Determination of Pre Coding Elements and Activities for a Pre Coding Program Model for Kindergarten Children Using the Fuzzy Delphi Method (FDM)

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***Abstract*—Computational Thinking (CT) skills are becoming increasingly crucial in education, particularly in early childhood education. Pre coding, which involves hands-on activities with real objects, has been shown to be quite effective in fostering kindergarten children's computational skills. Pre coding, on the other hand, is essential for boosting children's CT skills, but teachers frequently lack the information necessary to teach these skills successfully. Their successful adoption is hampered by the early childhood education community's lack of interest in CT skills and the sparse application of pre coding techniques. In order to help kindergarten instructors incorporate pre coding into their teaching and learning, this study focuses on defining the elements and activities described in a pre-coding program model. The study reviewed and compiled a list of prior literature's pre coding elements and activities. Subsequently, the Fuzzy Delphi Method (FDM) was utilised to refine and validate these elements and activities. Finally, the data collected from 11 selected experts relevant to this field of study were analysed using FDM to examine consensus. The results showed that the eight identified elements and 24 pre coding activities fulfilled the following required criteria: a threshold value (d) of lower than or equal to 0.2, an agreement percentage over 75%, and a fuzzy score value (A) higher than 0.5. These findings demonstrated the suitability of the identified pre coding elements and activities for integration into a pre coding program model for kindergarten children. In summary, this study provides valuable guidance for kindergarten teachers in implementing practical pre coding activities to enhance CT skills among children.**

***Keywords*—Expert consensus; pre coding; element; activity; kindergarten children**

I. Introduction

Computational thinking (hereafter called CT) refers to a set of cognitive skills for solving problems [1 - 3]. It is also considered a thinking process [4, 5] that involves an array of cognitive skills, including critical thinking, problem-solving, logical reasoning, and creative thinking [6, 7]. In view of this, CT has emerged as a fundamental skill that everyone needs to understand and master [8]. CT skill should be integrated into compulsory school education [9]. Moreover, CT has become one of the most effective approaches for teaching students, including early childhood, in line with the development of global modernisation [10, 11].

The CT teaching approach has also received increasing attention in education and research [12], with vast implementation across many countries, including the United States, the United Kingdom, Estonia, Australia, and Singapore [6, 9]. Coding and pre coding are widely recognised as two standardise methods used for teaching CT [13, 14]. Coding emphasises the use of digital devices, such as computers, as the primary learning tool in computer science education [15 - 18]. Teaching CT through coding typically involves learning programming, which is deemed one of the most effective methods to nurture CT skills [19, 20]. Whereas, pre coding does not require the utilisation of digital devices, it offers an alternatif approach to fostering CT skills [21, 22].

Although coding and pre coding share the same goal, i.e., applying one's CT skills, their implementation differs. Specifically, coding involves digital devices and is more generally introduced at the primary, secondary, and higher education levels [22]. In contras, pre coding is commonly introduced in the early stages of childhood as its implementation focuses on the active involvement of children through hands-on activities with concrete objects [21, 23], such as pencils and papers, puzzles, and wooden blocks [22, 24]. This learning method deeply resonates with children as it allows them to explore the real world and develop their CT skills [16]. In fact, pre coding is often associated with a simpler and fun implementation that corresponds with children's learning process and development stages [25, 26]. Futhermore, pre coding is particularly beneficial for students from B40 families with limited access to digital learning [27], making it a relevant, appropriate, and meaningful approach to children's education.

Nevertheless, the significance of pre coding in empowering CT skills among students has not been adequately conveyed to teachers [28, 29], including kindergarten teachers [30]. Even more critically, teachers are not equipped with sufficient knowledge to teach CT and pre coding skills [29, 31]. This matter has prevented teachers from successfully introducing CT skills through pre coding activities [32 - 35]. It was revealed that teachers in early childhood education were uninterested in CT skills, partly due to the lack of efforts to highlight their significance for children through pre coding [31, 36]. Besides, teachers are not always permitted to practice pre coding approaches and CT skills in their teaching sessions [30].

Considering the issues and problems encountered by teachers, this study aims to identify the key elements of pre coding and appropriate activities to developing structured model of a pre coding activity program. These pre coding model program elements serve as a guideline for kindergarten teachers to practise pre coding to encourage CT skills in children from an early age. This study also systematically discussed the setting and verifying elements of pre coding activities for the program model based on expert consensus through the Fuzzy Delphi Method (FDM) for its implementation.

This paper is divided into several sections: Section II presents a concise literature review regarding elements and activities of pre coding. Section III specifies the methodology of this study. Section IV describes the data analysis process. Section V details the findings and discussion. Finally, Section VI concludes the study and recommends future works.

II. Literature Review

Pre coding is a type of unplugged activity, better known as unplugged coding [21, 37, 38]. This activity supports the development of CT skills without using electronic devices, such as computers, mobile phones, and tablets [16, 21, 23, 38-40]. As such, this approach emphasises hands-on activities and utilises easily accessible concrete materials, such as papers and pencils, cards, and puzzles [23, 24, 37, 39, 41]. This hands-on approach aligns with the constructivism theory that focuses on children's learning via active exploration and real-world interaction [42]. Hence, meaningful real-world experience can improve children's learning process.

Pre coding is viewed as a learning process for kindergarten and preschoolers that adopts physical movement activities and enjoyable games to develop elementary knowledge, nurture CT, and introduce core computer science concepts [16, 43-45]. Pre coding activities are typically conducted through indoor games using a wide range of materials, including pens and papers, cards, and game figurines [24, 46, 47]. Past studies concluded that pre coding incorporates physical activity with accessible materials to provide a fun and meaningful experience that develops CT skills in kindergarten children.

Pre coding is considered a suitable and meaningful learning approach for kindergarten children because it incorporates physical activities without utilising digital devices, such as computers, which may be perceived as complex tools for young learners [37, 44, 48]. It is also viewed as more relevant for children [49] as it emphasises learning in context rather than focusing solely on specific content related to pre coding subjects [9, 42]. As outlined in constructivism theory, pre coding concentrates on continuous learning through environmental experiences that support children's thinking process and active involvement [42]. Therefore, pre coding learning is typically incorporated with other subjects, such as language, mathematics, science, and visual arts [50].

In addition, the pre coding approach helps children develop their computational skills, which further promotes their problem-solving, logic, and creative thinking abilities [51]. This method also provides children with a deep-thinking experience when engaging in a task [23], enabling them to solve complex problems effectively and creatively [24, 52]. Children's mastery of CT skills also promotes their high-level thinking abilities, allowing them to think creatively, express their views in many ways, and analyse problems from different viewpoints [53]. Thus, pre coding is essentially crucial in early childhood education.

In navigating today's digital world, this study assessed Malaysia's Industrial Revolution 4.0 (IR4.0) Policy, which underscores the need for the country to remain competitive within the digital ecosystem [54]. Among the essential skills required to address the challenges of IR4.0 are logical thinking, cognitive development, and creative thinking [17, 41, 55, 56]. As the Sustainable Development Goal (SDG) outlines, these skills are vital for achieving high-quality education. In order to meet the SDG targets and the IR4.0 goals, this study highlights the implementation of a pre coding program that nurtures CT skills in kindergarten children, ensuring these critical skills are developed from an early age.

There is also a growing demand to identify pre coding elements and activities that are suitable for implementation in early childhood education through a comprehensive literature review. Several researchers have conducted pre coding programs for children. Fig. 1 illustrates the definition of the respective pre coding elements, while Table I lists the pre coding activities based on previous studies.

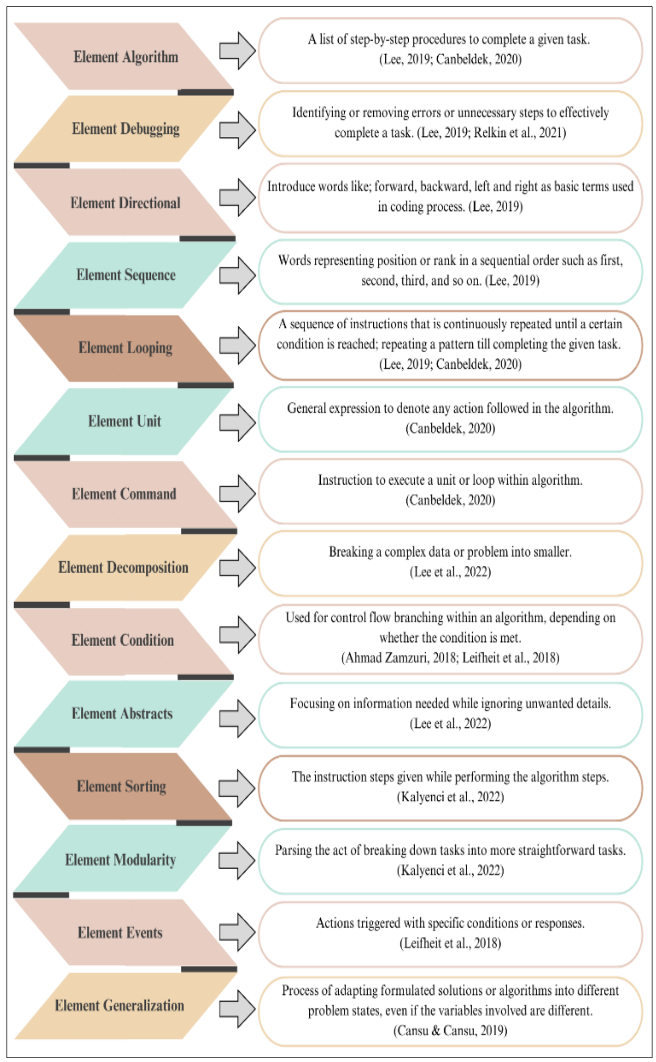

Fig. 1. Definition of pre-coding elements.

TABLE I. PRE CODING ACTIVITIES

No.	Pre coding activities	Previous studies
1.	Daily routine	[22]
2.	Storytelling	[16]
3.	Play	[16]
4.	Telling stories using books	[41]
5.	Coding sheet	[41]
6.	Treasure hunt	[41]
7.	Location search by map	[22]
8.	Following recipe	[22]
9.	Modelling how to perform a task	[22]
10.	Puzzle	[22]
11.	Activities using concrete materials	[16]
12.	Card use	[52, 57]
13.	LEGO pattern	[58]
14.	Sequencing stories	[58]
15.	Vocabulary building songs	[58]
16.	Direction game through cards	[58]
17.	Tic-tac-toe	[58]
18.	Hop scotch coding	[17]
19.	Neighbourhood walk activity map	[17]
20.	Robot Robi's Friend (activity map)	[17]
21.	Story card	[37]
22.	Coding through stories	[59]
23.	Storigami	[59]
24.	Robotic kits	[16]
25.	Tetris activity	[46]
26.	"Repetition Drawing" activity	[46]

Algorithmic elements are often prioritised in pre coding skills for children [4, 16, 23, 24, 37, 39, 40]. These pre coding elements, which are considered vital for children, teach them to follow a set of step-by-step instructions built to solve a task or problem [16, 24, 37]. These elements also encourage logical thinking involving data analysis processes and systematic problem-solving, rendering them suitable for teaching children [16, 38, 39].

Repetition control structure is another essential skill element in pre coding learning [23, 37]. This structural element refers to a set of continuous repeating instructions as long as specific conditions are fulfilled [23, 40]. The repetition control structure in a pre coding program aims to assist children in performing each task or activity based on the assigned conditions and counter value [23, 38, 46]. Hence, the string of this element becomes a key skill for children to master [38].

Furthermore, the sequence control structural element [37, 40, 58, 60] is a critical skill that needs to be mastered to understand the CT skill concept [40]. The sequence control structural element is typically introduced and implemented through daily routine activities [24]. Lee et al. [24] noted that nurturing this element helps children recognise sequence patterns in their daily routines. In other words, daily routine activities can foster children's understanding of the sequence control structures. The study also revealed that children who successfully master this skill could indirectly anticipate future events and identify patterns or past patterns according to their understanding of daily routine activities. Hence, this skill is vital for children's development, as it boosts their cognitive abilities.

Three field experts assessed the initial pre coding element list to obtain confirmation and initial evaluation. The experts accepted only seven pre coding elements that were deemed appropriate for the early childhood pre coding program model, as presented in Table II.

TABLE II. PRE CODING ELEMENTS AFTER EXPERT INTERVIEWS

No.	Pre coding elements
1.	Algorithm
2.	Debugging
3.	Directional
4.	Sequence
5.	Looping
6.	Command
7.	Decomposition

The directional element is also a key pre coding skill [16, 17, 21, 24, 41]. Children need to master this element when learning to code, as it is frequently utilised in the coding process [41. The directional element describes the interaction between one object and another, such as the spatial relationship, 'in front,' 'beside,' and 'at the edge' [17]. In addition, specific words, such as 'forward,' 'backward,' 'to the right,' and 'to the left,' are often employed to describe the concept of direction [41]. Using arrows and hand signals during pre coding learning is instrumental in helping children recognise the intended direction correctly and accurately [21]. In short, applying this element indirectly provides an easier, faster, and more meaningful understanding of the concept of direction.

Besides, error detection, or debugging, is a significant element of pre coding skills [21, 48, 61]. Debugging refers to the identification of unnecessary steps or errors to complete a task more effectively [21]. Additionally, debugging encourages children to explore, observe, reflect, and communicate when seeking solutions for their tasks [62] since activities or tasks involving this element are relatively open-ended in nature [48].

Lastly, the resolution element is a vital component of pre coding skills [24, 63, 64]. This element breaks down complex problems or systems into smaller parts to facilitate understanding of the solution process [24, 64] Besides, simplifying the problems nurtures the thinking process to recognise specific patterns and dismiss irrelevant elements when solving problems [24] Mastering the resolution element allows children to present various solutions when evaluating their strengths and limitations before selecting the optimal strategy for solving the problem [65]. hence, the resolution element must be emphasised as these problem-solving skills help children to think faster when solving a problem.

III. METHODOLOGY

The Human Research Ethics Committee of Universiti Pendidikan Sultan Idris granted the approval for this study from January 31, 2023, to January 31, 2024. This study employed the Fuzzy Delphi Method (FDM) to obtain expert consensus on the elements and activities suitable to be incorporated in a pre coding model for preschoolers. The FDM adapts the classic Delphi method, which integrates fuzzy number sets while maintaining the Delphi method itself [66]. This method was selected because it shortens the cycle process and avoids data loss, thus enhancing economic efficacy in terms of time and cost [26]. Besides, FDM is an effective technique due to its theory set fuzzy that resolves uncertainties against experts' consensus.

FDM is also a structured and systematic analytical procedure [67]. It has been broadly employed to validate the components for training contents due to its ability to obtain fuzzy score values in the form of ranks, which can serve as a determinant and priorities for an element based on expert consensus [27–29]. The design of this study consists of three stages: literary review, expert assessment, and FDM analysis. The study method is elucidated in Fig. 2.

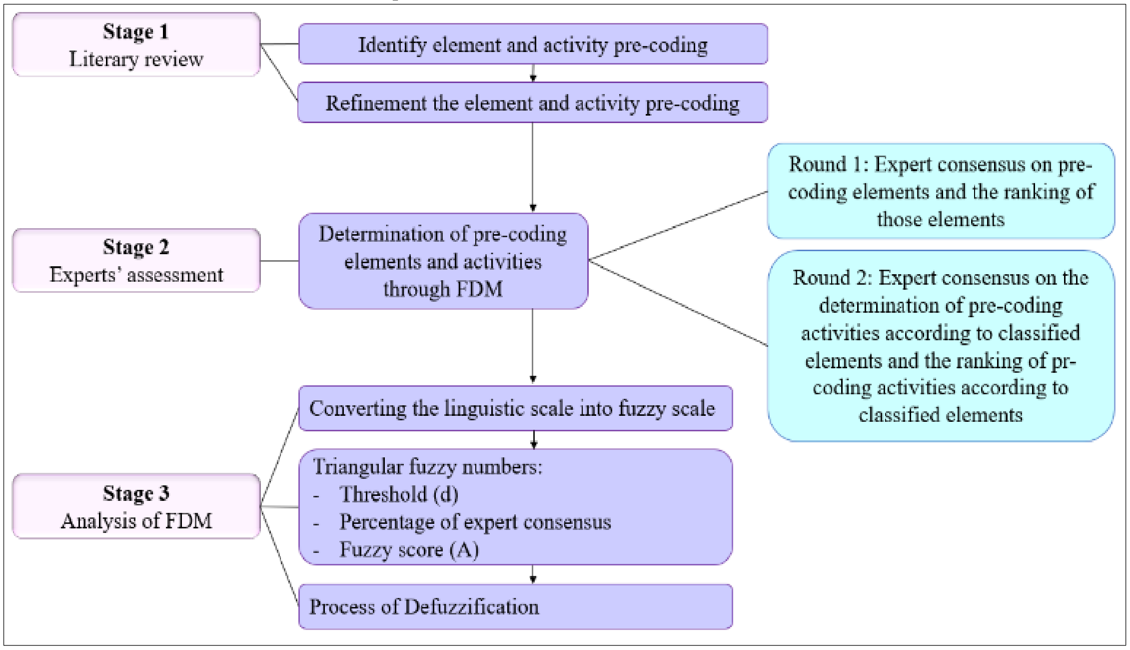

Fig. 2. Study method.

A. Literary Review Stage

The first stage aimed to identify the appropriate elements and activities for developing the pre coding program model for kindergarten children. A comprehensive literary review was carried out via several research databases, including Scopus, Elsevier, Springer Link, Research Gate, and Google Scholar. The data from this literary review comprised a preliminary list of pre coding elements and activities. The data were then evaluated by three experts specialising in computer science and CT skills through Google Meet interviews to assess the suitability and acceptablilty elements and pre coding activities for kindergarten.

B. Expert Assessment Stage

The FDM method was applied by constructing a questionnaire and analysing the data based on expert consensus. The questionnaire was developed based on the elements and activities identified from the literary review stage. The questionnaire consists of a 7-point linguistic scale a balanced range of response options, capturing a broader spectrum of attitudes, opinions, and behavior [68], as shown in Table III. In this process, three experts (Table IV) reviewed the questionnaire to ensure content validity, clarity of wording, and structural integrity.

TABLE III. THE 7-POINT LIKERT SCALE AND FUZZY SCALE

Linguistic variable	Likert scale	Fuzzy scale
Strongly disagree	1	(0.0,0.0,0.1)
Highly disagree	2	(0.0,0.1,0.3)
Disagree	3	(0.1,0.3,0.5)
Moderately agree	4	(0.3,0.5,0.7)
Agree	5	(0.5,0.7,0.9)
Highly agree	6	(0.7,0.9,1.0)
Strongly agree	7	(0.9,1.0,1.0)

TABLE IV. BACKGROUND OF THE THREE EXPERTS INVOLVED DURING THE DATA VALIDATION PROCESS

Expert no.	Expertise	Experience (years)	Organisation
1	Early childhood education	6	Public university
2	Early childhood education	6	Public university
3	Language and communication	6	Public university

TABLE V. BACKGROUND OF THE 11 EXPERTS INVOLVED IN THE FDM ANALYSIS

Expert no.	Field expertise	Experience (years)	Organisation
1	Early childhood education	6	Public University
2	Critical thinking skills	13	Public University
3	Early childhood education	20	Public University
4	Early childhood education	18	Other governmental agencies
5	Early childhood education	18	Other governmental agencies
6	Computer science (Coding)	21	Other government bodies
7	Computer science (Coding)	20	Other government bodies
8	Computer science (Coding)	20	Other government bodies
9	Computer science (Coding)	23	Other government bodies
10	Computer science (Coding)	15	Other government bodies
11	Information and Communication Technology (ICT)	7	Other government bodies

The questionnaire was distributed to 11 selected experts in fields related to the study [13], and the results were analysed using FDM. According to [13, 69-72], the appropriate number of experts for FDM is between 10 and 50. The experts were selected based on their expertise in the study context [73] and their work experience of over five years [74]. This study involved nine experts from government universities and two from other government bodies in Malaysia. This wide range of specialists guarantees a thorough comprehension of the topic by utilising both scholarly and real-world perspectives. Their diverse backgrounds give the study's conclusions a well-rounded viewpoint. Table V lists the demographic information of the selected experts.

The developed questionnaire facilitated the determination of pre coding elements and activities using the FDM. This FDM method was carried out in a face-to-face workshop attended by all 11 selected experts and consisted of two rounds. The first round aims at achieving expert consensus on the pre coding elements and their priority positions. The second round focuses on expert consensus in the context of the activities related to the classified elements and their respective priorities. The data were collected after each round and analysed using FDM.

1) Round 1: Expert Consensus on Pre coding Elements and Priority Ranking of the Identified Elements: All 11 experts participated in the first round to identify, evaluate, and confirm the pre coding elements. They discussed the pre coding element determination questionnaire to develop a suitable pre coding program model for kindergarten children. Based on the expert agreement, the elements were improved during the discussion by adding several new elements and removing those deemed irrelevant. All elements (added, rejected, or retained) aligned with the agreement and consensus reached by all experts during the FDM workshop.

The discussion proceeded with a voting process by the 11 experts to determine the priority position of the pre coding elements. Individual voting was performed by marking the agreement level for all items related to the pre coding program model, as agreed during the discussion. The voting results were analysed using FDM to determine the priority ranking of the elements.

2) Round 2: Expert Consensus on the Determination and Priority of Pre coding Activities based on the Classified Elements.

The second round involved expert consensus regarding the determination and priority of activities according to the classified elements. All 11 experts discussed to identify the pre coding activities based on the elements classified in the questionnaire. They shared their views and opinions to assess the appropriate level of the pre coding activities classified by elements for inclusion in the pre coding program model. The pre coding activities were also modified according to the classified elements, resulting in the addition of new pre coding activities and the removal of irrelevant ones. All pre coding activities (added, rejected, or retained) aligned with the agreement and consensus of the experts in the FDM workshop.

Subsequently, individual voting was performed to reach a consensus on the priority of pre coding activities based on the elements classified for inclusion in the pre coding program model. All 11 experts voted using a 7-point Likert scale to indicate their agreement level for each item. The findings were analysed using FDM to identify the priority of pre coding activities for each element.

IV. DATA ANALYSIS

A. Conversion of the Likert Scale to the Fuzzy Scale

Table VI shows that each Likert scale item has a corresponding fuzzy scale. In the FDM analysis process, the Likert scale value was converted to fuzzy numbers using Microsoft Excel's VLOOKUP function. Fuzzy set theory [75] was applied to convert expert agreement levels into suitable fuzzy number sets. Accordingly, the Likert scale findings from the experts were translated into fuzzy values consisting of three main values: the minimum value (m1), the most reasonable value (m2), and the maximum value (m3).

B. Data Analysis using the Fuzzy Delphi Method (FDM)

FDM data analysis comprised two key components: fuzzy triangular numbering (triangular fuzzy numbers) and fuzzy evaluation (defuzzification). Both parameters are vital when deciding to accept or reject an element based on expert consensus [39]. In particular, triangular fuzzy numbers influence the threshold value (d) and the percentage of expert agreement. Meanwhile, defuzzification impacts the fuzzy score value (A), which indicates the priority position of pre coding elements and their priority for each element [67].

The Likert scale data from the 11 experts were filled into a Microsoft Excel template for the FDM analysis. The data analysis involves assigning fuzzy triangular numbers (m1 to m3), followed by the analysis of four key aspects: (i) the average value of the fuzzy scale (m1, m2, and m3), (ii) the threshold value (d), (iii) the percentage of expert consensus for each element and pre coding activity, and (iv) fuzzy score value (A) to determine the acceptance and priority of elements and activities available through defuzzification.

1) Fuzzy scale average value (m1, m2, and m3): Fig. 3 presents a triangular graph of the mean against the triangular values (m1, m2, and m3). The m1, m2, and m3 values range from 0 to 1, which corresponds to the fuzzy numbers (0,1).

2) Threshold Value (d): The threshold value (d) determines the expert consensus for each item in the questionnaire [76]. Based on the fuzzy number range (0,1), the threshold value (d) is calculated using two sets of fuzzy numbers, m (m1, m2, and m3) and n (n1, n2, and n3), as shown in Formula 1:

$$d(m, n) = \sqrt{1/3\,[(m1 - n1)^2 + (m2 - n2)^2 + (m3 - n3)^2]} \quad (1)$$

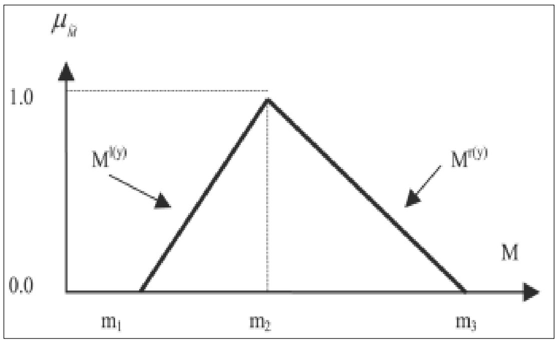

Fig. 3. Triangular graph representing the mean against the triangular values.

The data is considered to successfully reach expert agreement when the threshold value (d) is equal to or less than 0.2 [77]. Table VI describes the interpretation of the data based on the threshold value (d).

TABLE VI. DATA INTERPRETATION BASED ON THE THRESHOLD VALUE (D)

Threshold value (d)	Description	Interpretation
d ≤ 0.2	The threshold value is equal to or less than 0.2	Accepted
d > 0.2	The threshold value is greater than 0.2	Rejected, or a second round may be conducted involving only experts who disagree

3) Percentage of expert consensus: This study also considered the percentage of expert agreement to determine the acceptance of each element and activity. An element or activity is accepted if the percentage of agreement is 75% or higher [14]. Otherwise, the element or activity is either eliminated or a second round should be conducted involving only the experts who disagreed.

4) Fuzzy score value (A): The fuzzy score value (A) is obtained via defuzzification to determine the acceptance level of each item based on expert consensus. An item is accepted if its fuzzy score (A) achieves an a-cut value equal to or greater than 0.5 [78]. Formula 2 is used to calculate the fuzzy score value (A):

$$\text{Fuzzy score (A)} = (1/3) \times (m1 + m2 + m3) \quad (2)$$

In addition, the fuzzy score value (A) plays a role in determining the priority position of the pre coding elements and pre coding activities in the questionnaire. The setting of the priority position for these pre coding elements and activities is based on the results of expert discussion and agreement.

V. FINDINGS AND DISCUSSION

A face-to-face discussion in the FDM workshop involving 11 experts was conducted to evaluate and determine pre coding elements and activities for developing a suitable pre coding program model for kindergarten children. The experts successfully reached a consensus on eight elements and 24 pre coding activities; seven elements were retained, one was rejected, and two new elements were added. Next, the expert voting performed through the FDM analysis converted the Likert scale results into a fuzzy scale. The outcome showed that all eight elements and 24 pre coding activities met the conditions and reached expert consensus, where the threshold value (d) is between 0.092 and 0.204, which is < 0.2. Table VII lists the FDM analysis element designation and pre coding activities.

TABLE VII. RESULTS OF THE FDM ANALYSIS ELEMENT DESIGNATION AND PRE CODING ACTIVITIES

Pre coding element	Number of items related to suitable pre coding activities
Algorithm element	5
Loop control structure element	3
Sequence control structure element	3
Direction indicator element	4
Error detection element	3
Decomposition element	2
Choice control structure element	2
Pattern recognition element	2

For the second condition, the study recorded over 75% of expert agreement for each element and pre coding activity, which ranged from 81.8% to 100%. Meanwhile, the third condition measures the fuzzy score value (A) to determine the acceptance level of each item, which needs to exceed 0.5. Based on the results, the fuzzy score value (A) for the pre coding elements and activities ranged from 0.788 to 0.924, proving that all pre coding elements and activities are acceptable and suitable for inclusion in the pre coding program model for kindergarten children.

The key point of this FDM analysis is its appropriateness and ability to confirm the identified pre coding elements and activities [79]. In addition, the FDM analysis assists in boosting the accuracy of pre coding elements and activities for the pre coding program model since the experts accepted all items that met the key FDM requirements based on the threshold value (d), percentage of expert agreement, and fuzzy score value (A). The results were further strengthened by the open discussions among the experts, which enabled them to present their views on the items found in the questionnaire [67]. These expert views were also considered to ensure that the results aligned with the study's context.

The success of this study stems from the proper selection of experts who shared their expertise in fields relevant to this study, including computer science with a speciality in coding skills, early childhood education, and thinking skills. The diverse pool of expertise facilitated the smooth FDM process and significantly assisted in determining the appropriate pre coding elements and activities for developing the pre coding model for kindergarten children.

The selection of FDM also influenced the quality of the study, as this method utilised the fuzzy theory to address the problem of ambiguity in data acquisition. The FDM also reduced boredom among experts and prevented data leakage during the data collection process [67] since its implementation is more organised, systematic, and shorter than traditional Delphi methods.

It should be noted that this study has a limited sample size of 11 experts. However, all selected experts have proven experience in their respective fields relevant to the study, including early childhood education, computing and meta-technology, and thinking skills. Despite the small sample size, the number of experts was sufficient, as the odd number of experts facilitated the process of reaching a consensus.

In short, this study reinforced the exceptional effectiveness of FDM [70, 80] for determining elements and activities for developing a pre coding program model suitable for kindergarten children. The strength of FDM, marked by its systematic procedure and enhanced accuracy of data analysis, particularly in reducing ambiguity, proved highly valuable for this study.

VI. Conclusion and Future Research

This study effectively identified key elements and activities for developing a pre coding program model suitable for kindergarten children. Based on the applied FDM approach with expert consensus, eight pre coding elements and 24 pre coding activities were deemed suitable for inclusion in the pre coding model for kindergarten children. This findings lies in several major contibution aspects.

The main contribution of this study is the development and validation of a pre coding program model specifically designed for preschool children in a systematic manner by establishing 8 pre coding elements and 24 suitable pre coding activities based on expert consensus. This study simultaneously fills an important gap in early childhood education related to CT. By emphasising pre coding (device-free activities), this study provides an accessible and non-digital-dependent approach to CT, making it highly relevant for underprivileged populations with limited access to digital. In the Malaysian context, the children from B40 families may be affected because they have limited access to digital devices, such as smartphones or laptops. So that, by integrating pre coding program model, it also helps overcome the challenges these children face in developing their CT skills.

Next, this study also contributes to encountering Malaysian kindergartens challenges during the implementation of pre coding in their teaching and learning. In other words, the pre coding program model becomes practical tools to empower teachers in promoting the application of CT skills through pre coding activities. Directly, this can solve the problem of teachers in Malaysia who do not have knowledge about pre coding and some may not have even heard of the concept of pre coding [81]. However, it is not surprising if some teachers may still face issues in integrating pre coding into their instruction, even after being provided with a comprehensive model for guidance. Applying teachers' knowledge and enthusiasm for pre coding should be the primary priority in order to address this. After that, give teachers who are proficient in pre coding ongoing training.

This study also supports the national agenda of the country. The position pre coding as a new approach in early childhood education, align with the policies and objectives of IR4.0 and contribute to the achievement of Malaysia's SDG targets. Therefore, the application of inclusive quality education through pre coding activities is well-suited to the principles of Educational Sustainable Development (ESD), which seeks to meet current needs without compromising the ability of future generations to do the same. Apart from that, implementing the pre coding program for kindergarten children aligns with the Malaysian government's objective of fostering cognitive skills, such as logical thinking, problem-solving, and creative thinking in young learners, which are critical for navigating future technological landscapes and preparing the community for the demands of IR4.0.

Additionally the use of ranking-based elements is an important topic that requiring adressing. While this model contains elements that were outlined based on expert consensus, ranking may not be necessary when implementing activities related to these elements, as readiness and appropriateness are crucial in children's learning. Nevertheless, researchers recommend that algorithm elements be first introduced to children because they represent the most essential elements in coding. Algorithms offer a step-by-step implementation procedure, making it easier for children to understand and engage with coding concepts [16, 21, 24].

Finally, future researchers may verify the model experimentally. Test the efficacy of the suggested pre coding program model in enhancing kindergarten children CT abilities through experimental research in actual classroom environments. Then compare the results with those of other pre coding and coding techniques currently in use to evaluate the relative efficacy of the model. In the other hand, other research may create and execute pre coding pedagogy whereas focused on teacher training programs, making sure that instructors have the know-how to carry out the curriculum successfully. The most important part here is the researcher need to look into how these training sessions affected the teachers' self-assurance, comprehension, and pre coding classroom habits. Lastly integration pre coding with other learning domains such as mathematics, sciences, and language.

In conclusion, this research significantly contributes to transforming early childhood education by integrating computational thinking skills using pre coding activities and promotes an inclusive, useful, and creative approach to contemporary learning issues.

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REFERENCES

[1] F. K. Cansu and S. K. Cansu, "An overview of computational thinking," *Int. J. Comput. Sci. Educ. Schools*, vol. 3, no. 1, pp. 17–30, 2019. https://doi.org/10.21585/ijcses.v3i1.53.

[2] P. Curzon, J. Waite, K. Maton, and J. Donohue, "Using semantic waves to analyse the effectiveness of unplugged computing activities," in *WiPSCE '20: Workshop in Primary and Secondary Computing Education*, 2020. https://doi.org/10.1145/3421590.3421606.

[3] B. Maraza-Quispe, A. Maurice, O. Melina, L. Marianela, L. Henry, W. Cornelio, and L. Ernesto, "Towards the development of computational thinking and mathematical logic through Scratch," *Int. J. Adv. Comput. Sci. Appl.*, vol. 12, no. 2, 2021. https://doi.org/10.14569/ijacsa.2021.0120242.

[4] X. Li, G. Sang, M. Valcke, and J. Van Braak, "Computational thinking integrated into the English language curriculum in primary education: A systematic review," *Educ. Inf. Technol.*, 2024. https://doi.org/10.1007/s10639-024-12522-4.

[5] K. M. Yusoff, N. Sahari, T. Siti, and N. Mohd, "Validation of the components and elements of computational thinking for teaching and learning programming using the fuzzy Delphi method," *Int. J. Adv. Comput. Sci. Appl.*, vol. 12, no. 1, 2021. https://doi.org/10.14569/ijacsa.2021.0120111.

[6] M. U. Bers, "Coding, playgrounds and literacy in early childhood education: The development of KIBO robotics and ScratchJr," in *2018 IEEE Global Engineering Education Conference (EDUCON)*, 2018. https://doi.org/10.1109/educon.2018.8363498.

[7] S. Grover and R. Pea, "Computational thinking: A competency whose time has come," in *Bloomsbury Academic eBooks*, 2018. https://doi.org/10.5040/9781350057142.ch-003.

[8] J. M. Wing, "Computational thinking," *Commun. ACM*, vol. 49, no. 3, pp. 33–35, 2006.

[9] A. Yadav and U. D. Berthelsen, "Computational thinking in education," in *Routledge eBooks*, 2021. https://doi.org/10.4324/9781003102991.

[10] N. Lapawi and H. Husnin, "Investigating students' computational thinking skills on matter module," *Int. J. Adv. Comput. Sci. Appl.*, vol. 11, no. 11, 2020. https://doi.org/10.14569/ijacsa.2020.0111140.

[11] B. Zurnaci and Z. Turan, "Educational robotics or unplugged coding activities in kindergartens? Comparison of the effects on pre-school children's computational thinking and executive function skills," *Think. Skills Creativity*, Article ID 101576, 2024. https://doi.org/10.1016/j.tsc.2024.101576.

[12] S. K. Y. Leung, J. Wu, J. W. Li, Y. Lam, and O. Ng, "Examining young children's computational thinking through animation art," *Early Child. Educ. J.*, 2024. https://doi.org/10.1007/s10643-024-01694-w.

[13] M. Adler and E. Ziglio, *Gazing into The Oracle: The Delphi Method and Its Application to Social Policy and Public Health*, London: Jessica Kingsley Publishers, 1996.

[14] Y. Lin, H. Liao, S. Weng, and W. Dong, "Comparing the effects of plugged-in and unplugged activities on computational thinking development in young children," *Educ. Inf. Technol.*, 2023. https://doi.org/10.1007/s10639-023-12181-x.

[15] D. P. McLennan, "Creating coding stories and games," *Teach. Young Child.*, vol. 10, no. 3, pp. 18–21, 2017. Retrieved from https://www.naeyc.org/resources/pubs/tyc/feb2017/creating-coding-stories-and-games.

[16] S. Metin, "Activity-based unplugged coding during the pre-school period," *Int. J. Technol. Des. Educ.*, 2022. https://doi.org/10.1007/s10798-020-09616-8.

[17] B. Somuncu and D. Aslan, "Effect of coding activities on pre-school children's mathematical reasoning skills," *Educ. Inf. Technol.*, 2022. https://doi.org/10.1007/s10639-021-10618-9.

[18] S. Papavlasopoulou, M. N. Giannakos, and L. Jaccheri, "Exploring children's learning experience in constructionism-based coding activities through design-based research," *Comput. Human Behav.*, vol. 99, pp. 415–427, 2019. https://doi.org/10.1016/j.chb.2019.01.008.

[19] C. Montuori, F. Gambarota, G. Altoé, and B. Arfé, "The cognitive effects of computational thinking: A systematic review and meta-analytic study," *Comput. Educ.*, vol. 210, Article ID 104961, 2024. https://doi.org/10.1016/j.compedu.2023.104961.

[20] S. Y. Lye and J. H. L. Koh, "Review on teaching and learning of computational thinking through programming: What is next for K-12?" *Comput. Human Behav.*, vol. 41, pp. 51–61, 2014. https://doi.org/10.1016/j.chb.2014.09.012.

[21] J. Lee and J. Junoh, "Implementing Unplugged Coding Activities in Early Childhood Classrooms," *Early Child. Educ. J.*, 2019. https://doi.org/10.1007/s10643-019-00967-z.

[22] D. Wang, C. Zhang, and H. Wang, "T-Maze: A tangible programming tool for children," in *Proc. 10th Int. Conf. Interaction Design Children*, June 20–23, 2011, pp. 127–135.

[23] A. Ç. Kirçali and N. Özdener, "A comparison of plugged and unplugged tools in teaching algorithms at the K-12 level for computational thinking skills," *Technol. Knowl. Learn.*, 2023. https://doi.org/10.1007/s10758-021-09585-4.

[24] J. Lee, C. Joswick, and K. Pole, "Classroom play and activities to support computational thinking development in early childhood," *Early Child. Educ. J.*, 2022. https://doi.org/10.1007/s10643-022-01319-0.

[25] M. Fleer, "Collective imagining in play," in *Children's Play and Development: Cultural Historical Perspectives*, pp. 73–87, 2013.

[26] G. Futschek and J. Moschitz, "Developing algorithmic thinking by inventing and playing algorithms," in *Proc. 2010 Constructionist Approaches to Creative Learning, Thinking and Education: Lessons for the 21st Century (Constructionism 2010)*, pp. 1–10.

[27] A. Devisakti, M. Muftahu, and H. Xiaoling, "Digital divide among B40 students in Malaysian higher education institutions," *Educ. Inf. Technol.*, vol. 29, no. 2, pp. 1857–1883, 2024. https://doi.org/10.1007/s10639-023-11847-w.

[28] S. L. Mason and P. J. Rich, "Preparing elementary school teachers to teach computing, coding, and computational thinking," *Contemp. Issues Technol. Teach. Educ.*, vol. 19, no. 4, pp. 790–824, 2019.

[29] P. J. Rich, R. A. Larsen, and S. L. Mason, "Measuring teacher beliefs about coding and computational thinking," *J. Res. Technol. Educ.*, pp. 1–21, 2020. https://doi.org/10.1080/15391523.2020.1771232.

[30] X. C. Wang, Y. Choi, K. Benson, C. Eggleston, and D. Weber, "Teacher's role in fostering preschoolers' computational thinking: an exploratory case study," *Early Educ. Dev.*, vol. 32, no. 1, pp. 26–48, 2021. https://doi.org/10.1080/10409289.2020.1759012.

[31] A. Strawhacker, M. Lee, and M. U. Bers, "Teaching tools, teachers' rules: Exploring the impact of teaching styles on young children's programming knowledge in ScratchJr," *Int. J. Technol. Des. Educ.*, vol. 28, no. 2, pp. 347–376, 2017. https://doi.org/10.1007/s10798-017-9400-9.

[32] M. Çetin and H. Ö. Demircan, "Empowering technology and engineering for STEM education through programming robots: a systematic literature review," *Early Child Dev. Care*, vol. 190, no. 9, pp. 1323–1335, 2018. https://doi.org/10.1080/03004430.2018.1534844.

[33] S. E. Jung and E. Won, "Systematic review of research trends in robotics education for young children," *Sustainability*, vol. 10, no. 4, p. 905, 2018. https://doi.org/10.3390/su10040905.

[34] X. C. Wang, "Fostering young children's computational thinking: A systematic review," presented at *Early Childhood Educational Research Workshop*, Wenzhou University, Wenzhou, China, 2019.

[35] B. Zhong and L. Xia, "A systematic review on exploring the potential of educational robotics in mathematics education," *Int. J. Sci. Math. Educ.*, vol. 18, no. 1, pp. 79–101, 2018. https://doi.org/10.1007/s10763-018-09939-y.

[36] K. Brennan and M. Resnick, "New frameworks for studying and assessing the development of computational thinking," in *Proc. 2012 Annual Meeting of the American Educational Research Association*, Vancouver, Canada, pp. 1–25, 2012.

[37] D. Kalyenci, Ş. Metin, and M. Başaran, "Test for assessing coding skills in early childhood," *Educ. Inf. Technol.*, 2022. https://doi.org/10.1007/s10639-021-10803-w.

[38] M. F. Küçükkara and P. Aksüt, "An example of unplugged coding education in pre-school period: Activity-based algorithm for problem-solving skills," *J. Inquiry Based Activities*, vol. 11, no. 2, pp. 81–91, 2021.

[39] E. Polat and R. M. Yilmaz, "Unplugged versus plugged-in: examining basic programming achievement and computational thinking of 6th-grade students," *Educ. Inf. Technol.*, 2022. https://doi.org/10.1007/s10639-022-10992-y.

[40] J. Del Olmo-Muñoz, R. Cózar-Gutiérrez, and J. A. González-Calero, "Computational thinking through unplugged activities in early years of Primary Education," *Comput. Educ.*, vol. 150, Article ID 103832, 2020. https://doi.org/10.1016/j.compedu.2020.103832.

[41] J. Lee, "Coding in early childhood," *Contemp. Issues Early Child.*, Article ID 146394911984654, 2019. https://doi.org/10.1177/1463949119846541.

[42] A. Csizmadia, B. Standl, and J. Waite, "Integrating the constructionist learning theory with computational thinking classroom activities," *Informatics Educ.*, vol. 18, no. 1, pp. 41–67, 2019. https://doi.org/10.15388/infedu.2019.03.

[43] L. Leifheit, J. Jabs, M. Ninaus, K. Moeller, and K. Ostermann, "Programming unplugged: An evaluation of game-based methods for teaching computational thinking in primary school," in *ECGBL 2018 12th European Conference on Game-Based Learning*, Academic Conferences and Publishing Limited, p. 344, 2018.

[44] T. Bell and J. Vahrenhold, "CS unplugged—How is it used, and does it work?" in *Adventures Between Lower Bounds and Higher Altitudes: Essays Dedicated to Juraj Hromkovič on the Occasion of His 60th Birthday*, pp. 497–521, 2018.

[45] A. Nurhopipah, J. Suhaman, and M. T. Humanita, "Pembelajaran ilmu komputer tanpa komputer (unplugged activity) untuk melatih keterampilan logika anak," *J. Masyarakat Mandiri*, vol. 5, no. 5, pp. 2603–2614, 2021. https://doi.org/10.31764/jmm.v5i5.5825.

[46] C. P. Brackmann, M. Román-González, G. Robles, J. Moreno-León, A. Casali, and D. Barone, "Development of computational thinking skills through unplugged activities in primary school," in *Proc. 12th Workshop on Primary and Secondary Computing Education*, pp. 65–72, 2017.

[47] E. N. Caeli and A. Yadav, "Unplugged approaches to computational thinking: A historical perspective," *TechTrends*, vol. 64, pp. 29–36, 2020. https://doi.org/10.1007/s11528-019-00410-5.

[48] E. Relkin, L. de Ruiter, and M. U. Bers, "TechCheck: Development and validation of an unplugged assessment of computational thinking in early childhood education," *J. Sci. Educ. Technol.*, vol. 29, no. 4, pp. 482–498, 2020. https://doi.org/10.1007/s10956-020-09831-x.

[49] M. Fleer, "Collective imagining in play," in *Children's Play and Development: Cultural Historical Perspectives*, pp. 73–87, 2013.

[50] R. Mohd Kusnan, N. H. Tarmuji, and M. K. Omar, "Sorotan Literatur Bersistematik: Aktiviti Pemikiran Komputasional dalam Pendidikan di Malaysia," *Malays. J. Soc. Sci. Humanit.*, vol. 5, no. 12, pp. 112–122, 2020. https://doi.org/10.47405/mjssh.v5i12.581.

[51] K. Murcia, E. Cross, S. Mennell, J. Seitz, and D. Sabatino, "How to code a sandcastle: Fostering children's computational thinking through an unplugged coding experience," *J. Innov. Adv. Methodol. STEM Educ.*, vol. 1, no. 1, pp. 1–12, 2024. https://so13.tci-thaijo.org/index.php/j_iamstem.

[52] Ü. Demir, "The effect of computer-free coding education for special education students on problem-solving skills," *Int. J. Comput. Sci. Educ. Schools*, vol. 4, no. 3, pp. 3–30, 2021. https://doi.org/10.21585/ijcses.v4i3.95.

[53] A. F. Monteiro, M. Miranda-Pinto, and A. J. Osório, "Coding as literacy in pre-school: A case study," *Educ. Sci.*, vol. 11, no. 5, Article ID 198, 2021. https://doi.org/10.3390/educsci11050198.

[54] Economic Planning Unit, Prime Minister's Department, "National Fourth Industrial Revolution (4IR) Policy," 2019. https://www.ekonomi.gov.my/sites/default/files/2021-07/National-4IR-Policy.pdf.

[55] S. Çiftci and A. Bildiren, "The effect of coding courses on the cognitive abilities and problem-solving skills of pre-school children," *Comput. Sci. Educ.*, vol. 30, no. 1, pp. 3–21, 2019. https://doi.org/10.1080/08993408.2019.1696169.

[56] V. Y. A. Prastika, N. Riyadi, and N. Siswanto, "Analysis of mathematical creative thinking level based on logical mathematical intelligence," *J. Phys. Conf. Ser.*, vol. 1796, Article ID 012011, 2021. https://doi.org/10.1088/1742-6596/1796/1/012011.

[57] Y. Gülbahar, S. B. Kert, and F. Kalelioğlu, "The Self-Efficacy Perception Scale for Computational Thinking Skill: Validity and Reliability Study," *Türk Bilgisayar Ve Matematik Eğitimi Dergisi*, 2018. https://doi.org/10.16949/turkbilmat.385097.

[58] A. Saxena, C. K. Lo, K. F. Hew, and G. K. W. Wong, "Designing unplugged and plugged activities to cultivate computational thinking: An exploratory study in early childhood education," *Asia-Pac. Educ. Res.*, vol. 29, no. 1, pp. 55–66, 2020. https://doi.org/10.1007/s40299-019-00478-w.

[59] B. Çabuk, G. Afacan Adanir, and Y. Gülbahar, "How to teach coding through stories in early childhood classrooms," in *CTE-STEM 2022 Conference*, 2022. https://doi.org/10.34641/ctestem.2022.449.

[60] Y. Lin, H. Liao, S. S. Weng, and D. Wang, "Comparing the effects of plugged-in and unplugged activities on computational thinking development in young children," *Educ. Inf. Technol.*, 2023. https://doi.org/10.1007/s10639-023-12181-x.

[61] E. Relkin, L. E. de Ruiter, and M. U. Bers, "Learning to code and the acquisition of computational thinking by young children," *Comput. Educ.*, vol. 169, Article ID 104222, 2021. https://doi.org/10.1016/j.compedu.2021.104222.

[62] M. Heikkilä and L. Mannila, "Debugging in programming as a multimodal practice in early childhood education settings," *Multimodal Technol. Interact.*, vol. 2, no. 3, Article ID 42, 2018. https://doi.org/10.3390/mti2030042.

[63] F. L. K. Samudin and T. Y. Meng, *Sains Komputer Tingkatan 1*, Kementerian Pendidikan Malaysia, 2016.

[64] C. S. Geck, Y. K. Hooi, Zaliha, and Fatimah, *Sains Komputer Tingkatan 4*, Kementerian Pendidikan Malaysia, 2016.

[65] G. Dietz, J. Landay, and H. Gweon, "Building blocks of computational thinking: Young children's developing capacities for problem decomposition," *Cogn. Sci.*, pp. 1647–1653, 2019.

[66] T. J. Murray, L. L. Pipino, and J. P. Van Gigch, "A pilot study of fuzzy set modification of Delphi," *Hum. Syst. Manage.*, vol. 5, no. 1, pp. 76–80, 1985.

[67] M. R. Mohd Jamil and N. Mat Noh, *Kepelbagaian Metodologi Dalam Penyelidikan Reka Bentuk Dan Pembangunan*, Selangor: Qaisar Prestige Resources, 2020.

[68] Russo, G. M., Tomei, P. A., Serra, B., & Mello, S. (2021). Differences in the use of 5-or 7-point likert scale: an application in food safety culture. Organizational Cultures, 21(2), 1.

[69] A. L. Delbecq, A. H. Van de Ven, and D. H. Gustafson, *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes*, Scott, Foresman, 1975. http://eduq.info/xmlui/handle/11515/11368.

[70] N. Yusof, N. L. Hashim, and A. Hussain, "A review of fuzzy Delphi method application in human-computer interaction studies," *AIP Conf. Proc.*, 2022. https://doi.org/10.1063/5.0094417.

[71] C. Harteis, "Delphi-technique as a method for research on professional learning," in *Methods for Researching Professional Learning and Development*, Springer, Cham, 2022, pp. 351–371. https://link.springer.com/chapter/10.1007/978-3-031-08518-5_16.

[72] C. Okoli and S. D. Pawlowski, "The Delphi method as a research tool: An example, design considerations and applications," *Inf. Manage.*, vol. 42, no. 1, pp. 15–29, 2004. https://doi.org/10.1016/j.im.2003.11.002.

[73] J. Nworie, "Using the Delphi Technique in Educational Technology Research," *TechTrends*, vol. 55, no. 5, pp. 24–30, 2011. https://doi.org/10.1007/s11528-011-0524-6.

[74] D. C. Berliner, "Describing the behavior and documenting the accomplishments of expert teachers," *Bull. Sci. Technol. Soc.*, vol. 24, no. 3, pp. 200–212, 2004. https://doi.org/10.1177/0270467604265535.

[75] L. A. Zadeh, "Fuzzy sets and systems," *Int. J. Gen. Syst.*, vol. 17, no. 2–3, pp. 129–138, 1990. https://doi.org/10.1080/03081079008935104.

[76] J. Valenzuela, "How to develop computational thinkers," 2020. https://www.iste.org/explore/how-develop-computational-thinkers.

[77] C.-H. Cheng and Y. Lin, "Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation," *Eur. J. Oper. Res.*, vol. 142, no. 1, pp. 174–186, 2002. https://doi.org/10.1016/s0377-2217(01)00280-6.

[78] S. Bodjanova, "Median alpha-levels of a fuzzy number," *Fuzzy Sets Syst.*, vol. 157, no. 7, pp. 879–891, 2006.

[79] S. Saedah, T. L. A. Muhammad Ridhuan, and M. R. Rozaini, *Pendekatan Penyelidikan Rekabentuk dan Pembangunan (PRP): Aplikasi kepada Penyelidikan Pendidikan*, Tanjong Malim, Perak: Universiti Pendidikan Sultan Idris (UPSI), 2020.

[80] A. F. R. L. De Hierro, M. Sánchez, D. Puente-Fernández, R. Montoya-Juárez, and C. Roldán, "A Fuzzy Delphi consensus methodology based on a fuzzy ranking," *Mathematics*, vol. 9, no. 18, Article ID 2323, 2021. https://doi.org/10.3390/math9182323.

[81] Rahman, S. N., Jamil, N., Rani, I. F. A., Basir, J. M., & Omar, R. (2024). Perspective of Private Kindergarten Teachers on Pre coding Program in Early Childhood Education/Pandangan Guru Tadika Swasta Terhadap Program Pre coding dalam Pendidikan Awal Kanak-Kanak. Sains Humanika, 16(3), 145-152. https://doi.org/10.11113/sh.v16n3.2127