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Sains Humanika

A Case Study: Innovation of Technology for Prototyping an Aquaponic Mobile Starter Pack in The TVET Syllabus Use Design Development & Research (DDR)

Kajian Kes: Inovasi Teknologi untuk Memprototaip Pek Permulaan Mudah Alih Aquaponik dalam Sukatan Pelajaran TVET Menggunakan Pembangunan Reka Bentuk dan Penyelidikan (DDR)

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Abstract

This study aims to develop a mobile Aquaponics Teaching Aid prototype starter pack for teaching purposes in the Design and Technology course, focusing on rural schools in Selangor, Negeri Sembilan, Melaka, Perak, and Pahang using the Design & Development Research (DDR) model. The implementation involved various measurement techniques, including observations, interviews, and surveys in the first phase. Fuzzy Delphi and Delphi techniques were also used in the second and third phases. A total of 18 experts were involved in the development of this product, including teachers who have served in several schools and university lecturers. The structured research results indicate that the product improvement is highly necessary for the purpose of student development in schools, as well as keeping up with the technological advancements of the present time. This will enable students in rural areas to compete in the exploration of knowledge, especially in the field of aquaponics systems and agriculture.

Keywords: Aquaponic, Education, Design & Development Research (DDR), Starter Pack Product, Design and Technology Course

Abstrak

Kajian ini bertujuan untuk membangunan sebuah alat bantu mengajar (ABM) *starter pack* set akuaponik mudah alih bagi kegunaan pengajaran terhadap subjek Reka Bentuk dan Teknologi (RBT) yang berfokus di sekolah luar bandar di negeri Selangor, Negeri Sembilan, Melaka, Perak, dan Pahang menggunakan model Penyelidikan Reka Bentuk dan Pembangunan (DDR). Pelaksanaan kajian ini melibatkan pelbagai teknik pengukuran, termasuklah pemerhatian, temu bual, dan tinjauan awal dalam fasa pertama. Teknik *Fuzzy Delphi* dan *Delphi* turut digunakan dalam fasa kedua dan ketiga. Seramai 18 orang pakar terlibat dalam pembangunan produk ini, termasuk guru-guru yang pernah berkhidmat di beberapa sekolah serta pensyarah di universiti. Hasil kajian menunjukkan bahawa penambahbaikan produk amat diperlukan untuk tujuan pembangunan murid di sekolah, sekaligus mengekalkan perkembangan teknologi masa kini. Perkara ini akan membolehkan murid di kawasan luar bandar dapat bersaing dalam penerokaan ilmu, terutamanya dalam bidang sistem akuaponik dan pertanian.

Kata kunci: Akuaponik, Pendidikan, Penyelidikan Reka Bentuk & Pembangunan (DDR), Produk Mudah Alih, Reka Bentuk dan Teknologi (RBT)

1.0 INTRODUCTION

The field of education is one of the critical sectors in a country for developing a potentially advanced society that can progress economically, politically, and socially. It holds its own significance in advancing the country on a global scale (Omongaldi, 2023). It is essential to understand that every individual undergoes formal schooling from the age of 5 to 18, which is then extended to higher levels (Raharjo et al., 2023). The best education system encompasses the diversity of Malaysian society and serves as a continuum for each individual to contribute to the nation's future by developing 21st-century (PAK21) skills (critical thinking, creativity, and holistic student character development) (Radin & Yasin, 2018). Quality education can be achieved through effective learning phases that can attain learning outcomes and objectives as specified in the Malaysia Curriculum and Assessment Standard Document (DSKP) or specific guidelines (Saifuddin & Kiong, 2018). In this context, teachers play a crucial role in teaching and educating students in the classroom (Aliyeva, 2023).

The role of a teacher as an educator is significant. Individuals bearing the title of a teacher must actively engage students in the classroom, provide clear explanations of the subject matter, integrate activities within the classroom, and relate them to core values in the learning process (Saifuddin & Kiong, 2018; Sulaiman et al., 2020). PAK21 in education emphasizes that every teacher should focus on fostering creative, critical, and innovative thinking in students and encouraging the holistic development of students' characters to fulfill the government's objectives as outlined in the Malaysia Education Blueprint (PPPM) (2021-2025) policy (Radin & Yasin, 2018). Moreover, the PPPM (2021-2025) highlights the role of a teacher in enhancing the professionalism of teachers, aiming to produce skilled students capable of adapting to changing environments (Sulaiman et al., 2020). PAK21 is an appropriate approach aligned with the globalization era in nurturing a skilled and competent generation (Radin & Yasin, 2018; Saidin et al., 2023) by integrating literacy skills, knowledge competency, good attitudes, and wise technology management, especially considering the rapidly advancing technological progress day by day (Fawaid et al., 2022). The effectiveness of teaching and facilitating (PdPc), based on PAK21, depends on a teacher's skills and willingness to shape the learning process in the classroom (Chhetri et al., 2020). Hence, the importance of teachers having creative, critical, and innovative thinking, as well as flexibility in adapting to changes in the teaching and learning process, is crucial, reflecting the rapid technological advancements in today's world (Sahaat & Nasri, 2020; Saidin et al., 2023).

The Ministry of Education (KPM) has provided several plans and methods to offer technology-based exposure and education (Chan, 2023). In 2017, KPM implemented and established KSSM, the Secondary School Standard Curriculum, which contains several crucial elements within the PPPM (Chin, 2023). KSSM introduced a new subject, and subject areas called "Reka Bentuk dan Teknologi" (RBT), which replaced the "Kemahiran Hidup Bersepadu" (KHB) subject and subject areas introduced since 1988 for students in Form 1 to Form 3 in daily secondary schools (Awi & Zulkifri, 2021; Yusoff et al., 2023). Referring to the topics taught, the RBT subject focuses on four aspects: design appreciation, technology application, product manufacturing, and product design assessment (Ismail & Che Kob, 2023). The subject aims to provide early exposure to young people to higher-order thinking known as Higher Order Thinking Skills (KBAT) (Kemahiran Berfikir Aras Tinggi) (Mahat & Haji Othman, 2023). According to KPM, the RBT subject is not only aimed at providing knowledge to students in using technology but is also one of the ministry's alternatives to produce students capable of improving, upgrading, and creating new technologies (Ibrahim, 2023).

RMK 10 (2011 – 2015) shows that a significant turning point in the Technical and Vocational Education (TVET) system is essential to develop a skilled workforce in the future as an initial step in implementing PAK21 (Flaherty et al., 2023; Saary & Zainuddin, 2020). The KPM has planned for TVET 4.0 (2018 – 2025) built on six (6) core areas and supported by 11 strategies to achieve the government's main objective in making the TVET education system globally competitive (Aizat et al., 2020; Rajikal & Isa Hamzah, 2020). TVET education places a strong emphasis on psychomotor skills (physical and practical) because this skill set is oriented towards the world of work (Sulaiman et al., 2020), which demands specific skills in operating various technologies (Ogur, 2023).

In general, learning styles can be divided into three aspects: visual (sight), auditory (hearing), and kinesthetic (movement) (Simatupang, 2019), also known as the VAK learning model (Abdullah et al., 2021; Yusof et al., 2023). Learning styles are a crucial element that teachers need to carefully consider before starting a teaching session because they can determine whether the objectives and goals of a learning topic are achieved or not (Maddukelleng et al., 2023). The importance of learning styles is associated with how students process and analyze information in the brain to acquire knowledge (Simatupang, 2019). It is undeniable that although each student has their own learning style, in general, they require assistance, support, and encouragement in their learning (Flaherty et al., 2023). Therefore, every student, and especially teachers in the classroom, needs to be aware of learning styles to identify suitable learning patterns and strategies for achieving higher academic levels. This can optimize and enhance the teaching and learning experience (Rahmawati, 2023).

One of the approaches adopted by teachers is the creation of a learning aid in their teaching. This learning aid encompasses all the tools used by teachers to enhance more effective teaching, including visual aids, audio materials, hands-on activities, reading materials, storytelling, smelling, using, and more (Padzil et al., 2021). It can help teachers explain concepts more clearly compared to oral explanations (Jaya et al., 2021). This approach can be associated with the visual learning style, which involves processing a learning topic into a visual format that can be seen, touched, and tested for its effectiveness, helping students understand the subtopics they are learning (Perumal et al., 2022). The constructivist theory that underpins student-centered learning encourages the use of media and learning aid in the classroom to enhance each student's thinking capacity. This aligns with PAK21 in determining a more strategic approach and methods that are engaging and suitable for the needs and potential of students today (Harefa et al., 2023). Additionally, the tendency of this learning style manifests in a higher visual form that can be received and applied in real-life situations (Perumal et al., 2022).

Aquaponics is referred to as a system that combines Aquaculture (freshwater fish farming) and Hydroponics (water-based agriculture) (Salman Shabbir et al., 2019), which is crucial for the economic development of the country, especially in Malaysia, as it is seen as capable of creating 2,000 job opportunities and targeting as much as 15,000 metric tons of freshwater aquaculture by 2025 (Hanafi et al., 2023). Therefore, the need for technology in developing technology-based aquaponics systems is necessary to achieve the best quality in various aspects such as water quality parameters, movement status, and monitoring without manual inspections, known as IoT technology. The operation of aquaponics is simple, where fish release food waste containing ammonia and waste for plants, which are converted into nitrate

and nutrients (serving as fertilizer for plants). The plants then release oxygen and water for fish growth (Zulkipli et al., 2019). Water pumps are one of the essential tools for maintaining the water cycle in an aquaponics system (Samsi et al., 2023).

In this study, the topic of Aquaponic System Design is the focus for the development of learning aid. Aquaponic System Design encompasses various types of systems and components that require a high level of mastery (Febriyananda Putri et al., 2023; Samsi et al., 2023). An appropriate learning aid needs to be developed to reduce students' difficulties in understanding the learning topic. According to the research, the performance of student groups involved in teaching methods using tools or simulation links and teaching modules in one of the Aquaponic System Design topics at the second level is better than student groups involved in conventional teaching methods (Agus et al., 2022). This indicates that the use of teaching aids (ABM) in the teaching and learning process is effective and achieves learning objectives. Additionally, the development of ABM for aquaponic systems can have a positive impact, not only enhancing students' understanding but also facilitating teachers in conducting the teaching and learning process (Yusoff et al., 2023).

The innovation in aquaponic systems will facilitate both students and teachers, especially in assisting the teaching and learning process in the classroom or at home (self-learning). Through this study, it can provide an understanding and convenience to students by identifying components of the aquaponic system and their functions. This portable Aquaponics Starter Pack also employs the concept of portability, allowing it to be taken anywhere. With the help of learning aid, the previously textbook-dependent teaching and learning process can be diversified in its delivery to students, ultimately introducing an element of enjoyment in learning (Ayub et al., 2019). The research objective is to identify, develop, and assess the opinions of experts on the portable aquaponic system's application in schools using the Fuzzy Delphi & Delphi techniques, which are based on expert opinions to address complex problems in reaching consensus or agreement (Perumal et al., 2022; Sulaiman et al., 2020).

2.0 TVET IN SCHOOL

TVET programs in Malaysia are offered to individuals with Malaysian Certificate of Education (SPM) certification, diplomas, and degrees by seven ministries, including the KPM and the Ministry of Higher Education (KPT) that offer TVET education (Abd Shukor & Masroom, 2020). Vocational education is provided at various levels, including primary school graduates, vocational colleges, community colleges, polytechnics, and universities. One of the reasons for the existence of technical and vocational programs is the demand for jobs in various skill areas (Saary & Zainuddin, 2020). The government continuously plans, promotes, and coordinates TVET program strategies in line with the economic, technological, agricultural, and societal needs of Malaysia (Bai & Paryano, 2019) , to create job opportunities for local communities and enable the country to compete globally. According to reports from the Bank Negara, the percentage of TVET programs in Malaysia increased significantly, from 22% in 2010 to 31% in 2017 (Aizat et al., 2020). It is clear that society at that time saw TVET programs as a means to enhance the quality of individuals' lives. As a result, the teaching and learning process must be introduced early to ensure that there are no gaps in the curriculum in schools and higher education centers.

The teaching and learning process in today's era no longer focuses on cooperative learning methods that use one-way communication but places the student as the central figure in the classroom, with the teacher or educator serving as a facilitator during teaching and learning sessions (Perumal et al., 2022). Furthermore, the need to enhance creativity skills in order to create an effective teaching and learning process is essential to meet the demands of contemporary education. With the diversity in learning, students will be more interested and enjoy the learning sessions.

Chong and Sungap (2021) categorizes several learning resources, namely, (i) humans (in the family, school, and society); (ii) books/libraries; (iii) mass media (magazines, newspapers, radio, television, etc.); (iv) the environment; (v) teaching tools (textbooks, maps, images, whiteboards, projectors, etc.); and (vi) museums, gardens, farms, etc. Referring to this statement, this learning aid can be categorized as a teaching tool defined as a visual material that can generate interest, enjoyment, and a deep sense of curiosity towards the learning topic (Chong & Sungap, 2021).

According to the study by Bailey and Van Harken, there are three findings obtained: (i) the use of visual images can help reduce students' anxiety about the research process and explain the role of researchers; (ii) enhance clarity in observation and more accurate interpretation of what is seen, and (iii) students can provide theoretical views, future predictions, and proactive classroom practices (Mansor et al., 2023). Through these points, the use of such learning aids, such as this mobile aquaponics system, can directly and indirectly help students avoid feeling bored and losing focus during the teaching and learning sessions.

This study is also based on cognitive theory, which plays a role as an agent of thinking and assessing and understanding each form of material provided by educators, namely teachers to students. The word "cognitive" comes from the English word that means related to something or consciously involved in something, involving mental or conscious activities (such as thinking, reasoning, or remembering) that has been used since 1586 (Indarta et al., 2021). Through this theory, cognitive theory places more emphasis on the learning process than the learning outcomes. By involving a learning aid in learning, students can experience the learning process from the beginning to the end, which then leads them to KBAT, besides ensuring that the concepts and principles of a learning topic can be focused on during the teaching and learning process (Radin & Yasin, 2018).

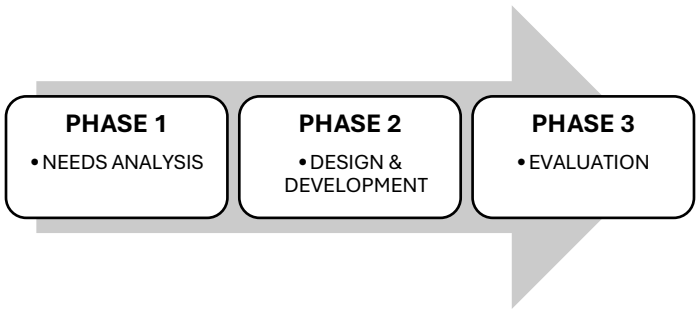


Figure 1 DDR method and technique

This study employs the Design and Development Research (DDR) model to develop a mobile aquaponics system. DDR is often used for the development and testing of a product to ensure its usability before large-scale production (Long & Mustapha, 2019). DDR is a unique, comprehensive, and systematic research method for products that are still in the development process (Saifuddin & Kiong, 2018). It is further validated and can be relied upon by experts. DDR can be divided into three phases: requirement analysis, design and development, and assessment (Saifuddin & Kiong, 2018; Samsi et al., 2023), as seen in Figure 1.

The requirement analysis phase involves determining whether a study is necessary through various methods, such as qualitative, quantitative, or mixed methods based on research (Long & Mustapha, 2019; Odema et al., 2018). The subsequent phase is the design and development phase, emphasizing the planning and development of a product that can address problems. The Fuzzy Delphi technique is used in the second phase, and the Delphi technique is employed in the third phase to obtain expert consensus on the developed product. The Fuzzy Delphi ranking will produce three values: minimum, most reasonable, and maximum values chosen by the experts (Danacı & Yıldırım, 2023). The final phase is the assessment phase, which focuses on evaluating the product's impact on various stakeholders through internal or external evaluations. This phase must follow the measurement method procedures to be used (Tuni et al., 2023).

The use of the mobile aquaponics system learning aid will serve as a tool that benefits users (students and teachers) throughout the teaching and learning process (Ewar et al., 2023). Information delivery (input) along with the use of various materials in the classroom will create a more enjoyable and effective learning environment, promoting better communication and interaction between students and teachers (Wulandari et al., 2023).

■3.0 MATERIALS AND METHODS PROPOSED

This study adopts the DDR approach pioneered by Richey and Klein (Yong et al., 2023). The study emphasizes that the use of the DDR approach is highly systematic and structured, involving only three essential phases: requirement analysis, design & development, and assessment. Ellis & Levy also state that the DDR approach can serve as a guide in research, including the generation of new theories to solve problems, the design and development of new models in various fields of study, and the development of new methods and processes in the implementation of existing models or equipment (Kamaruddin & Masnan, 2023).

In the requirement analysis phase, observations were conducted in the school environment. Initial information revealed limitations in the teaching and facilitation process for subjects related to agriculture, especially in the areas of fertigation, aquaponics, and hydroponics. Upon further investigation, it was found that the learning aid used by teachers and students was not suitable and could not achieve the learning objectives due to factors such as malfunctioning learning aid and the use of outdated ones. As a result of these observations, interviews were conducted with five teachers to gain a clearer picture. The findings revealed that teachers faced challenges in the teaching and learning process due to the inadequate functionality of the learning aid.

The interview findings inspired the development of a new product that aligns with current needs. Once the basic idea was sketched out, the next step was to create the product using 3D computer-aided design software, specifically AutoCAD, with the goal of producing a new and improved product. The final step in the product development process was the creation of a prototype using actual materials based on the previously generated dimensions and designs.

During this phase, a questionnaire instrument based on Fuzzy Delphi standards was developed, involving several experts as research respondents. The Fuzzy Delphi technique was used in this phase because it combines Fuzzy Logic and Delphi methods, which are used to gather, organize, and obtain the opinions of a group of experts in the context of complex decision-making or predicting future situations. This technique offers several advantages, such as efficient data collection.

For the final phase, which is the Evaluation Phase, the chosen technique is the Delphi technique, which consists of several components, and the questionnaire instrument is distributed to the appointed experts. Two rounds of expert validation are conducted in this phase. In the first round, the survey form is distributed to obtain opinions and suggestions from the experts, and subsequently, the researcher will make improvements based on the suggestions from the experts in the first round.

The use of the Delphi technique in this phase is because it is a method used to gather opinions from a group of experts. This technique has several advantages that make it a choice in decision-making, such as having a comprehensive approach, and experts can provide their opinions anonymously or hide their identities without being known publicly. It can help avoid the influence of hierarchy or domination by a specific individual or group.

Table 1 Research Methodology using Design, Development & Research Case Study

	Phase	Sequential Process	Instrumentation	Technique	Respondent
1	Needs Analysis	1. The researcher conducted observations during teaching sessions and identified limitations in subject-based RBT and agriculture teaching sessions. 2. The researcher evaluated the existing learning aid and areas for improvement.	Instrumentation 1	Observation Interview	Teacher
2	Design & Development	1. Evaluate findings from conducted interviews. 2. Sketch product designs using pencils for easy modification as needed. 3. Create component and overall drawings using Autocad software. 4. Develop learning aid product functionality. 5. Develop a survey based on Fuzzy Delphi standards.	Instrumentation 2	Fuzzy Delphi Method	Teacher
3	Evaluation	1. Develop an instrument based on Delphi technique. 2. Distribute the instrument to 2 rounds of appointed experts. 3. Analyses of expert feedback and suggestions.	Instrumentation 3	Delphi Method	Teacher & Lecturer

Overall, this study was conducted based on Table 1 as shown above. The classification into the 3 main phases of the study was guided by the DDR method and appropriate techniques to achieve the objectives of the study. Each phase underwent meticulous evaluation processes before any views and conclusions were drawn. It is worth noting that the suitability of respondents in each phase is crucial to the stability of the findings obtained. Three instruments were developed as clear assessment mediums, indicating that the DDR Model is effective in problem-solving and product development.

Table 2 Research Methodology using Design, Development & Research Case Study

	Phase	Occupation	Number	Field	Experience (Years)
1	Needs Analysis	• Teacher	5	Design and Technology	5 ~ 15
2	Product Design and Development	• Lecturer • Teacher • Technician • Private sector employees	10	Experience in Technical and Vocational Education and Training (TVET)	3 ~ 20
3	Evaluation	• Head of RBT subject committee	1	Head of RBT subject committee since 2020	18
		• Senior teacher of Technical and Vocational subject	1	Senior teacher of Technical and Vocational subject since 2022	12
		• Senior Lecturer in Agricultural Sciences Department	1	Senior university lecturer in the agricultural education sector	6 ~ 15

The study was conducted in five selected rural secondary schools in Selangor, Negeri Sembilan, Melaka, Perak, and Pahang. Five teachers were chosen as research respondents. The respondents consisted of experienced educators in the field of education, specifically teaching Design and Technology.

Based on Table 2, the profile of the respondents for the needs analysis was selected, and they had varying levels of experience and years of service. The next phase involved ten experts who were involved in determining the design and development of products with experience in the field of Technical and Vocational Education and Training (TVET). The product evaluation study in the third phase involved three experts using the Delphi method. Through the data obtained, the researcher was able to make conclusions regarding the development of this mobile aquaponics system.

3.1 Development Of A Mobile Aquaponics Product

Product development is the process of designing, developing, and producing a product that meets specified requirements. This process involves various stages, starting from the initial idea to the successful production of the product. For the initial development of this product, the researcher took into account all the suggestions and expectations provided by teachers during the needs analysis. The researcher needed to create a product that could assist both students and teachers in the PDCP process. This product was also expected to be easily transportable and usable anywhere without significant obstacles. Therefore, the researcher sketched suitable components for the product using pencil drawings for easy adjustments. The resulting product should be easy to obtain, easy to assemble, and suitable for students at different skill levels.

The development of the product required specific research to ensure its production was efficient and organized. Hence, guidance was necessary to prevent deviation from the initial planning. The use of AutoCAD software was highly suitable for obtaining an overall view of the intended product. Subsequently, the researcher developed the full functionality of the product using readily available tools and materials.

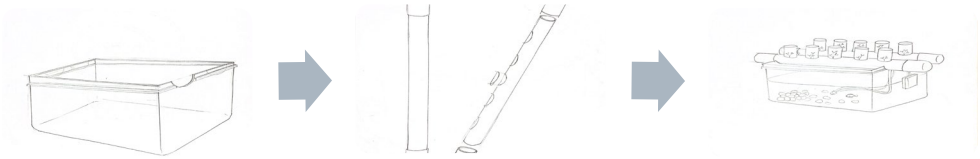
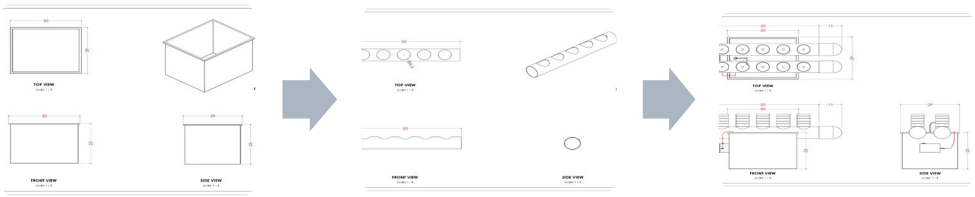
No.	Activity	Diagram Simulation Description
1	Sketches	
2	3D Drawing	
3	Installation process	

Figure 2 Sketching process, 3D drawing, and product installation process.

The article discusses the materials and tools used in the development of the learning materials primarily focusing on the use of readily available recycling materials from the home environment to save costs, as the learning aid system is intended to be developed in collaboration with students. Therefore, financial considerations also need to be taken into account by the researcher. The researcher independently develops the product to ensure that it can be later developed independently and used as a practical exercise for students.

In the initial stage, the researcher collects the necessary materials and tools, such as drinking water bottles, PVC pipes, multipurpose containers, and other easily obtainable items. In the subsequent stage, the researcher will develop the product based on AutoCAD designs, and in the final stage, electronic tools like the Battery Management System (BMS) and electronic water pumps will be used to create this aquaponic system. Refer to Figure 2.

The researcher has used easy-to-handle equipment, such as cutting knives and hole drill saws, with only these two tools being employed to develop the product. Safety is emphasized to prevent any accidents.

■4.0 RESEARCH FINDINGS

The research findings are based on the analysis of the requirements conducted, survey questionnaires distributed during the product development phase, and questionnaires developed for distribution to experts during the testing phase. The obtained findings are crucial for the development of a more efficient product, and the advice and feedback provided by appointed experts have been very helpful throughout the researcher's product development process.

4.1 Requirement Analysis Phase 1

Findings from the requirement analysis process in the first phase of the study indicate that the learning aid used by teachers in the learning and facilitation process are merely mock-up/models and do not function. Using non-functional learning aid has led to students having a limited understanding of how the aquaponic system operates. Furthermore, the study revealed that the learning aid used are impractical and at times have a large physical size, making their storage difficult.

The learning aid at the Green House of the school are permanent and cannot be relocated. Observations also found that these permanent learning aid rely on a single power source and lack alternative power sources. This will lead to potential issues in the aquaponic system in the future if specific attention, such as weekend maintenance, is not provided, and inclement weather may force teachers to attend school to ensure a continuous power supply to prevent water pump system failures.

The final results from the conducted interview instruments suggest a high need to develop this product based on the responses from the participating teachers. Table 3 below summarizes the justifications provided by the teachers.

Table 3 Assessment Summary by the Panel in Phase 1

No	Panel	Justification
1	Teacher A	*"Yes, I believe that having a portable aquaponics learning aid system would make it easy. Students can take it back home and it won't clutter the workshop. After a certain period, students can bring back this aquaponics system to school for evaluation if we conduct practicals with them."*
2	Teacher B	*"It would be great if there's a system that can be powered by a power bank. It would save teachers from having to come on weekends to ensure the water pumps are running smoothly. Teachers won't have to bother the security guard to check on the aquaponics system late at night."*
3	Teacher C	*"Initially, I was a bit perplexed about creating a learning aid for aquaponics because these systems are usually expensive, and students may not have enough funds if we want to do practicals with them. Moreover, I often see aquaponics systems set up in fish ponds."*

The study's findings also revealed a high demand for the creation of a mobile aquaponics system that can be used both inside and outside the classroom in the professional development process. The interviewed teachers provided positive insights on the topics discussed and expressed hope for suggestions to develop a Mobile Aquaponics System (MAS) that can provide solutions to the challenges and concerns faced by educators.

4.2 Design & Development In Phase 2

The results of the Phase 2 study, which utilized the Fuzzy Delphi technique, found that all 10 appointed experts provided positive findings and subsequently agreed with the product developed based on the data in Figure 3 below. All the experts met the primary criteria of Fuzzy Delphi, and the overall group agreement percentage obtained a full score of 100%. Only 2 experts scored 96%. The findings also revealed that the threshold value, d, obtained by all the experts exceeded 0.065%. Regarding the ranking, Expert 8, Expert 5, and Expert 6 secured the first, second, and third positions, while the last position was held by Expert 7 with a threshold score of 0.066.

Bil	Item / Elemen	Syarat *Triangular Fuzzy Numbers*		Syarat *Fuzzy Evaluation Process*				Kesepakatan Pakar	Elemen DITERIMA	Ranking
		Nilai *Threshold* , d	Peratus Kesepakatan Kumpulan Pakar, %	m1	m2	m3	Skor *Fuzzy (A)*			
1	Pakar`1	0.086	96.0%	0.788	0.940	0.996	0.908	TERIMA	0.908	8
2	Pakar 2	0.075	100.0%	0.788	0.944	1.000	0.911	TERIMA	0.911	6
3	Pakar 3	0.084	96.0%	0.780	0.936	0.996	0.904	TERIMA	0.904	9
4	Pakar 4	0.076	100.00%	0.804	0.952	1.000	0.919	TERIMA	0.919	5
5	Pakar 5	0.073	100.00%	0.820	0.960	1.000	0.927	TERIMA	0.927	2
6	Pakar 6	0.075	100.00%	0.812	0.956	1.000	0.923	TERIMA	0.923	3
7	Pakar 7	0.066	100.00%	0.764	0.932	1.000	0.899	TERIMA	0.899	10
8	Pakar 8	0.070	100.00%	0.828	0.964	1.000	0.931	TERIMA	0.931	1
9	Pakar 9	0.075	100.00%	0.788	0.944	1.000	0.911	TERIMA	0.911	6
10	Pakar 10	0.075	100.00%	0.812	0.956	1.000	0.923	TERIMA	0.923	3

LINK OF SYSTEM	
Peratus	Results
0%	TOLAK
100%	TERIMA

Figure 3 Fuzzy Delphi Technique Result on Phase 2

4.3 Evaluation Phase 3

In the first stage of evaluating the product produced, the percentage of Delphi instrument ratings, as shown in Table 4, was assessed. Expert A accounted for 85% of the total, with highly satisfactory ratings of 4 and 5 points. Additionally, the panel recommended improving the product by requesting that the PVC pipe used as a tool for seed sowing be easily stored in the versatile container if not in use. The experts found that if the practice is not followed, the created product should be storage-friendly, and it could be considered to divide the PVC pipe into two parts and store them in the same container to save space.

Table 4 Delphi Score (Round 1)

Question List		Expert		
		A	B	C
A	i.	5	4	3
	ii.	4	4	4
	iii.	4	3	4
	iv.	5	5	4
	v.	4	4	4
B	i.	4	5	4

	ii.	4	5	4
	iii.	5	4	3
	iv.	4	4	4
	v.	4	4	4
C	i.	4	4	4
	ii.	4	4	3
	iii.	4	3	4
	iv.	5	4	4
	v.	4	4	4
Total Marks (75)		64	61	57
Percentage %		85%	81%	76%

The percentage for Expert Group B is 81% of the total, with satisfactory ratings, which are scores 3, 4, and 5. Additionally, the panel believes that improvements can be made to the versatile container to make it more student-friendly and easier to carry home. Experts suggest that students face difficulty in carrying heavy items back home, and it is hoped that adding wheels to the versatile container can make it easier for students to transport their equipment for either home or storage.

Expert Group C, on the other hand, accounts for 76% of the total score, which is 100%. The scoring evaluation is also satisfactory, with scores of 3, 4, and 5. Furthermore, the panel agrees with the product's development but hopes that a product development manual can be provided for student and teacher reference. A manual is crucial in assisting teachers and students in the product development process in the future.

Table 5 Justifications of expert consensus in Delphi (Round 1)

No	Panel	Justification
1	Expert A	*"If possible, the PVC pipe used can be separated into 2 parts, making it easy to store in a container."*
2	Expert B	*"It's even better if the multipurpose container has wheels, so students can push it if they want to move it."*
3	Expert C	*"A manual can be provided, teachers and students can refer to the manual if they want to assemble the product later."*

Based on Table 5, it can be observed that the idea behind the development of this product is to have a positive impact on agricultural product development, especially in enhancing the field of technical and vocational education. However, based on the results of the first round of this Delphi technique, several improvement ideas were suggested by the panel. Expert A suggested that the PVC pipes used can be divided into 2 or more sections for easier storage. Expert B recommended the addition of wheel components to the multipurpose container, while Expert C proposed creating a product development manual for future reference by teachers and students. The findings from all these suggestions have led to improvements in the product.

Moving on to the second round, the Delphi technique results, as shown in Table 5, indicate that the responses from all three panelists were highly favorable, with a 100% agreement among all three experts, achieving a full score. For Expert A, the percentage obtained was 100%, and the rating for the assessment was excellent, with a total of 5 marks. Expert B also scored 100% with an excellent rating of 5 marks for all questions. As for Expert C, the percentage obtained was also 100%, and the rating for the assessment was at a very good level, with 5 marks for each question.

Table 6 Delphi Score (Round 2)

Question List		Expert		
		A	B	C
A	i.	5	5	5
	ii.	5	5	5
	iii.	5	5	5
	iv.	5	5	5
	v.	5	5	5
B	i.	5	5	5
	ii.	5	5	5
	iii.	5	5	5
	iv.	5	5	5
	v.	5	5	5
C	i.	5	5	5
	ii.	5	5	5
	iii.	5	5	5
	iv.	5	5	5
	v.	5	5	5
Total Marks (75)		75	75	75
Percentage %		100%	100%	100%

The article discusses the impressive results in the second round, which were influenced by the recommendations for improvements made by the Expert Panel in the first round. The suggestions put forward were substantial and considered necessary to implement. Each expert's recommendations were taken seriously, as every improvement made would impact the scores in the second round. The improvements

carried out in accordance with the provided suggestions and the excellent work presented to each expert had an effect on the total scores. Table 4 indicates that there were experts who still provided scores on scales 3 and 4, but after the improvements were made based on the recommendations, Table 6 shows that all experts were satisfied with the enhancements that were implemented.

■5.0 FUTURE RESEARCH RECOMMENDATIONS

The findings and results of the conducted research lead to several recommendations that can serve as guidelines for future studies. Possible research recommendations include adding additional power sources, such as solar power sources capable of generating electricity from sunlight. Solar panels are readily available from various suppliers at reasonable prices, and their installation is easy and energy-efficient. The use of solar energy is highly encouraged to preserve the environment and breathe new life into the agricultural sector on a smaller scale within the country.

■6.0 CONCLUSION

In conclusion, the developed product is a highly essential and suitable learning aid product for use in agriculture and the Technical & Vocational field. Based on observations and interviews conducted in the first phase, there is a clear need for a mobile aquaponics product. This product underwent several design iterations to provide an initial concept before being developed. After its development, several experts were appointed to examine the concept and product design to ensure that it was truly necessary and suitable. Furthermore, three experts in the relevant fields were appointed to evaluate the functionality of the developed product. Two rounds of questioning were conducted to ensure that the developed and improved product fully met the standards, recommendations, and requirements provided by the experts. The use of the DDR method for this research was highly appropriate, as it allowed a group of experts to contribute their insights during the product development process.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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