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Integrating Sustainable Agriculture in Teaching Mathematics: Development of a Project- based Learning Prototype

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ABSTRACT

This developmental study seeks to develop a Project-Based learning prototype that integrates sustainable agriculture in teaching mathematics. Data was gathered through the in-depth interviews using the developed semi-structured questionnaire. The study used the Clarke and Braun thematic analysis to analyze the data collected. The researchers found the following themes: Profitability of Aquaponics, Requisite for Computational Skills, Integration of Aquaponics in Teaching Unit Conversion, and Promoting Competencies through Self-discovery as Elements in Crafting Teaching-Learning Package for Sustainable Agriculture. Based on the result, the researchers developed a Project-Based Learning Prototype that integrates Sustainable Agriculture in teaching mathematics at the grade 7 level. It has been concluded that the proposed teaching-learning prototype should promote competencies through self-discovery, that is, using real-life situations rather than hypothetical ones to engage students in meaningful projects, develop critical thinking and problem-solving skills, and prepare them for future work and careers. Further, it is recommended that future research may investigate the effectiveness and implementation of the developed teaching-learning prototype. Also, school administrators should ensure educators have access to adequate resources, training, and help to implement aquaponics education effectively.

Keywords: *Aquaponics, Mathematics Education, project- based Learning, sustainable agriculture, unit of conversion*

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INTRODUCTION

Today's education plays a role in making future leaders and citizens more capable of going beyond limits to discover and uncover a more sustainable tomorrow. It is crucial for nations to regularly examine and improve their educational systems in order to reach international standards, especially at a time when mathematical literacy is critical for scientific advancement, economic prosperity, and societal improvement. Like many other countries, the Philippines understands the importance of preparing its students for an increasingly technologically advanced and challenging world. Regrettably, recent assessments of the nation's mathematics education program revealed a misalignment with PISA's skills (OECD, 2019). The efficiency of existing teaching strategies and the extent to which students can apply their mathematical knowledge to actual circumstances are both questioned by this discrepancy. The contextualization of mathematics is one of the fundamental ideas stressed by the PISA framework (OECD, 2022). Hence, this study aims to address the problem of oversimplified and uncontextualized self-learning modules in mathematics. Furthermore, it also seeks to support the United Nations' goal of achieving quality education by 2030 (United Nations, 2018). Additionally, section 10.2 of the Implementing Rules and Regulations (IRR) of Republic Act (RA) 10533 states, "The curriculum must be contextualized and flexible enough to allow schools to localize and improve it by their respective educational and social settings."

Integrating topics into sessions enables teachers to collaborate with other educators and motivate students. Most importantly, incorporating real-world experiences and issues that interest students into interdisciplinary classes allows educators to craft more engaging and relevant learning experiences (Maresca, 2022). As education continuously evolves, it is right to encapsulate a better paradigm in making learning more practical and valuable. Promoting an integrative approach is one of the promising approaches. Integrative learning is a comprehensive term encompassing a range of institutions, strategies, and activities that connect the gaps between theory and practice, formal and informal education, and academic and community life. This approach supports a new framework that includes disciplinary depth, multidisciplinary breadth, interdisciplinary integration, and transdisciplinary competencies (Ignjatovic, 2020).

Learners have a better understanding when a teaching strategy encapsulates a real-life problem, making them participate actively. In Project-Based Learning, students engage in solving real-life problems along with underlying questions over an extended period ranging from a week to a semester. Through PjBL, seeking solutions for real-life problems will enhance students' attitudes toward learning by making learning exciting and more interactive. This teaching and learning strategy fosters problem-solving skills, influences goal orientation, stimulates curiosity, promotes active engagement with the topic, supports mastery of new knowledge, cultivates critical thinking, enhances peer learning, and improves communication skills (Serin, 2019).

Agriculture, forestry, and fisheries (AFF) are the development objectives in Region XI that have been focused on increasing production and labor productivity, improving food security, climate resiliency, and agricultural governance (Lumen, 2020). The agricultural industry in the Philippines poses a persistent challenge, much like the educational system, particularly regarding mathematics. The PISA results show that Filipino students' mathematical proficiency needs to be improved in the essential knowledge and abilities required for active social engagement. This study uses a project-based learning approach to develop an instructional tool that combines sustainable agriculture with math instruction to address these issues.

Research Questions

1. What are the areas in Aquaponics that are relevant to learning Mathematics?
2. What competencies should be addressed by the learning prototype?
3. What teaching-learning prototype can be proposed?

METHODS

Study Design

This study employs a developmental research design, incorporating documentation, interviews, and observations. It focuses on qualitative data analysis and presentations to ensure a comprehensive examination of products, tools, processes, and models. The objective is to provide reliable and actionable information. This method creates a feedback loop, where practice informs research and research informs practice, necessitating the consistent collection of empirical data to enhance the study's effectiveness (Richey & Klein, 2005).

This study intends to create an innovative and contextually appropriate project-based learning prototype that combines sustainable agriculture and mathematics teaching using a developmental design method. The design process ensures that the learning materials are systematically developed, refined, and improved to address the specific needs of Grade 7 students and facilitate their understanding and application of mathematical concepts in the context of sustainable agriculture.

Participants

The participants of this study consist of three Grade 7 teachers from a public school in Davao City and three experts in the field of agriculture. The researchers purposefully selected these participants based on specific criteria relevant to the study. The teachers were required to have at least ten years of service and experience in creating self-learning modules for Grade 7 mathematics. The agricultural experts were chosen for their experience in building Aquaponics Systems, extensive knowledge of aquaponics, or teaching experience in Rural Farm Schools or Supervised Agricultural Experience (SAE) programs.

This study employed purposive sampling, a non-probability method in which researchers select specific participants to achieve the study's objectives. The primary aim of purposive sampling is to generate a sample that can be logically assumed to be representative of the broader population (Nikolopoulou, 2023). By using purposive sampling, the researchers can ensure that the study includes participants who have expertise or direct involvement in the integration of sustainable agriculture in teaching mathematics at the Grade 7 level. The participants were carefully selected to include mathematics educators, sustainable agriculture practitioners, curriculum specialists, and experts in project-based learning who can provide rich and meaningful information related to our research objectives. The insights gained from the selected participants enabled the study to gain a comprehensive understanding of the integration of sustainable agriculture in teaching mathematics, ensuring that the research findings are robust and meaningful for the specific context under investigation.

Instrumentation

An interview guide containing questions about aspects of Sustainable Agriculture and a Project-based learning prototype was developed. The researchers used semi-structured interviews as an instrument

to gather the experiences and ideas of the respondents. A semi-structured interview is a type of interview that is flexible and allows changes in the structure of the questions. The interview guide was validated and evaluated by the experts to ensure the validity and reliability of the questions.

Data Analysis

The researchers employed a thematic analysis approach as developed by Braun and Clarke (2006). They applied the six phases of reflexive thematic analysis: familiarizing the data, generating initial codes, constructing themes, reviewing potential themes, defining and naming themes, and producing the final report.

RESULTS

Areas in Aquaponics that are Relevant in Learning Mathematics

The themes that emerged in the areas of aquaponics that are relevant in Learning Mathematics are the following: Profitability of Aquaponics and Requisite for Computational Skills.

Profitability of Aquaponics

Experts underscored aquaponics as profitable through generating a business to gain income from building aquaponics. Under this theme is the supporting core idea: (1) Aquaponics as a profitable agricultural technology.

> *"… you can generate an income out of them."* – E1
>
> *"Even in highly urbanized areas, you can pursue Aquaponics as a business."* – E2
>
> *"Aquaponics is already a double business- it's the fish and the plants."* – E3

Aquaponics is a process that involves growing fish and vegetables simultaneously. Because it maximizes the resources used to grow fish and vegetables while reducing pollution, it is frequently promoted as a more sustainable approach to food production (Lobillo- Eguíbar et al., 2020). In addition, fish grow more quickly, and it conserves water. Because cultivating natural food will result in a 20–30% reduction in variable costs, aquaponics can also shorten the fish growth cycle by 10–30%, making it economical for fish farmers (Llemit, 2018). Canlas (2020) also claims that aquaponics has enormous potential as a business venture and as a means of supplying food. A plant bed measuring 25 square feet is said to support a single person for their entire life.

The profitability of aquaponics creates an opportunity for the farmers to gain income. And for them to identify the profit of their business, they have to deduct expenses from the revenue. That process requires basic mathematical skills and can be a competency that the learners may acquire. In developing the Learning Prototype, the researchers used the profitability of aquaponics to generate an activity that will enhance student's competency in estimating possible revenue based on the size of the Aquaponics System and calculating the profit by deducting expenses from revenue.

Requisite for Computational Skills

The participants emphasize the significance of mathematics in successfully implementing and managing aquaponics systems, which require specific skills, particularly in calculations and computations for various aspects of aquaponics, such as determining the appropriate amount of nutrient solution, calculating fish density, and understanding unit conversions. They added that mathematics is vital in aquaponics, as students must apply mathematical concepts and skills to perform accurate calculations. These computations include measuring materials, maintaining pH levels, and determining suitable fish quantities based on available space. Participants highlighted the interdisciplinary nature of aquaponics, where scientific principles from various fields converge. This implies that engaging with aquaponics can make students feel like chemists or engineers due to the need for computational skills and an understanding of plant and nutrient requirements.

> *"...in applying chemicals, you have to calculate how many chemicals you will put in. For example, one is to one, solution A or solution B, and then you should also consider the milliliters so in that way you can hit mathematics by applying it in aquaponics."* – E1

> *"In starting your Aquaponics system, you have to compute the area [of the container] and volume of the water. For you to be able to know the density of the fish that you put in your Aquaponics System…there is a lot of mathematics involved like computing parameters, PH level, and temperature of the water. It does not have to be advanced mathematics; basic math will do."* – E2

> *"It is only the computation or the conversion of the number of fish and the ages of the fishes. The older a fish is, the higher their food should be. You should compute or weigh the fish every 15 days. Then you will compute its weight, count its numbers and compute their average weight."* – E3

To develop computational skills, an aquaponics system is built using school concepts and an aquaculture background. Through these, students can learn the primary step in basic measurements, which could connect the dots between the theoretical concepts and the real world. Additionally, by implementing this idea, students have an intuitive understanding of the principles. From the paradigm used, learners are very participative and interested in project-based teaching. With that, learners' scores have improved (Wang et al., 2020). The participants stressed the importance of math in various aquaponics processes, including nutrient solution calculations, stocking density calculations, unit conversions, and pH level maintenance. Students need these computational abilities to learn about aquaponics and interact with it successfully. Students can improve their computing abilities and make connections between theoretical ideas and practical applications by introducing aquaponics into their studies.

Competencies that the Learning Package should Address

Integration of Aquaponics in Teaching Unit Conversion

Studying mathematics in different institutions that offer vocational courses like agriculture should adjust the skill chosen by students to use it in a variety of problems in the workplace (Fatimah & Prabawanto, 2020). Competencies that the learning package should address refer to the application of mathematical competencies and knowledge to precisely convert between different units within the factors of aquaponics. Under this theme are two supporting core ideas, which are (1) unit conversion

and (2) Integration in the aquaponics system.

Participants have stated that when it comes to competencies the learning package should address, they are most likely to share those aligned with the unit conversion. Participants stated that the most essential learning competency that involves unit conversion is the least learned competency in the 2nd quarter of the most recent school year. This concept is captured from the statements of all of the participants.

> *"In the second quarter, when it comes to measurement, of course, one of them is the measurement involving conversion of units. Like how to identify the data, the length; in water, the volume."* – T1

> *"If we base the document, the least learned in quarter 2 are conversion of units …"* – T3

Johnson et al. (2017) stated that mathematical concepts are social structures that students and teachers carry out collectively. According to the result of the Programme for International Student Assessment (PISA) 2018, the Philippines is one of the Organization for Economic Co-operation and Development (OECD) countries with the lowest score in reading, mathematics, and science, on par with Panama and the Dominican Republic (OECD, 2019). Solving for unit conversion serves as the primary focus of teachers for students who are less active in the 7th grade. The responses of the participants support this idea.

> *"As I can remember, students are underperforming on solving problems involving conversion of units. They find it hard to create ways even by manually solving the problem."* – T2

> *"In grade 7, we can involve measurement … to concretize in creating a module that has a relative in aquaponics … how many cubic units are needed in one drum."* – T1

> *"… have basic knowledge about conversion quantities … basic units like kilograms to grams, liters to millimeters … I have observed that most students were not able to solve basic conversions."* – E2

Participants highlighted that integrating unit conversion within an aquaponics system necessitates proficiency in converting units accurately. Consequently, the researchers identified two critical learning competencies under Unit Conversion: converting measurements between units in both the Metric and English systems, and solving problems involving unit conversions.

In addition to that, the researchers were able to target other related competencies from other related areas, such as applying basic mathematical operations used in calculating weights and measuring, designing products out of local, recyclable solid and liquid materials in making valuable products, constructing real-life structures using measures of quantities, and understanding the idea of revenue, expenses, and profit. These competencies are targeted due to the process of converting units of measurement, creating an output through a series of activities, and solving for profit to promote the Aquaponics System.

Proposed Teaching-Learning Prototype

Promoting Competencies through Self-discovery

Integrating Sustainable Agriculture in teaching Math and Science shows how amazing we can apply textual knowledge practically (BVS Team, 2021). It is to develop a learning prototype that promotes self-discovery and is also based on real-life situations and not merely focusing on hypothetical situations.

> *"… activities that are more on self-discovery and learning by doing. Activities that are more on actual basis and hands-on activities."* – T2

> *"… it would be better that situations are not hypothetical and involves discovery approach."* – T1

According to Krajcik and Shin (2014), Project-Based Learning (PjBL) engages students in constructing knowledge through the completion of meaningful projects and the development of real-world products. PjBL's core principle is to capture students' interest and stimulate critical thinking by enabling them to acquire and apply new knowledge to solve real-world problems (Indrawan, 2019).

Additionally, participants underscored the importance of fostering essential competencies such as critical thinking and problem-solving when designing a learning prototype. This approach ensures that students develop the crucial skills required for real-life situations.

> *"… in applying the concepts of mathematics to agriculture, there should be critical thinking, problem solving, and common sense most especially."* – T2

> *"… problem solving, there should be illustrations, integration of aquaponics, word problem, etc."* – T3

Bani-Hamad (2020) identified project-based learning as the most effective method for implementing 21st-century skills—such as critical thinking, creativity, collaboration, and communication. This approach equips students with the competencies necessary for future work and career success. This shows that PjBL will achieve the needed mathematical competencies, such as critical thinking and problem-solving through hands-on, self-discovery, and self-exploratory activities. Participants also emphasized promoting capabilities in integrating sustainable agriculture through self-discovery and project-based learning, encouraging the application of textual information in real-world circumstances. With the help of this method, students may actively participate in their education, gain a deeper comprehension of critical ideas, and prepare for opportunities and challenges in the agricultural industry and elsewhere.

By employing the Project-Based Learning approach, researchers designed the Learning Prototype to incorporate a sequence of hands-on activities, self-discovery, and exploratory tasks rooted in real-life scenarios. This method ensures that students develop realistic and achievable projects and present their work in creative ways. Through these activities, students are anticipated to attain all the targeted competencies.

CONCLUSION

Based on the results, hereunder were the conclusions drawn by the researchers: First, aquaponics has been unanimously recognized by all experts as a profitable agricultural technology, providing opportunities for income generation through the construction and operation of aquaponics systems. Incorporating aquaponics in mathematics education helps develop computational skills, enhances students' understanding of theoretical concepts through practical application, and improves their scores in project-based teaching. Second, mathematics plays a crucial role in successfully implementing and managing aquaponics systems, requiring specific computational skills and calculations for various aspects such as nutrient solution, fish density, and unit conversions. Also, participants emphasized the need for integrating unit conversion within the aquaponics system as an essential competency in the learning prototype, as it addresses the least learned competency and supports sustainable agriculture. Finally, the proposed teaching-learning prototype should foster competencies through self-discovery, focusing on real-life situations rather than hypothetical scenarios. This approach aims to engage students in meaningful projects, enhance critical thinking and problem-solving skills, and prepare them for future careers. Thus, Project-Based Learning (PjBL) emerges as an effective pedagogical strategy that aligns with the objective of promoting essential competencies, such as critical thinking and problem-solving, in developing a learning prototype for aquaponics education.

Additionally, the following are the suggestions that can help further the people who can benefit from the study. Future research may, first, explore the impact of integrating sustainable agriculture topics and mathematics in building aquaponics systems on students' learning outcomes and their ability to apply mathematical concepts in real-world contexts. Second, investigate the role of technology, such as ICT integration, in enhancing students' understanding and engagement with aquaponics systems. Third, investigate the effectiveness and implementation of the developed teaching-learning prototype in mathematics education. Also, school administrators should ensure educators have access to adequate resources, training, and help to implement aquaponics education effectively.

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