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Urban Farming-Based Learning: A Community Engagement Model for Agricultural Vocational Schools

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ABSTRACT

Background: Agriculture in the modern era faces increasingly complex challenges that require innovative and sustainable solutions.
Contribution: Students on SMK Negeri 2 Rantauprapat lacked comprehensive understanding and hands-on exposure to modern methods such as aquaponics, hydroponics, and integrated urban farming systems.
Method: This study applied a participatory action research approach designed to evaluate students baseline understanding, measure knowledge improvement, and enhance practical skills in sustainable agriculture through an urban farming-based community engagement program at the Vocational School of Agriculture Labuhanbatu (SMK Negeri 2 Rantauprapat).
Results: Through training and community activities including collaborative pond construction, establishment of a hydroponic house, and development of a biofilter system students acquired both theoretical and practical skills. The initiative also fostered teamwork and a sense of ownership. Evaluation confirmed its effectiveness, as knowledge levels surged from pre-test benchmarks to over 70%, and even exceeded 90% in some areas.
Conclusion: The evaluation results directly reflect the study's novelty. The survey on student interest revealed a very positive response, with more than 80% expressing strong interest in integrating urban farming and aquaponics into the curriculum, building facilities, and pursuing entrepreneurship. This high level of engagement underscores the effectiveness of the program's novel approach in bridging theory, practice, and community implementation.

1. Introduction

Agriculture in the modern era faces increasingly complex challenges that require innovative and sustainable solutions. Issues such as land scarcity, climate change, soil fertility degradation due to excessive chemical inputs, and the declining interest of younger generations to pursue agriculture are becoming critical [1], [2]. Urbanization has further exacerbated the problem, reducing productive agricultural land while food demand continues to rise in line with population growth [3], [4]. In addition, conventional agricultural practices, which rely heavily on synthetic fertilizers and pesticides, threaten environmental sustainability and long-term food security [5]. Addressing these challenges requires new approaches that emphasize ecological balance, efficient resource use, and active community participation.

One promising solution is the implementation of urban farming integrated with biochar-based sustainable practices. Urban farming, defined as agricultural practices carried out in urban areas, emphasizes efficient and productive use of limited land [6]. Biochar, a carbon-rich produced through the pyrolysis of biomass, has been recognized for its capacity to improve soil fertility, enhance water retention, and increase crop productivity while simultaneously reducing greenhouse gas emissions [7], [8].

Studies on biochar derived from oil palm residues, such as fronds and empty fruit bunches (EFB), reveal its high carbon content (28–34%) and its potential as an effective soil amendment. As an ameliorant, biochar contributes not only to soil quality improvement and water management but also serves as a form of long-term carbon sequestration, making it an environmentally friendly solution [9], [10].

In Indonesia, vocational schools of agriculture have a crucial role in preparing skilled graduates who are capable of applying modern and sustainable agricultural practices. SMK Negeri 2 Rantauprapat, as a vocational institution specializing in agriculture, holds significant potential to train students with both theoretical knowledge and practical skills. However, sstudents still lack comprehensive understanding and hands-on exposure to modern methods such as aquaponics, hydroponics, and integrated urban farming systems. This knowledge gap highlights the need for targeted educational interventions. Without direct engagement in innovative practices, vocational students' risk being left behind in addressing the sustainability challenges of modern agriculture [11].

Although the benefits urban farming and biochar have been widely studied, their application in the context of vocational education and community engagement in Indonesia remains limited and fragmented. Current practices have not fully integrated biochar-based farming into vocational school programs as structured learning tools. Moreover, there is crucial research gap connecting urban farming as both a pedagogical method and a sustainability intervention in formal education.

The novelty of this study lies in its holistic integrating of urban farming-based learning with biochar application within a vocational school setting, bridging the disconnect between theoretical knowledge, practical skills, and community-oriented implementation [12]. This community promotes entrepreneurship and innovation, as students are encouraged to develop agribusiness models from small-scale urban farming practices [13]. Third, it strengthens community engagement, as the program not only benefits students but also inspires the surrounding community to adopt sustainable agricultural practices. Finally, the integration of biochar within this learning framework ensures ecological benefits, including soil enrichment, improved water efficiency, and long-term carbon sequestration [14], [15].

Globally, urban farming has evolved from small-scale community gardens to technologically advanced systems, such as hydroponics, aquaponics, and biochar-integrated cultivation [16]. Research demonstrates that urban farming can sshorten food supply chains and improve local food access [17], enhance soil health and productivity through biochar application [18], integrate waste recycling and resource efficiency, reducing dependency on external inputs [19] and strengthen environmental education and sustainable development in schools [20]

Extensive research supports the integration of urban farming and biochar for sustainable agriculture that biochar significantly improves soil nutrient retention and crop yield [21]–[23], it increases soil water-holding capacity and reduces drought stress [24], biochar also contribute as a form of carbon sequestration, biochar contributes to climate change mitigation [25] and also biochar enhances efficiency in hydroponic and aquaponics [26]. Not only about the advantage of biochar, the contribution of biochar should be implemented on school and community. It can be based urban farming projects have proven to increase awareness, interest, and skills in agriculture among students and local communities [27].

Biochar from oil palm residues provides a locally available, low-cost, and sustainable soil amendment option in Indonesia [11], [28]. Although the benefits of urban farming and biochar have been widely studied, their application in the context of vocational education and community engagement in Indonesia is still rare. Current practices have not fully integrated biochar-based farming into vocational school programs as structured learning tools. Moreover, there is limited research connecting urban farming as both a pedagogical method and a sustainability intervention in education. The novelty of this study lies in its holistic integration of urban farming-based learning with biochar application in a vocational school setting. This program therefore presents a timely opportunity to advance both educational innovation and sustainable agricultural practice. It contributes at several levels are scientifically by enriching literature on the integration of biochar-based urban farming in vocational education systems and practical contribution to providing students with hands-on skills in modern, sustainable agriculture and resource management.

3. Method

This study applied a participatory action research approach designed to evaluate students baseline understanding, measure knowledge improvement, and enhance practical skills in sustainable agriculture through an urban farming-based community engagement program at the Vocational School of Agriculture Labuhanbatu (SMK Negeri 2 Rantauprapat). A total of 64

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students participated in the program, which integrated surveys, tests, statistical analyses, and direct field practice in constructing an aquaponics based urban farming house.

2.1. Baseline Survey

A structured questionnaire was distributed to assess students' prior knowledge, exposure, and understanding of urban farming and aquaponics. Indicators included awareness of urban farming, knowledge of aquaponics, experience of visiting an urban farm or aquaponics site, and understanding of environmental benefits.

This research instrument is a knowledge assessment questionnaire comprising four closed-ended (dichotomous) questions. Each question is designed to measure a different aspect of basic knowledge.

1. Question 1 (Q1): General knowledge of the urban farming concept.
2. Question 2 (Q2): Understanding of the aquaponics as a method of urban farming.
3. Question 3 (Q3): Direct experience, which can contribute to knowledge.
4. Question 4 (Q4): Understanding of the benefits and impacts of urban farming.

This questionnaire was self-developed by the researchers based on a literature review and the research objectives. To ensure content validity, the questionnaire was validated by two experts (expert judgment) in the fields of urban agriculture and vocational education. The validation process aimed to evaluate relevance to whether each question aligned with the measured indicators. Clarity: Whether the language used was easily understood by the respondents. Appropriateness: Whether the response choices (Yes/No) were suitable.

The revised questionnaire was then trialed on a small number of students with characteristics similar to the main study sample but not included in it. This trial aimed to check the clarity of instructions and ease of completion. Based on trial found that validation and reability showed on Table 1. Table 1 showed that question preparation for pretest is valid and good for reability.

Table 1. Validation and Reability Test based on Trial students

Item	r (item–total)	r_table (df=13, α=0.05≈)	
Q1	0.707	0.514	Valid
Q2	0.807	0.514	Valid
Q3	0.560	0.514	Valid
Q4	0.807	0.514	Valid
Total Question	**KR-20 / Alpha Cronbach's Alpha**		**Interpretation**
4	0.898		Good (≥0.70)

2.2. Pre-Test

A 10-item quiz (multiple choice and short answer) was conducted to evaluate conceptual understanding of urban farming and aquaponics. Questions covered definitions, components, functions, benefits, and applications in vocational education.

2.3. Data Analysis and Statistics

Data were tabulated and visualized using bar charts and stacked graphs. A Chi-square test (x^2) was applied to determine the significance of differences between students who understood and those who did not (not yet + yet). The response data from 64 students for the four questions. For the Chi-square analysis, this data was organized into a contingency table. The hypotheses were formulated as follows: the null hypothesis (H_0) stated that there was no significant difference in the proportion of knowledge among the response categories for each question, while the alternative hypothesis (H_1) proposed that a significant difference did exist. The Chi-square test was then applied to determine if the observed distribution of responses deviated significantly from the expected distribution. The Chi-square test was applied to evaluate differences in knowledge levels for each question as shown in Eq. (1):

$$X^2 = \sum \frac{(O - E)^2}{E} \quad (1)$$

After Chi square for each question was found, continue with calculated all of the question as shown in Eq. (2):

$$\sum x^2 = X^2_{Q1} + X^2_{Q2} + X^2_{Q3} + X^2_{Q14} \quad (2)$$

2.4. Training and Community Engagement

Students participated in training sessions covering are biochar production from oil palm residues, integration of biochar into planting media, aquaponics and assembly (fish tanks, pumps, grow beds), and application of sustainable urban farming practices. This stage emphasized hands-on learning and direct practice as a form of vocational training. A follow-up test was conducted after the training and the construction of the aquaponics-based farming house to measure improvements in students' knowledge and skills.

3. Results and Discussion

3.1. Baseline Survey

The baseline survey involving 64 vocational students revealed a generally low awareness and exposure to urban farming and aquaponics. Only 20.3% of students reported understanding urban farming, and 39.1% understood aquaponics. None had ever visited an urban farming or aquaponics, while 45.3% understood its environmental benefits and showed on Table 2.

The Chi-square analysis revealed a statistically significant difference in students' responses across the four baseline survey indicators ($\chi^2 = 41.46$, df = 6, $p < 0.001$). The presents findings are consistent indicating that students often demonstrate higher awareness of the environmental aspects of sustainable agriculture than its practical applications. [29], [30] reported that vocational students recognized the ecological benefits of aquaponics but lacked opportunities for direct practice due to limited school facilities. Similarly, [31] emphasized that

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while aquaponics is widely perceived as innovative and sustainable, its integration into vocational and higher education is still limited on a global scale. Compared to these studies, the current research highlights a similar pattern, emphasizing the need for integrating experiential projects such as school-based aquaponics to strengthen both knowledge and practice.

Table 2. Baseline survey for Audience about Urban Farming and Aquaponic

Question	Respondance			
	Not yet	**Yet**	**Already know**	**Total**
Have you heard about urban farming? (Q1)	27	24	13	64
Do you know the aquaponic? (Q2)	27	12	25	64
Have you ever visited an urban farming/aquaponics site? (Q3)	41	23	0	64
Do you understand the benefits of urban farming for the environment and society? (Q4)	35	0	29	64

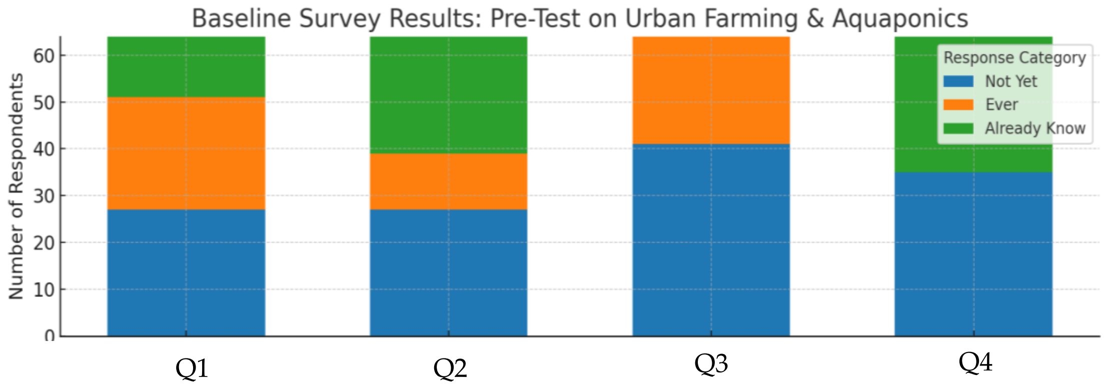

Figure 1. Baseline Survey Before Pre-Test on Urban Farming and Aquaponics Among Vocational High School Students

As seen in Figure 1, while conceptual knowledge of urban farming and aquaponics exists, the absence of practical engagement suggests that students are unable to translate awareness into skills. These findings have important implications in preparing students for careers in sustainable agriculture. Incorporating aquaponics-based urban farming modules into vocational curricula could provide students with hands-on experience, fostering both technical competence and entrepreneurial skills. Moreover, such interventions align with the broader goals of sustainable development by equipping future generations with the knowledge and capacity to address food security challenges in environmentally responsible ways [32].

3.2. Pre-Test Quiz

The pre-test quiz revealed varying levels of student knowledge about urban farming and aquaponics. While the majority of students correctly identified the concept of aquaponics (85%) and the main system components (100%), their understanding of the role of plants within the system was relatively low (50%). Similarly, only 60% of respondents correctly recognized the different types applicable to urban farming and showed on Figure 2. These findings highlight that while vocational students possess basic conceptual knowledge, they still lack a deeper and more practical understanding of system components and ecological roles within aquaponics.

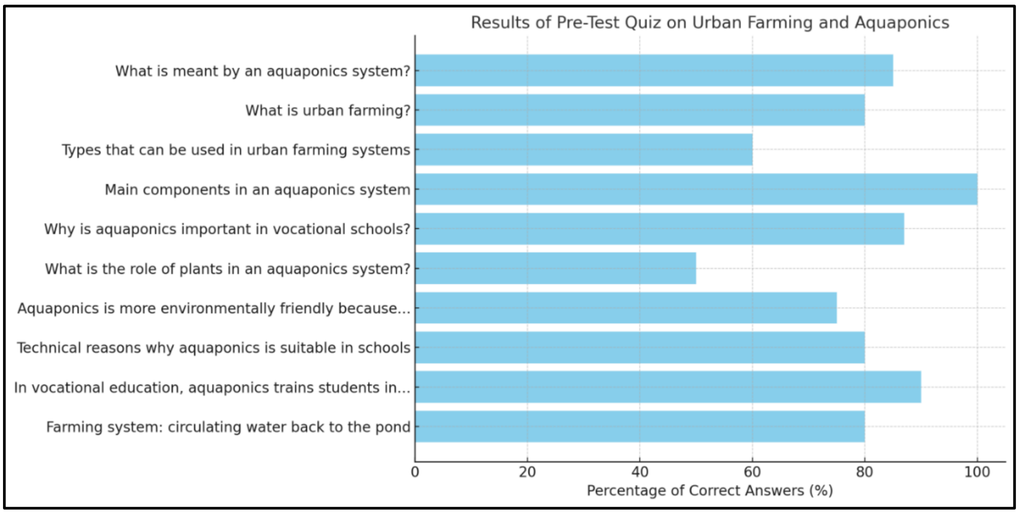

Figure 2. Results of Pre-Test Quiz on Urban Farming and Aquaponics among Vocational High School Students

Figure 2 showed that was a gap between understanding basic definitions and components versus understanding the functions and interactions within the system. While 85% of students could correctly define an aquaponics and 100% identified its main components, this demonstrates excellent mastery of declarative knowledge. However, only 50% of respondents understood the specific role of plants in the system. This reveals a weakness in functional knowledge. The understanding that plants are not just a crop, but a critical part of the biological water filtration unit, is a key concept that half of the learners are missing. Suggesting that while students can grasp the technical definitions of sustainable farming systems, they often struggle to understand the ecological and functional interactions involved [33]. Similar studies in vocational schools in Indonesia and other developing countries have shown that although students are able to recall basic definitions, deeper conceptual knowledge, such as nutrient cycling and environmental sustainability, remains underdeveloped [33].

Figure 2 also showed that 70% of students recognized the importance of aquaponics in training practical skills, only 60% could identify the types of systems applicable to urban farming. This suggests that the connection between aquaponics theory and its broader practical applications within the urban farming sector is not yet solid. The results underscore the importance of targeted teaching strategies in vocational curricula. While students demonstrate strong recognition of technical components (e.g., aquaponics and their elements), the weaker grasp of ecological roles (e.g., plants as biofilters) suggests a gap between theory and applied systems thinking. Incorporating hands-on training, demonstration projects, and school-based

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aquaponics laboratories could bridge this gap, aligning with the growing emphasis on experiential learning in sustainable agriculture education [34]. Furthermore, enhancing awareness of environmental benefits could foster not only technical competence but also a sense of responsibility for sustainable practices, strengthening students' readiness for green entrepreneurship and future agribusiness opportunities.

3.3. Training and Community Engagement

The community engagement program titled "Promoting Agricultural Sustainability Through Urban Farming-Based Learning" was implemented at the Vocational School of Agriculture, Labuhanbatu showed on Figure 3. This initial stage helped raise awareness and build enthusiasm for the program.

Figure 3. Socialization Session about Urban Farming at the Vocational School of Agriculture Labuhanbatu Followed by Students, Teachers, Lectures and Speakers.

The socialization, training activities emphasized practical, hands-on learning, including the construction of small-scale fish ponds, the establishment of an aquaponic house, and the development of a biofiltration system using water hyacinth and biochar and showed on Figure 4. These activities were designed to integrate theoretical knowledge with applied agricultural practices. The program not only improved students' technical skills in sustainable farming but also enhanced their sense of ownership, teamwork, and community responsibility. Students reported that direct involvement in pond construction and aquaponic system assembly increased their motivation and understanding of the practical relevance of urban farming in modern agriculture.

(a) Training Activities Emphasized Practical

(b) The Establishment of an Aquaponic House

(c) Biofiltration System using Water Hyacinth and Biochar

Figure 4. Applied agricultural practices.

Hands on engagement in agricultural projects significantly improves student learning outcomes and community awareness [35]. Project-based learning models in vocational schools have been demonstrated to strengthen students' problem-solving skills and entrepreneurial mindsets [36]. Furthermore, the incorporation of biofilters, particularly through the use of biochar and aquatic plants, reflects sustainable innovations found in other aquaponics studies, where such systems effectively reduce nutrient loads and improve water quality [37]. This shows that integrating environmental engineering principles into vocational training can mirror global best practices in sustainable agriculture education.

The training and engagement program demonstrated that vocational education can serve as a catalyst for local agricultural innovation. Combination of traditional pond culture with biochar-based biofilters and natural plants such as water hyacinth, the program introduced students to circular economy concepts and sustainable waste management. Such experiential learning approaches not only prepare students for future agribusiness opportunities but also foster community participation and environmental stewardship. Importantly, the involvement of students in building the infrastructure themselves reinforced the idea that sustainability can be achieved through low cost, locally available resources, making the model scalable for broader community applications.

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3.4. Post Test and Evaluation Survey

The perception mapping of farming systems showed on Figure 5 based on 64 respondents revealed that urban farming was perceived as the highest impact (39.1%) despite relatively high effort. In contrast, traditional farming systems received the lowest ratings only 18.8% of preferences. Meanwhile, plantation-based farming was positioned in the middle range with 23.4% of students recognizing its relevance. Figure 5 showed that perception of urban farming required active management to ensure its correct positioning as a high-value and efficient activity. As this constitutes the final stage of the study, a limitation exists in the form of external factors. Consequently, further research is recommended to subsequently develop and implement future communication and training programs. These programs must consistently highlight the favorable effort-to-impact ratio of urban farming. The use of visual aids, success stories, and hands-on workshops is crucial to demonstrate its accessibility and multifaceted benefits.

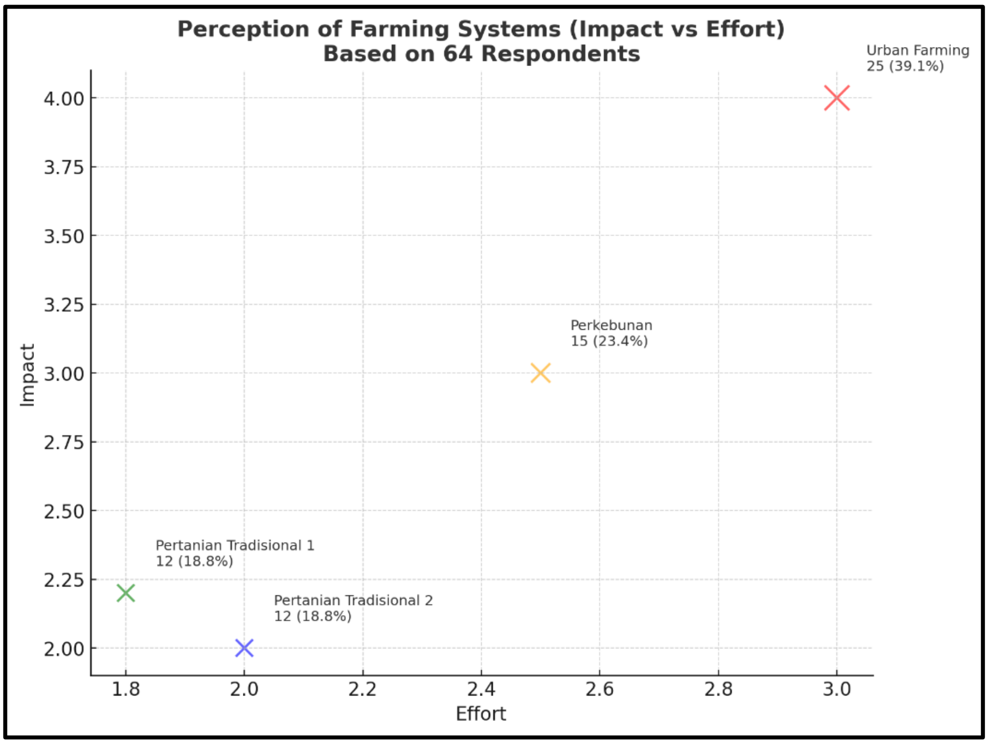

Figure 5. The Perception Mapping of Farming System such as urban farming, traditional, plantation according to students on Vocational school Survey

Younger generations, particularly students, are more attracted to innovative and visible agricultural practices such as urban farming and aquaponics, which they perceive as modern, environmentally friendly, and compatible with urban lifestyles [37]. Urban farming demonstrates its potential as a gateway to increasing Gen Z's interest in agriculture. Despite requiring relatively higher effort, students believed the benefits in terms of impact and sustainability justified this investment. The findings highlight the importance of integrated hands-on urban farming projects in vocational schools as an effective strategy for agricultural education. By combining aquaponics, biofiltration, and biochar applications, students not only gain technical skills but also develop a deeper appreciation for sustainable agriculture [38].

The post-test results on aquaponics knowledge in Figure 6 showed a substantial improvement compared to the pre-test. In the post-test, the percentage of correct answers ranged from 70% to 95%, indicating strong learning gains across all indicators. The highest scores were observed in “One water indicator that must be monitored in aquaponics” (95%) and “Causes of non-optimal plant growth” (92%), demonstrating students’ improved understanding of water quality management and plant health in aquaponics. In contrast, the pre-test results in Figure 4 revealed lower performance, with correct responses ranging between 50% and 90%, and significant weaknesses in understanding the role of plants and technical aspects of aquaponics. The lowest pre-test score was “The role of plants in aquaponics” (50%). This highlights that the training program successfully addressed knowledge gaps, particularly in ecological and technical integration.

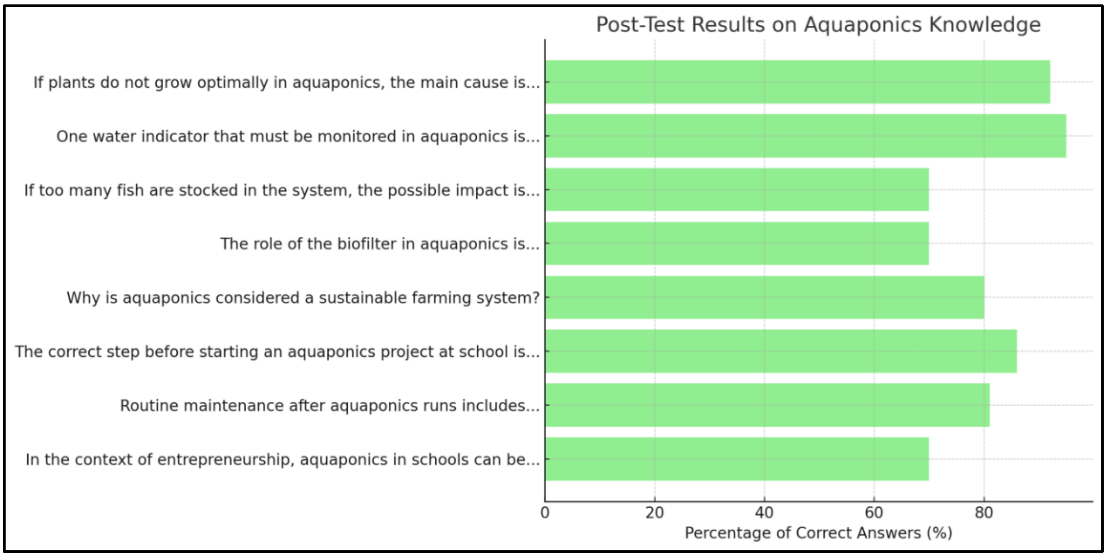

Figure 6. Post Test Results on Aquaponic and Urban Farming Knowledge among Vocational High school Students

Hands on training and project-based learning enhance knowledge retention and problem solving skills in vocational students [32], [34]. Similar improvements were reported in aquaponics-based learning interventions, where active participation in system construction and management increased conceptual clarity [33]. Compared to these studies, the present results further confirm that integrating theory with practice is effective in improving vocational students’ understanding of sustainable farming systems. Students not only demonstrated better knowledge of water management, biofilter functions, and system sustainability, but also improved their understanding of the entrepreneurial potential of aquaponics. The increase in scores indicates that experiential learning activities such as pond construction, aquaponic house assembly, and biofilter development played a critical role in strengthening comprehension.

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The evaluation survey involving 64 students in Figure 7 demonstrated a generally high level of interest in urban farming and aquaponics. More than 80% of respondents expressed either "very interested" or "interested" across all indicators. The strongest interest was observed in the statement "I hope this activity will be included in the learning curriculum", where nearly all students (close to 100%) responded positively. Similarly, over 90% supported the idea of schools providing aquaponics facilities, and more than 85% agreed that aquaponics is an efficient method for farming in limited land. This study just finished until on post test and evaluation survey because several factors such as the durations and external factor so that the aquaponics plants was not measured by high plant and production. so that to capitalize on this success and ensure long-term impact, The Ministry of Education and related stakeholders should consider a wider integration of urban farming and aquaponics into the national vocational education curriculum.

Vocational students show strong enthusiasm for sustainability-related learning when linked to practical applications [35]. Similar studies have reported that integrating aquaponics into school curricula not only enhances agricultural competencies but also increases student engagement. However, some students may initially perceive such activities as more technical than enjoyable, emphasizing the need to combine technical training with engaging, student-centered approaches. Overall, the evaluation survey confirms that vocational students are ready and motivated to adopt sustainable agriculture practices, and that structured programs on urban farming and aquaponics are well aligned with their learning needs and aspirations.

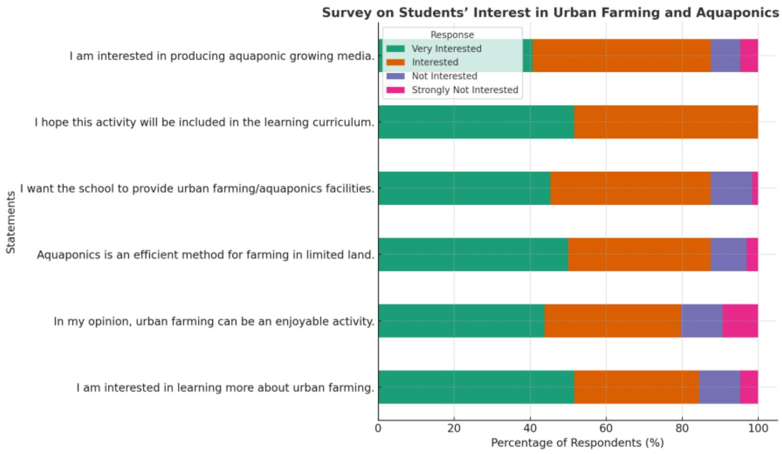

Figure 7. Evaluation Survey From 64 Students About Urban Farming

4. Conclusion

Based on the discussion it can be concluded that students initially had limited awareness and exposure to urban farming and aquaponics. The pre-test assessment confirmed correct responses ranging between 50–80%. Training and community engagement strengthened teamwork, sense of ownership, and community responsibility. The evaluation responses consistently exceeding 70% and reaching above 90% in some indicators. The evaluation survey on students' interest revealed a very positive response and interest in integrating urban farming and aquaponics into the school curriculum, building facilities, and pursuing aquaponics-based entrepreneurship.

This study was limited by durations and external factor so that to capitalize on this success and ensure long-term impact, The Ministry of Education and related stakeholders should consider a wider integration of urban farming and aquaponics into the national vocational education curriculum. This would formalize the learning and provide a structured framework for sustainable agriculture education across all relevant schools.

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