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Harnessing Fuzzy Delphi: Designing the innovative DiD-Art application

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Abstract
This research aimed to develop an android-based drawing art application (*DiD-Art*). Using the Fuzzy Delphi Method, researchers surveyed 20 experts to evaluate seven constructs and 37 items for the application. The findings revealed expert agreement on all constructs and items, meeting the three Fuzzy conditions. The research resulted in a design framework for the *DiD-Art* application, which will serve as a teaching and learning material for Visual Art Education teachers. This study leverages digital technology to enhance accessibility and impact art education. Thus, future research could focus on implementing and evaluating the application's effectiveness in real classroom settings.

Keywords: Fuzzy Delphi Method, digital application, expert consensus, Visual Arts Education

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1.0 Introduction

Digital education has emerged as a crucial focus in developing talent and human capital for the digital economy, particularly in enhancing students' technological competencies and digital literacy (Ministry of Education Malaysia, 2023). The Malaysia Education Development Plan 2013-2025 emphasizes digital education transformation through Shift 7, which leverages Information and Communication Technology (ICT) to enhance learning quality. This initiative aims to cultivate a digitally fluent generation of educators and students, with high-quality digital educational materials becoming increasingly essential.

In Visual Arts Education (VAE), technology integration represents a significant pedagogical advancement. Research shows that incorporating new media technology in VAE instruction provides substantial educational benefits (Wan Lokman et al., 2020). Digital applications like ArtRage and Autodesk Sketchbook have become widespread tools for digital drawing and sketching, bridging traditional and digital art-making techniques (Olaoye & Luz, 2024). Platforms like Adobe Spark enable multimedia storytelling, expanding artistic exploration in education. These technological tools are transforming traditional classroom boundaries, enabling ubiquitous learning while fostering critical thinking and creativity. This shift aligns with the Fourth Industrial Revolution (IR 4.0), marking the transition from conventional to digital pedagogy (Roshasfarizan & Dayana, 2022).

1.1 Problem Statement

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VAE fundamentally aims to enhance students' perceptual and observational capabilities, necessitating effective methodological approaches to develop sensory maturity. Research indicates a direct correlation between teacher effectiveness and student performance improvements (Hattie, 2021).

The convergence of IR 4.0 and evolving educational paradigms has heightened the emphasis on innovation and creativity in learning environments (Norfarahi et al., 2020). Moreover, the COVID-19 pandemic has accelerated the necessity for virtual learning platforms to ensure unrestricted access to education (Rahman & Ramli, 2021). Furthermore, research by Aizat, (2017) identifies that 72.1% of respondents cite inadequate art room equipment as a barrier to effective teaching and learning, necessitating digital alternatives to conventional art-making methods.

1.2 Purpose of the Study

The purpose of this study is to design and develop a drawing art application called *DiD-Art* as a teaching aid for teachers who are implementing VAE teaching and learning in schools. This study uses the Fuzzy Delphi Method (FDM) to obtain expert consensus on the constructs and items required in designing and developing the application.

Research Objectives and Research Questions

The objective of the study is to develop the *DiD-Art* application for the topic of drawing art in the teaching and learning of VAE at the secondary school level.

The research questions are:

a. Based on expert consensus, what constructs and items are needed in the DiD-Art application?
b. What is the proposed design of the DiD-Art application in terms of the agreed constructs and items?

1.3 Conceptual Framework

The conceptual framework of this study is based on the Design and Development Approach (DDR) introduced by (Richey and Klein, 2014), which involves three phases: needs analysis, design and development, and usability evaluation. The crucial phase in this study is the design and development phase. According to Mohd Ridhuan, (2016), three main factors make this phase crucial. First, the model or product developed must be relevant and pertinent in the educational context. Second, the construction and development of the product should be practical, with scientific values related to education and based on reliable theories. Lastly, the development and design of the product should strengthen and enhance the teaching and learning process in the field of education.

However, this study focuses only on the design and development phase, involving the design of constructs and items that have been developed based on document analysis, literature review, and findings from the needs analysis phase (Maznah et al., 2023). Accordingly, seven constructs and 37 items have been formulated, involving i) technology infrastructure construct (4 items); ii) student needs and facilities construct (7 items); iii) teaching and learning objectives construct (4 items); iv) application content construct (8 items); v) application interface display construct (4 items); vi) activity filling construct (6 items); and vii) learning assessment construct (4 items).

This quantitative study employs FDM to obtain expert consensus to verify, assess, and either reject or accept the suitable constructs and items in the design and development of the *DiD-Art* application for the drawing art topic. This method involves using fuzzy set theory combined with the classical Delphi method. In this method, the Likert scale selected by experts will be converted to a fuzzy scale using fuzzy numbering, which consists of binary terms (0, 1). The integration of fuzzy numbering will produce three values: the minimum value, the most reasonable value, and the maximum value, which the experts will select. This method can be conducted in one round compared to the classical Delphi method. Therefore, the duration of the study can be significantly reduced.

2.0 Methodology

This study involves two phases in the development of the application. First, the methods of document analysis, literature review, and needs analysis findings are conducted to form the constructs and items that will be utilized in the development phase later. The Form 3 VAE textbook and the Curriculum and Assessment Standard Document serve as the main references in forming the constructs and items for producing the *DiD-Art* application. The constructed constructs and items must cover the objectives of the application development to ensure that the learning objectives can be achieved through its use. In addition, the expected learning outcomes should also be attained after the teaching and learning sessions have been completed (Nuzul, 2020). Subsequently, a questionnaire instrument using a seven-point Likert scale was constructed and validated by experts in terms of language and content before being distributed to experts from different fields of expertise to obtain consensus on the previously formed constructs and items.

2.1 Respondents and Study Sample

This study uses purposive sampling, which is considered very appropriate for obtaining expert opinions and consensus on a particular matter. Hasson et al., (2000) also supported the use of this method in FDM. This study involves 20 experts, including four instrument validation experts and 16 FDM experts. The selection of experts was based on their experience and expertise in their respective fields. The number of experts used in this study follows the recommendations of (Harry Jones & Twiss, (1978), who suggested between 10 and 50 experts for the Delphi method. Conversely, (Adler & Erio Ziglio, (1996) stated that a number of experts between 10 and 15 is sufficient if there is homogeneity. Therefore, this study utilizes 16 experts, adjusted to the context of the study as stated in Table 1.

Table 1: List of FDM Experts

Expert	Qualification/Tittle	Areas of Expertise	Experience
1	PhD/Associate Prof.	Art Education, Curriculum and Instruction	18 yrs
2	PhD/Associate Prof.	Art & Design Education, Instructional Multimedia, Visual Thinking	23 yrs
3	PhD	Computer Science, Multimedia, Computational Thinking, Game-based Learning	21 yrs
4	PhD	Arts Education	25 yrs
5	PhD	Art History (Specialization in Islamic Art)	15 yrs
6	PhD	Arts Education, Graphics, Animation, Multimedia, Technology in Education, Augmented Reality	21 yrs
7	PhD/Associate Prof.	Special Education, Career Development, Educational Technology	16 yrs
8	PhD	Fines Art	27 yrs
9	PhD	Curriculum and Technology	25 yrs
10	PhD	Technology (TVET)	25 yrs
11	PhD	Curriculum and Technology	36 yrs
12	PhD	History Education, Qualitative Research and Curriculum Design	30 yrs
13	PhD	Mathematic Education, Quantitative Research, and Curriculum Design	28 yrs
14	PhD	TVET/RBT Education	16 yrs
15	PhD	Arts Education	13 yrs
16	PhD	Visual Art Education, Museology, Philosophy of Visual Arts	12 yrs

2.2 Research Instruments

The research instrument employed in this study is a set of questionnaires that contain two sections, namely the Respondent Demographics section and the expert evaluation section for constructs and items. The formation of the main constructs is based on the analysis of essential documents, namely the Curriculum and Assessment Standard Document, the Form 3 VAE textbook, the selected conceptual model, which is the Discipline-Based Art Education (DBAE) Model by the Getty Center (1980), Cognitive Theory by Jean Piaget, and Cognitive Theory Multimedia Mayer. The elements of the questionnaire developed by the researcher can be based on literature reviews, pilot studies, and experience (Skulmoski et al., 2007).

These reference sources serve as the foundation for the formation of constructs and items before experts perform validation. The continuation of the findings of phase one of the study also provided concrete evidence of the need to develop a drawing art application. The constructed questionnaire instrument uses a seven-point scale for assessment. The researcher prefers the seven-point scale since the higher the number of scales, the more precise and accurate the obtained data will be. The scale from 1 to 7 aims to replace the Fuzzy values, as summarized in Table 2 for the seven-point linguistic scale. Respondents are requested to indicate their level of agreement according to this scale.

Table 2: 7-Point Linguistic Variable Scale

Likert Scale	Linguistic Variable	Fuzzy Scale
1	Strongly Disagree	(0.0, 0.0. 0.1)
2	Very Disagree	(0.0, 0.1. 0.3)
3	Disagree	(0.1, 0.3. 0.5)
4	Moderately Agree	(0.3, 0.5. 0.7)
5	Agree	(0.5, 0.7. 0.9)
6	Very Agree	(0.7, 0.9. 1.0)
7	Strongly Agree	(0.9, 1.0. 1.0)

Source : Mohd Ridhuan, (2016)

2.3 Data Collection and Analysis Process Using the Fuzzy Delphi Method (FDM)

In implementing FDM for a study, several procedures must be followed. Researchers using the FDM must adhere to these procedures to obtain empirical findings. Diagram 1 displays the flowchart of the procedures for studies using FDM.

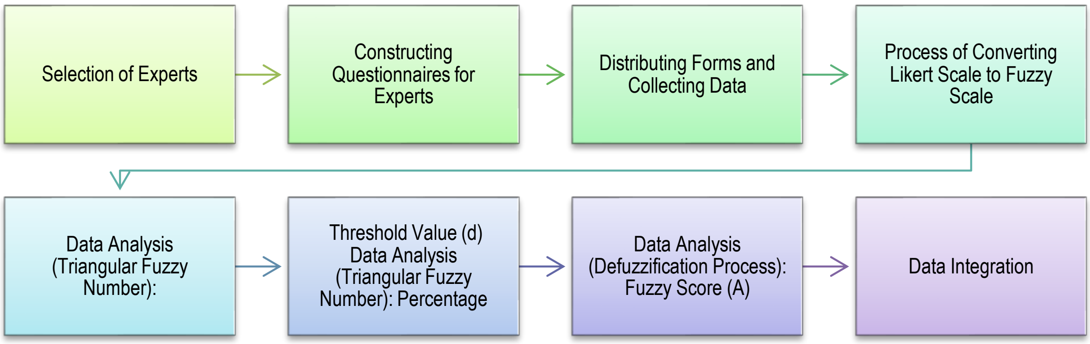

Diagram 1: Procedure for conducting a study using the FDM

Steps for Implementing FDM

1. A total of 16 experts were involved in the study. Accurate selection of experts is crucial. An initial explanation of the experts' assignments is necessary to ensure the research objectives are met.
2. The construction of the set of questionnaires as the research instrument is done through document analysis, literature review, and preliminary findings from the needs analysis phase. This set of questionnaire items contains two main sections, namely the Respondent Demographics section and the Construct Evaluation section. There are seven constructs consisting of 37 items.
3. All appointed experts were provided with a set of questionnaires through face-to-face methods or via email, based on their agreement. The involved experts needed to evaluate all items in the constructs according to the provided scale.
4. In the process of converting linguistic variable scales to triangular Fuzzy numbers represented by the values m1m1, m2m2, and m3m3, the researcher needs to input data per expert for each construct and item into MS Excel software. The linguistic variable scales will be converted to Fuzzy scales to determine the minimum, most reasonable, and maximum values. The accuracy of the obtained data depends on the higher the Fuzzy scale.

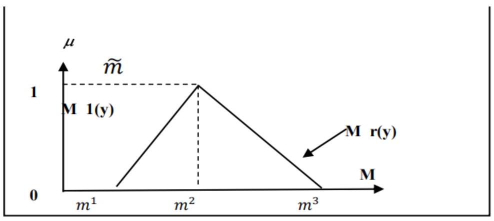

Diagram 2: Triangular Mean Graph Against Triangular

5. The data analysis process aims to obtain the Threshold value (d) based on the triangular Fuzzy numbers. The Threshold value (d) represents the level of consensus among experts regarding the items. The condition that must be met is that the Threshold value (d) should not exceed or equal 0.2; Thus, expert consensus has been achieved.

$$d(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$$

Diagram 3: Formula for Calculating Threshold Value (d)

6. The data analysis for determining item acceptance for the second condition is to determine the percentage value for consensus among the experts involved. The percentage value must be equal to or exceed 75% for each item. If the percentage value is less than this threshold, the item will be rejected and will not be analyzed for the next step, which is the Defuzzification process.
7. The purpose of this analysis process is to obtain the Fuzzy Score (A). The third condition that needs to be met is that the Fuzzy Score (A) must exceed or equal the median value (alpha-cut value), which is 0.5. This indicates that the element is accepted by expert consensus. Additionally, the Fuzzy Score (A) also serves as a determinant of the position and priority of an element based on expert consensus views. The formula for calculating the Fuzzy Score (A) is:
   a) A=13×(m1+m2+m3)A=31×(m1+m2+m3), or;
   b) A=14×(m1+2m2+m3)A=41×(m1+2m2+m3), or;
   c) A=16×(m1+4m2+m3)A=61×(m1+4m2+m3).

The alpha-cut value is the median value between '0' and '1', which is αcut = (0+1)2 = 0.5αcut = 2(0+1) = 0.5. If the resulting value of A is less than the alpha-cut value = 0.5, that item will be rejected since it does not indicate expert consensus. According to Bojdanova

(2006) in Ramlan & Ghazali, (2018), the alpha cut value should exceed 0.5. Tang & Wu, (2010) also supported the notion that the alpha-cut value should exceed 0.5.

3.0 Research Findings

These findings align with broader trends in technology adoption within educational contexts, emphasizing accessibility, mobility, and user-centered design. For instance, portable devices such as tablets and smartphones received high expert consensus, with the tablet achieving the highest acceptance at 88% expert consensus and a fuzzy score of 0.908, followed by smartphones with 81% expert consensus and a fuzzy score of 0.885. In contrast, the desktop computer, with only 50% expert consensus and a threshold value of 0.195, was rejected, underscoring the shift away from less mobile technologies. The high acceptance of features like understandable icons (100% expert consensus and a fuzzy score of 0.960) and easy navigation (100% expert consensus and a fuzzy score of 0.954) reflects principles of user-experience design, which prioritize intuitive interfaces to enhance engagement and reduce cognitive load. Furthermore, the application's alignment with curriculum standards, as seen in items like objectives focused on Standard Curriculum and Assessment Documents (100% expert consensus and a fuzzy score of 0.960), resonates with constructivist learning theories, emphasizing contextually relevant and goal-oriented tools. By grounding its design in expert consensus, technological affordances, and pedagogical principles, the study highlights how technological and educational objectives can converge to create an effective learning application.

A key insight from these findings is that when learning technologies are developed in consultation with experts and built on sound teaching principles, they can fundamentally reshape how modern education takes place. Tools like *DiD-Art* demonstrate this potential – by combining interactive media, user-friendly design, and alignment with learning goals, they show how technology can encourage hands-on learning, enable students to work together, and adapt to different learning styles. The systematic application of FDM in this research offers a model that others can follow when creating educational software that effectively balances technological capabilities with learning goals. This methodological approach holds valuable lessons for educational technology development more broadly, showing how to create innovative tools that remain grounded in their educational context.

Table 2: Expert Consensus Analysis of FDM for the Constructs and Items for the Design of the *DiD-Art* Application

Construct / Item	Triangular Fuzzy Numbers Criteria		Defuzzification Process Criteria				Expert Consensus	Ranking
	Threshold Value, d	Percentage of Group Expert Consensus	m1	m2	m3	Fuzzy Score (A)		
Construct 1 (Technology Infrastructure)								
1. Desktop Computer	0.195	50%	0.688	0.850	0.944	0.827	REJECT	
2. Laptop Computer	0.151	81%	0.763	0.906	0.969	0.879	ACCEPT	3
3. Smartphone	0.124	81%	0.763	0.913	0.981	0.885	ACCEPT	2
4. Tablet (Android)	0.110	88%	0.800	0.938	0.988	0.908	ACCEPT	1
Construct 2 (Student Needs and Facilities)								
5. Internet Facilities	0.095	88%	0.838	0.956	0.988	0.927	ACCEPT	4
6. User Guide	0.107	94%	0.825	0.950	0.981	0.919	ACCEPT	6
7. Easy Navigation	0.033	100%	0.875	0.988	1.000	0.954	ACCEPT	2
8. Understandable Icons	0.018	100%	0.888	0.994	1.000	0.960	ACCEPT	1
9. Clear and Simple Interface Display	0.033	100%	0.875	0.988	1.000	0.954	ACCEPT	2
10. Appropriate Time Settings	0.128	81%	0.775	0.919	0.981	0.892	ACCEPT	7
11. Directed Learning Instructions	0.117	88%	0.838	0.950	0.975	0.921	ACCEPT	5
Construct 3 (Teaching and Learning Objectives)								
12. Clear Teaching Objectives	0.047	100%	0.863	0.981	1.000	0.948	ACCEPT	2
13. Objectives Focused on Standard Curriculum and Assessment Documents (DSKP)	0.018	100%	0.888	0.994	1.000	0.960	ACCEPT	1
14. Objectives Focused on Assessment Elements	0.133	88%	0.800	0.931	0.975	0.902	ACCEPT	4
15. Objectives that Asses Assessment Based on Student Levels	0.057	100%	0.850	0.975	1.000	0.942	ACCEPT	3
Construct 4 (Application Content)								

16. Content Integrated with Visual Arts Education Curriculum (VAE) Standard Curriculum for Secondary Schools (KSSM)	0.059	94%	0.863	0.975	0.994	0.944	ACCEPT	1
17. Content relevant to current developments	0.114	94%	0.800	0.938	0.981	0.906	ACCEPT	7
18. Learning content in the application aligned with the topic	0.091	94%	0.850	0.963	0.981	0.931	ACCEPT	2
19. Examples of activities provided to assist teaching and learning	0.133	88%	0.800	0.931	0.975	0.902	ACCEPT	8
20. Appropriate use of language style	0.100	94%	0.838	0.956	0.981	0.925	ACCEPT	3
21. Clear audio	0.107	94%	0.825	0.950	0.981	0.919	ACCEPT	5
22. Quality video	0.107	94%	0.825	0.950	0.981	0.919	ACCEPT	5
23. Interesting and relevant infographics	0.100	94%	0.838	0.956	0.981	0.925	ACCEPT	3
Construct 5 (Application Interface Display)								
24. Delivery of standard content is attractive	0.059	94%	0.863	0.975	0.994	0.944	ACCEPT	1
25. Suitable layout of the interface display	0.071	94%	0.850	0.969	0.994	0.938	ACCEPT	3
26. Use of icons in the application is attractive	0.057	100%	0.850	0.975	1.000	0.942	ACCEPT	2
27. Continuity of arrangement according to learning topics	0.071	94%	0.850	0.969	0.994	0.938	ACCEPT	3
Construct 6 (Activity Engagement)								
28. Selection of suitable activities	0.125	81%	0.813	0.938	0.981	0.910	ACCEPT	5
29. Assessment support activities (quizzes)	0.125	81%	0.813	0.938	0.981	0.910	ACCEPT	5
30. Training activities can be conducted through self-learning	0.095	88%	0.838	0.956	0.988	0.927	ACCEPT	2
31. Content of activities captures students' attention	0.119	81%	0.825	0.944	0.981	0.917	ACCEPT	4
32. Implementation of teaching activities meets learning outcomes	0.095	88%	0.838	0.956	0.988	0.927	ACCEPT	2
33. Tutorial videos are easy to understand and follow	0.080	94%	0.838	0.963	0.994	0.931	ACCEPT	1
Construct 7 (Assessment of Learning)								
34. Monitoring students' progress during learning activities	0.174	75%	0.788	0.913	0.963	0.888	ACCEPT	4
35. Content has continuity with the final assessment of activities	0.129	88%	0.813	0.938	0.975	0.908	ACCEPT	2
36. Assessment elements encourage students to complete tasks	0.124	88%	0.825	0.944	0.975	0.915	ACCEPT	1
37. Appropriate time allocation for each activity	0.129	88%	0.813	0.938	0.975	0.908	ACCEPT	2

4.0 Conclusion

DiD-Art was developed using expert feedback through the FDM, meeting key quality standards: a threshold value under 0.2, 75% expert agreement, and an α-cut value over 0.5. The application shows promise for Visual Arts Education through its easy-to-use features, alignment with curriculum, and mobile access. The study shows how FDM can help create effective educational tools by combining expert knowledge with practical needs. This approach offers a useful model for developing future educational technology that adapts to different learning situations.

However, the research has some limitations. While experts provided input, the study may not fully capture how students and teachers would use the tool in real classrooms. The validation looked at design features rather than measuring actual learning results. Future research should study how the application affects student learning, engagement, and artistic skills over time in different school settings.

Providing resources like guides or tutorials on how to integrate the app into lessons would help teachers make the most of its features. These improvements would help teachers effectively use the app to support their students' learning in VAE.

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Paper Contribution to Related Field of Study

This research enhances educational technology design and VAE by demonstrating the effectiveness of the FDM in creating strong digital applications. FDM provides a new way to combine expert opinions into practical design principles, filling the gap in existing literature on reliable methods for educational software development. It offers a replicable model for future researchers and includes quantitative validation measures to assess educational fields, indicating potential for broader applications.

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