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Development of an Advanced Multisystem Aquaponic and Model for the Topic of Educational Aquaponic Design Technology in Malaysia

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ABSTRACT

This study aims to develop a Multisystem Aquaponic Model as a teaching aid for the Aquaponic Design topic within the Technology curriculum in Malaysian secondary schools. Specifically, the objectives are to identify the needs and key elements required for the development of the model, to design the Multisystem Aquaponic Model and to validate its use as an instructional tool for teaching Aquaponic Design. Grounded in constructivist learning theory and guided by the Analysis, Design, Development, Implementation, Evaluation (ADDIE) instructional design model, this study adopts a Design and Development Research (DDR) approach utilizing qualitative methods. Data were collected through interviews with three subject-matter experts—secondary school teachers specializing in Design and Technology. The interviews aimed to gather insights into the essential components for model development and to validate the final design. A structured interview protocol was employed to ensure consistency across expert feedback. The findings indicate that the Multisystem Aquaponic Model was well-received and deemed valid for use as a teaching aid. The availability of this model is expected to enhance student achievement, deepen conceptual understanding and serve as a valuable supplementary resource for learners.

1. Introduction

The topic of Aquaponic Design in the secondary school Design and Technology curriculum introduces students to agricultural technology that integrates aquatic animal farming with plant cultivation, utilizing water as the primary medium [4]. Students are expected to master eight subtopics, which include understanding the concept of aquaponics, identifying system components, sketching and constructing aquaponic system models and proposing design improvements [5]. A core element of this topic is Aquaponic System Design, which encompasses several models such as the *Raft System*, *Ebb and Flow* and *Nutrient Film Technique (NFT)*. The availability of this instructional

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tool is expected to enhance students' academic performance, improve conceptual understanding and serve as a supplementary reference for learners [1-3].

The use of teaching aids is therefore critical in enhancing students' conceptual understanding. Such tools help maintain learner focus while also fostering creativity and innovation in system design [6]. This study focuses on the development of a Multisystem Aquaponic Model as a teaching aid, which integrates multiple aquaponic system types into a single model. The goal is to improve students' comprehension of aquaponic systems through hands-on interaction and visual representation.

2. Literature Review

Students frequently encounter challenges in comprehending the concepts and interactions within aquaponic systems due to the limited availability of effective teaching aids. This often results in reliance on text-based and verbal explanations, which diminishes student engagement and restricts the practical application of teaching and learning processes [7]. Although educators acknowledge the significance of teaching aids, their utilization remains moderate [8]. The absence of such tools fosters passive and disengaging teaching methods, negatively affecting student motivation and comprehension [9]. Additionally, the lack of suitable teaching aids hinders students' ability to fully grasp the subject matter, underscoring the need for educators to employ creative teaching methods [10].

In light of these challenges, the development of a Multisystem Aquaponic Model as a teaching aid is essential for enhancing students' understanding through visualization and more interactive learning experiences. This study is guided by the constructivist learning theory, which emphasizes the construction of knowledge through experience and social interaction, wherein learning occurs via guided and active participation. The Multisystem Aquaponic Model is utilized in this study as a teaching aid that supports students' Zone of Proximal Development (ZPD) in mastering aquaponic design. By engaging with the model directly, receiving explanations from educators and integrating their prior experiences with fish farming and plant cultivation, students can better comprehend the principles of aquaponics.

This research also adopts the ADDIE model, which encompasses five key phases. The analysis phase identifies the needs and foundational elements required for model development. The design phase involves generating physical sketches informed by the analysis. The development phase focuses on creating the model based on these sketches. The implementation phase evaluates the model's effectiveness in an educational setting, while the evaluation phase assesses its overall suitability through expert interviews [11].

3. Problem Statement

Students consistently face challenges in understanding the concepts and interactions within aquaponic systems, largely due to the absence of effective teaching aids. This reliance on text-based and verbal explanations alone diminishes student engagement and limits the practical application of learning activities [7]. Although educators acknowledge the importance of teaching aids, their usage remains only moderate [7]. The lack of these resources results in passive and unengaging teaching methods, which adversely affect student motivation and comprehension [9]. Furthermore, the absence of suitable teaching aids contributes to students' inability to fully grasp the subject matter, emphasizing the critical role of teachers' creativity in instructional systems [10].

To address these issues, the development of a Multisystem Aquaponic Model as a teaching aid is essential. This model aims to enhance students' understanding by incorporating visualization and fostering a more interactive learning experience.

4. Methodology

4.1 Design Methodology

This study adopts the DDR approach to create a Multisystem Aquaponic Model as a teaching aid for the topic of Aquaponic Design. A qualitative research method, involving expert interviews, was employed to gather insights and validate the use of the model. Three experienced Design and Technology educators were selected as respondents. The research instrument, an interview protocol inventory, was developed to collect information on the requirements and validity of the model. Prior to conducting the interviews, the protocol was validated by experts, specifically lecturers from the Department of Engineering Technology at Sultan Idris Education University.

Structured interviews were carried out to gather detailed information regarding the key elements and validity of the model. The data collection process included recording the interview sessions and transcribing them to ensure accuracy. Thematic analysis was used to identify key themes aligned with the research objectives and to assess the validity of the model as a teaching aid.

The development of the Multisystem Aquaponic Model followed the ADDIE model, which encompasses five phases:

i. Analysis Phase: Identifying the needs and key components for the development of the teaching aid.
ii. Design Phase: Planning the structure and functionality of the model.
iii. Development Phase: Constructing the physical model based on the design.
iv. Implementation Phase: Testing the model and introducing it to educators through demonstration sessions.
v. Evaluation Phase: Ensuring the model's validity as a teaching aid through feedback provided by the teachers.

For a cylindrical tank, the equations related to flow rate, volume *v* and pressure were derived from physics principles and calculated using Eq. (1). In this study, these calculations provide foundational data for the water tank design and functionality within the aquaponic system.

$$V = (3.14159)HR^2 \quad (1)$$

The design of the cubical water tank will be modified based on the required volume for various design specifications. This process aims to develop a model that is both effective and aligned with educational needs. The system addresses the challenges students face in understanding the concepts and interactions within aquaponic systems, which are exacerbated by the lack of effective teaching aids. As a result, learning often relies solely on textual and verbal explanations, reducing student engagement and limiting the practical application of teaching and learning activities [7].

Although educators recognize the importance of teaching aids, their usage remains moderate [8]. The absence of such tools fosters passive and unengaging teaching methods, negatively impacting student motivation and comprehension [9]. Furthermore, the lack of appropriate teaching aids contributes to students' difficulties in fully grasping the subject matter, emphasizing the importance of incorporating creative teaching methods into instructional systems [10]. In response to these

challenges, the development of a Multisystem Aquaponic Model as a teaching aid is crucial. This model is intended to enhance students' understanding through visualization and interactive learning experiences. The study is conducted to achieve the following objectives to:

i. Identify the requirements and key elements for designing the Multisystem Aquaponic Model as a teaching aid for the topic of Aquaponic Design.
ii. Develop the design of the Multisystem Aquaponic Model and validate its use as a teaching aid for the topic of Aquaponic Design.

5.2 Conceptual Framework

The development of the Multisystem Aquaponic Model design as a teaching aid serves as the independent variable and affects the dependent variable, which is the validation level of the model for use as a teaching aid in the topic of Aquaponic Design. The following Figure 1 is the conceptual framework used in this study:

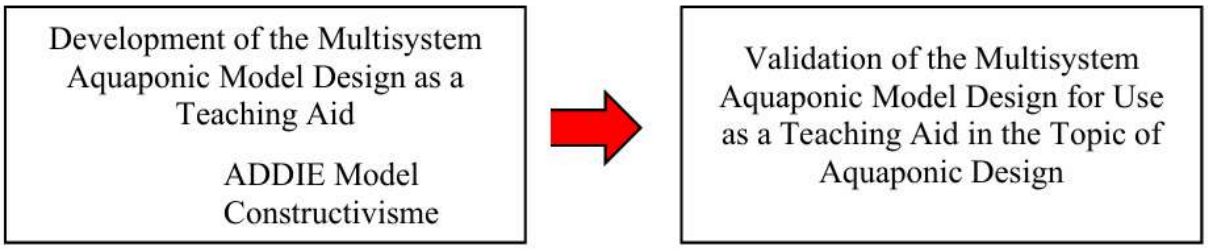

Fig. 1. Conceptual framework of the study

6. Results

The design phase in the ADDIE model utilizes data from the analysis phase to plan and determine key elements in developing the new Multisystem Aquaponic model as a teaching aid. This process includes selecting an appropriate design, choosing suitable materials, determining colour schemes and defining the size and functionality of the model. To ensure precision and accuracy, the researcher uses AutoCAD software to create detailed 2D sketches and technical drawings. This allows for better visualization and refinement of components such as the piping system, water tank and other essential elements. The finalized design serves as a structured guide for the model's construction, ensuring that it effectively facilitates students' understanding of the aquaponic system by providing a clear and comprehensive representation of its functions. The following Figure 2 are the 2D sketches of the new Multisystem Aquaponic model:

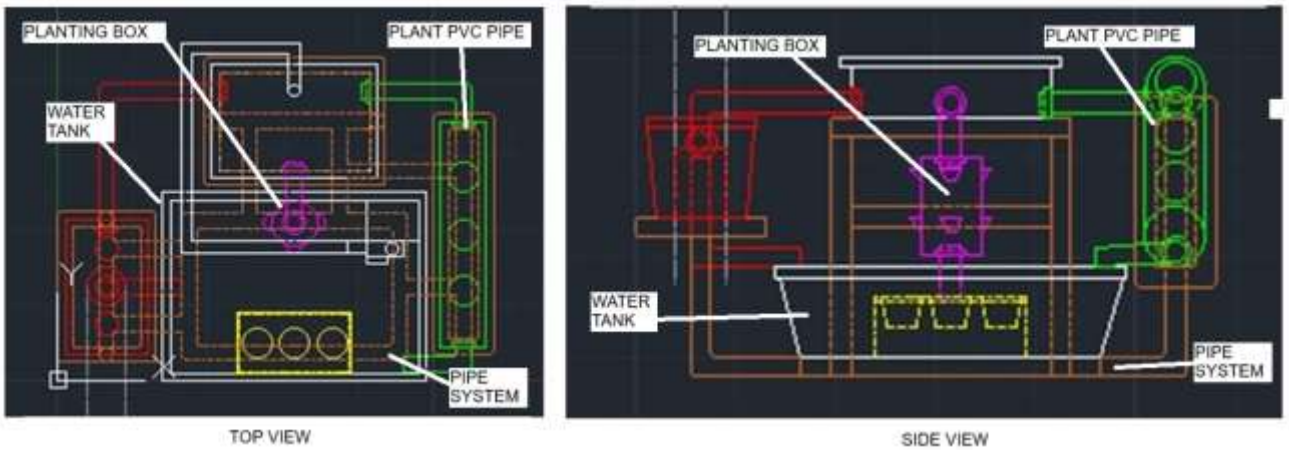

Fig. 2. 2D Sketch of the new multisystem aquaponic

The Raft system allows plants to float directly on water using materials like polystyrene, enabling direct nutrient absorption for faster growth [12-14]. However, it risks root rot and bacterial infections [13]. The Ebb & Flow system uses a siphon bell to regulate water flow in the planting medium, enhancing biofiltration but requiring continuous electricity and maintenance [14]. The NFT system, pioneered by Myers *et al.,* [15], circulates a thin nutrient film to plant roots, using minimal water but requiring additional filtration [16,17]. Vertical aquaponics system combines fish farming with soil-free planting, optimizing space but sometimes producing less flavourful crops [17]. This study integrates the vertical system into the Multisystem Aquaponic Model to expose students to diverse aquaponic techniques beyond textbook knowledge [18,19]. Figure 3 shows types of Aquaponic Systems.

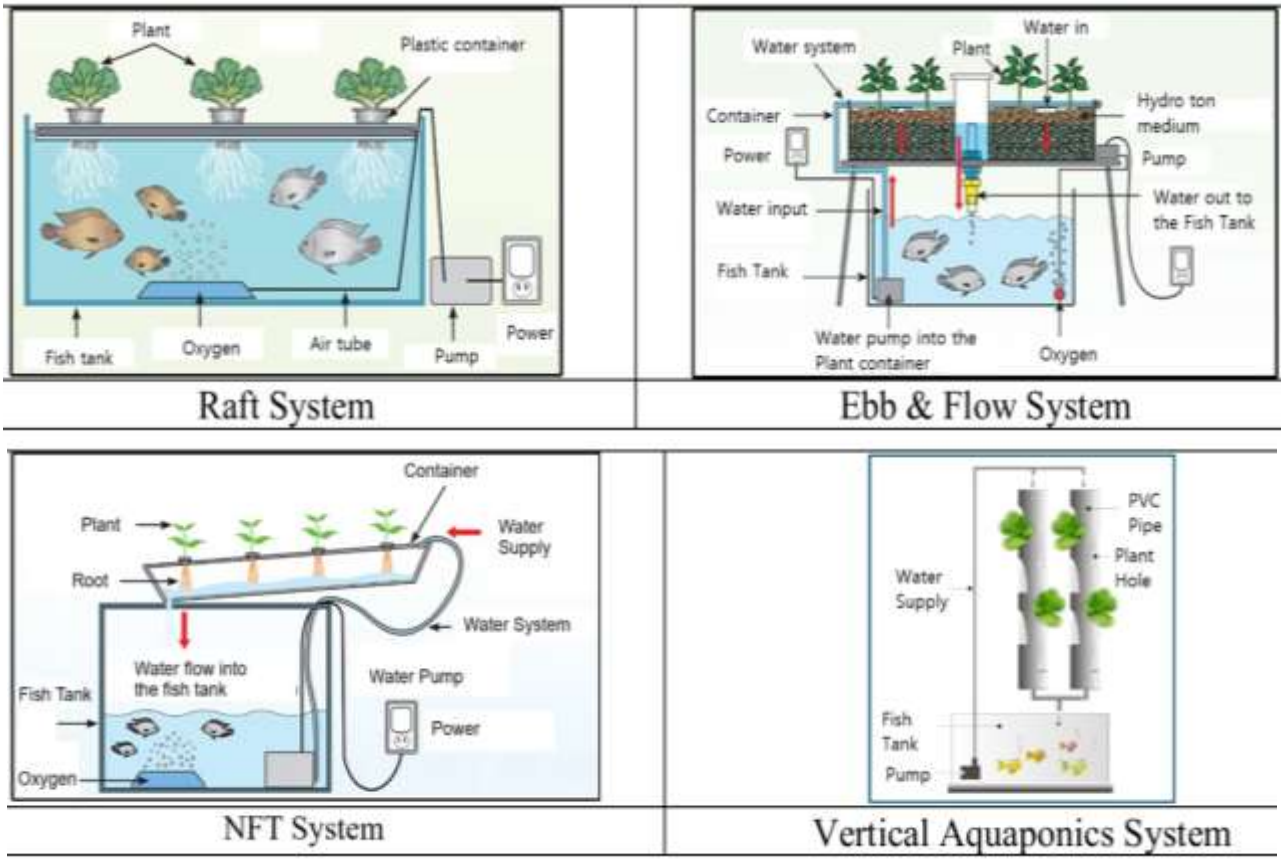

Fig. 3. Types of aquaponic systems [13]

This study uses the constructivist learning theory, which emphasizes the formation of knowledge through experience and social interaction, with learning occurring through guidance and active experience. In this study, the Multisystem Aquaponic Model is used as a teaching aid that supports students' ZPD in understanding Aquaponic Design [20]. Students can view the model directly, receive explanations from the teacher and connect their prior experiences with fish farming and plant cultivation to understand the concept of aquaponics [21-24]. This study also uses the ADDIE model, which consists of five phases: the analysis phase aims to identify the needs and key elements in developing the model; the design phase generates physical sketches based on the analysis; the development phase creates the model based on the sketches; the implementation phase tests the effectiveness of the model; and the evaluation phase assesses its suitability through expert interviews [25]. The development phase of the ADDIE model involves the construction of the Multisystem Aquaponic Model as a teaching aid for the *Aquaponic Design* topic. This process begins with the preparation of materials, including PVC pipes, plastic containers and other suitable components to ensure the model's durability and ease of use. The framework of the model is constructed by cutting and connecting the PVC pipes with adhesive according to the design specifications [26,27]. Next, the system components are assembled, which involves drilling holes in the NFT system, Ebb and Flow system, vertical aquaponic system and filtration tank to accommodate plant containers and connect the PVC pipes [28-30]. The final stage includes the finishing process, where different parts of the model are painted in distinct colours to differentiate each system: green for the NFT system, blue for the vertical aquaponic system, white-yellow for the Ebb and Flow system and red for the fish tank and filtration container [31]. Figure 4 shows processes of developing the New Multisystem Aquaponic Model.

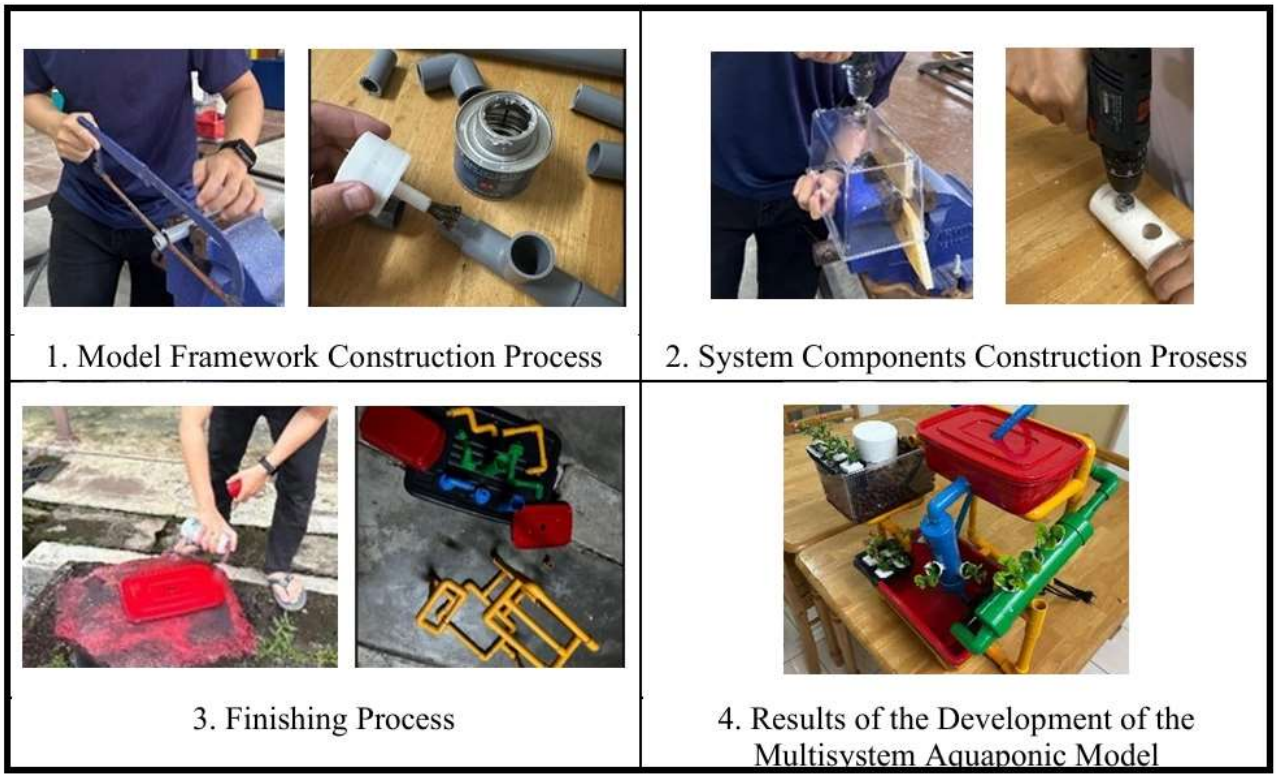

Fig. 4. Processes of developing the new multisystem aquaponic model

7. Conclusions and recommendations

This section of the discussion emphasizes the importance of developing the new Multisystem Aquaponic Model as a teaching aid, particularly in the context of Malaysia, where the absence of suitable teaching aids can impede students' understanding of complex topics such as aquaponic design. The study revealed that the model must effectively illustrate the aquaponic process, including the interaction between aquaculture and hydroponic systems, as well as key components such as fish, plants, piping systems and drainage mechanisms. Furthermore, the model must align with the learning objectives outlined in the secondary school curriculum to ensure it facilitates students' understanding of the fundamental concepts and functions of each system component. These findings highlight the critical role that appropriate teaching aids play in enhancing student comprehension and improving the overall effectiveness of teaching and learning in Malaysia's educational system.

Additionally, this section discusses the development and validation of the Multisystem Aquaponic Model as a teaching aid. The evaluation results indicate that the model meets the required criteria and has been successfully validated by experts. Teachers of Design and Technology provided positive feedback on the model's design and functionality, emphasizing that it enables students to clearly understand the aquaponic process in an interactive and engaging manner. The model effectively integrates key elements such as aquaculture systems, hydroponics and their interconnections, while also allowing students to physically manipulate its components. Its compact and lightweight design makes it well-suited for classroom use in Malaysian secondary schools. Experts recommended improvements, such as the inclusion of a user manual and enhancing material durability to ensure the model's longevity. These suggestions will help make the model a more widely adopted tool in Malaysian education, supporting a more hands-on, engaging and effective learning experience.

Based on the findings of the study, several recommendations have been proposed to improve the effectiveness of teaching aids for the Aquaponic Design topic in Malaysia. The teaching model should be designed to be simple, interactive and clear, with an emphasis on the relationship between aquaculture and hydroponic systems. To enhance student focus, the use of attractive and colourful materials is encouraged. A comprehensive user manual for both teachers and students are essential to ensure effective utilization. Durable materials and a modular design are recommended to guarantee long-term use. Furthermore, the integration of digital technologies, such as mobile applications and virtual reality (VR), can significantly enrich the learning experience. These recommendations aim to make the teaching and learning process more engaging and effective in Malaysian schools, while aligning with contemporary educational practices.

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