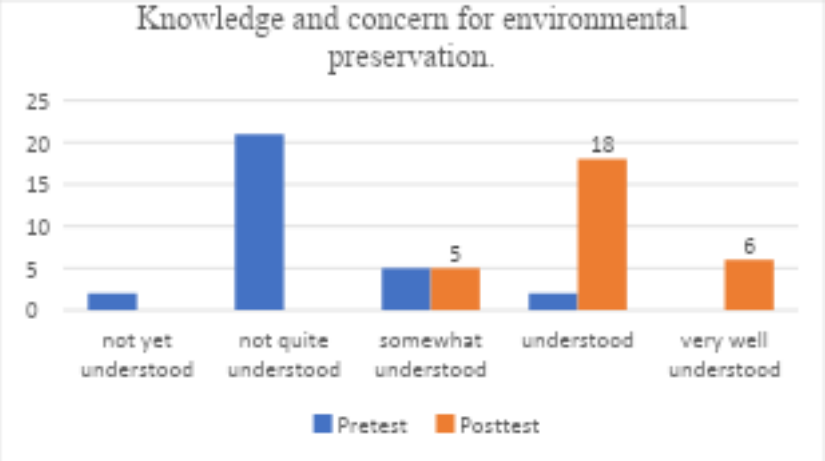

Figure 2. Graph of increased knowledge and concern for environmental sustainability among participants (students) before and after the community service program activity.

This demonstrates that the implementation of contextual methods, with learning practices that demonstrate the role of each component in the ecosystem, significantly

improves student understanding. The calculation is based on percentages from polling results via gForm. According to [8], fostering environmental awareness should be initiated as early as possible among students. This is a key foundation for developing a technical generation that is not only vocationally competent but also responsible for ecosystem sustainability [3]. Although some students still show limitations in understanding ecological concepts comprehensively, a contextual approach has proven effective in increasing their awareness and concern for environmental issues.

Figure 3. Student knowledge of entrepreneurship

Entrepreneurial knowledge, including the definition of entrepreneurship, knowledge of business opportunities that can be developed from aquaponic cultivation, and determining target markets for aquaponic cultivation products, showed that 93.1% of students were categorized as understanding or very understanding (Figure 3). This is because entrepreneurial knowledge is one of the subjects included in the curriculum at *SMK Muhammadiyah* 3 Purwokerto. So that students have obtained the basic knowledge learned from grade 10. Based on the results of the poll via the Google Form platform, it is hoped that students will be able to develop independently in entrepreneurship.

The analysis of students' knowledge of aquaponic cultivation techniques at the end of the activity showed an increase in knowledge. This was due to mentoring activities that began with sowing vegetable seeds, transferring vegetable seeds from the seedbed to the aquaponic cultivation framework, providing nutrients/fertilizers, spreading fish seeds, monitoring vegetable and fish growth, and harvesting [9].

1. Sowing: This activity was supervised by the community service program team and monitored based on observations reported by students through social media groups, including photos of vegetable and fish growth. Participants were instructed to follow each step of the seedling process, which was then grown in rockwool for 7–9 days. The vegetable seeds were first soaked in water for approximately 3 hours before being placed in the growing medium [2].
2. The vegetable seedlings were transferred to net pots and implanted into the hydroponic framework, which was provided with recirculating water.
3. Nutrient or fertilizer application. The fertilizer used is AB mix, which contains nutrients for hydroponic vegetable growth, consisting of micro and macro nutrients. It is divided into solution A and solution B (hence the name AB mix). The two solutions are kept separate to prevent sedimentation. Solution A generally contains the macro nutrient Nitrogen (N), with the micro nutrients Calcium (Ca), Potassium (K), and Iron (Fe). Meanwhile, solution B contains the macro nutrients Phosphorus (P), Magnesium (Mg), Sulfur (S), and other micro nutrients such as Manganese (Mn), Zinc (Zn), Copper (Cu),

Boron (B), and Molybdenum (Mo). Students are given hands-on experience preparing the fertilizer and adding it to the water in the reservoir.

4. Stocking of fish fry: The fish stocked in the reservoir are tilapia fry measuring 7-9 cm, with the expectation that they will have high survival and growth rates, enabling them to adapt to the narrow growth medium with high stocking densities. During cultivation, the fish are also fed pellets to support their growth.
5. Harvesting: Harvesting activities are carried out by all participants, including students, accompanying teachers, and the Community Service Program team. Harvesting is carried out periodically, as the vegetable seedlings are allowed for continuous harvesting, rather than a total harvest, while waiting for the fish to reach the desired consumption size.

All students involved responded positively, demonstrating that this learning activity helped them better understand the concepts of ecology, ecosystems, and the environment, as well as entrepreneurial practices. The material was delivered by the Community Service program team (Figure 4). Participants were visibly excited to successfully harvest hydroponic vegetables grown and managed simultaneously with their classmates. This boosted students' confidence and motivation to grow vegetables and practice aquaponics independently with their families.

Monitoring and evaluation were conducted throughout the activity, focusing on improving students' understanding of the community service program activity and the growth and development of the vegetables and fish cultivated in aquaponics. Evaluation and monitoring also aimed to determine the overall success of the community service program activity. Analysis of student information gathering indicated that the community service program activity was successful and had an impact on increasing students' motivation to cultivate aquaponics independently (85%), and 55% said they would continue this activity as part of the school's entrepreneurship program

Figure 4. Community service program activity participants (vocational school students), entrepreneurship teacher and the Unsoed Community service program team

4. Conclusion

Based on the overall analysis, it can be concluded that students' knowledge of aquaponic cultivation as a contextual learning method in understanding ecological processes, ecosystem components, and as a learning tool for green economy-based entrepreneurship has increased. Students' understanding and concern for the role of society in environmental conservation and the importance of maintaining environmental balance have also increased. Participants' motivation to implement aquaponic cultivation independently has also increased. The community service activities carried out at *SMK Muhammadiyah* 3 Purwokerto were generally effective and had an impact on participants' motivation to become independent entrepreneurs.

5. Acknowledgement

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