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Development and Validating the Number and Mathematical Operations Problem-Solving Framework in the Form of Higher Order Thinking Skill (HOTS) through Bar Model Strategy - A Fuzzy Delphi Methods

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ABSTRACT

This study was conducted to develop and obtain the expert consensus using Fuzzy Delphi Method (FDM) on the Number And Mathematical Operations Problem-Solving Framework (NMOPSF) in the form of HOTS through Bar Model Strategy. NMOPSFthrough Bar Model strategy is developed as an important guide for pupils in solving HOTS problem-solving questions in Mathematics. Through FDM, the process of obtaining expert consensus was carried out on two stages. The first stage is a structured interview administered to 7 experts in Mathematics education to identify the components in the NMOPSFthrough Bar Model strategy. On the second stage, the consensus of 15 experts in Mathematics education was obtained using a 7-point Likert scale questionnaire. The interview conducted has identified four main components in NMOPSFthrough Bar Model strategy, namely Concept, Procedure/Algorithm, Representation and Strategy, two special components, namely the Value and ICT (Cybergogy) and two items namely Polya Model and the Bar Model Strategy. From the research conducted, it is found that all the components and items for the NMOPSFthrough Bar Model strategy have met the three main conditions of FDM which is the threshold value ($d_{construct}$) ≤ 0.2, the percentage of expert group consensus $\geq 75\%$ and the value of α-Cut (Fuzzy score) ≥ 0.5. These findings suggest that all the components and items for the NMOPSFthrough Bar Model strategy are necessary to help Year Five pupils solve HOTS problem-solving questions in Mathematics well.

Keywords: Fuzzy Delphi Method, framework, HOTS, Bar Model, performance

1. INTRODUCTION

The unsatisfactory performance in Mathematics is a problem which has worldwide major attention, despite Mathematics being considered to be the backbone of technology and various related fields (Obiero, 2018). Despite various studies that have been conducted on certain factors that have been identified as the main determinants of student performance in Mathematics, the performance is still at a low level (Obiero, 2018). The same situation is happening in Malaysia. Pupils' ability to solve problems in Mathematics has not yet reached the set target (Tuan Siti Humaira & Mohamad Amir Shah, 2016). Poor pupils performance in Mathematics becomes more apparent with the existence of problem solving questions in Mathematics (Sharifah et al., 2018) and so when element of HOTS became a priority with the introduction of the Malaysian Education Blueprint (MEB) 2013-2025. With the introduction of MEB, the number of HOTS problem-solving questions in public examinations in Malaysia including Mathematics increases every year (Ministry of Education, 2012). This matter needs

to be addressed, as the students' ability to answer problem-solving questions in mathematics, including HOTS elements in TIMSS and PISA, will be the benchmark of Malaysia's educational achievements at the international level. In MEB, our country aims to be in the top third groupin TIMSS and PISA within the next 15 years (MOE, 2012).

An increase in the number of HOTS problem-solving questions up to 80% in public examinations in Malaysia by 2016 as contained in the MEB (MOE, 2012) is seen as a surprise to students and could not be very well handled (Azrul Azwan et al., 2017). The results of the Elementary School Achievement Test (UPSR) 2016 which is a public examination in Malaysia for Year 6 students showed that the students experienced a significant decline in their performance compared to the previous years. The National Average Grade points that showed a significant decrease in the 2016 UPSR Examination occurred due to HOTS problem-solving questions exists in it where it challenges the candidate's level of thinking (Azrul et al., 2017). Meanwhile, the UPSR results in 2018 and 2019 showed that the largest percentage of students' marks for the subject of Mathematics was in grade D, which only reached the minimum level with 29.8% in 2018 and 30.23% in 2019 (MOE, 2018a; MOE, 2019). Not only that, students' poor performance in solving mathematical problems also exists in international assessments especially TIMSS and PISA. For Mathematics subjects, the performance of our students in TIMSS which started in 2007 and PISA which started in 2009 still does not reach the target and below the international average achievement. (Mohd Azarul et al., 2019; MOE, 2018b; MOE, 2016). This caused our country to be in the bottom third group until the latest round.

The study shows that the HOTS problem solving questions that exists in it is the main cause of this problem (Abdul Halim et al., 2017; Mohd Azarul et al., 2019). The Malaysian students are still having difficulties solving problem-solving questions especially the HOTS level Mathematics (Arihasnida et al., 2018). Mathematical facts, knowledge and skills still cannot be applied when solving mathematical problems, especially when involving HOTS elements (Abdul Halim et al., 2017; Yap & Siti Rahaimah, 2018). Students are also not used to solve problem solving questions in Mathematics involving HOTS elements (Abdul Halim et al., 2015). This problem exists because pupils not understanding the problems posed in the problem-solving questions, students are unable to understanding the concept, students lacking basic mathematical facts and various other related problems (Mohd Azarul et al., 2019; Phonapichat et al., 2014). If this situation is allowed to continue, it is feared that the most worrying problem will arise in the learning of Mathematics, that students will not be interested in solving Mathematics problem-solving questions (Phonapichat et al., 2014).

The inability of students in answering HOTS Mathematics problem-solving questions is a serious matter and needs to be given extra surveillance. This is because students who constantly face this cycle of failure, not only will it affect their motivation, but also their attitude and self-confidence (Muenks et al., 2018). Simultaneously, it can also affect the educational performance of our country globally. Therefore, we need to identify an appropriate strategy or method to help students understand and able to solve problems solving questions involving HOTS in Mathematics better (Azrul Azwan et al., 2017). In this matter, teachers have to play a very important role. Teachers who have a good HOTS strategy will produce students who are HOTS literate (Rajendran, 2019).

Studies that have been carried out by Augustine and Effandi (2020), Erni Sofinah and Mundia (2018), Ragu and Marzita (2018) as well as Abdul Halim et al. (2017), found that the Bar Model strategy is an effective method that can help enhance pupils' perfomance in solving mathematical problems with HOTS elements. Bar Model Strategy is one of the best methods to solve mathematical problems from Singapore (Marin, 2015). Singapore always reaches the top in TIMSS and PISA every round to date. However, not many studies that have been carried out until now to develop a framework that teachers can be use as a guide to apply the Bar Model strategy effectively in their teaching and learning (TnL) sessions. This gap provides a

reasonable justification to researchers in the need to develop the Number And Mathematical Operations Problem-Solving Framework (NMOPSF) in the form Of HOTS through Bar Model Strategy. This framework that was developed will be able to provide the best guidance to teachers in their efforts to guide their students to solve problem solving questions involving HOTS elements in Mathematics well through the Bar Model strategy. To ensure that the framework developed can give optimal impact, it must have high validity. To achieve this goal, expert consensus needs to be obtained.

Therefore, the objective of the research is to develop and validate the Number And Mathematical Operations Problem-Solving Framework (NMOPSF) in the form Of HOTS through Bar Model Strategy**.** The research questions that need to be answered are (i) what is the Number And Mathematical Operations Problem-Solving Framework (NMOPSF) in the form Of HOTS through Bar Model Strategy? (ii) is NMOPSF in the form Of HOTS through Bar Model Strategy have satisfactory validation?

2. MATERIALS AND METHODS

2.1. Research Design

In this study, the Design and Development Research (DDR) proposed by Saedah et al., (2013) was used. This DDR is a modification of the DDR proposed by Richey and Klein (2007). According to Saedah et al. (2013), DDR capable in providing a reliable and useful information. There are three phases that need to be carried out in this modified DDR. The first phase is the needs analysis, the second phase is the design and development and then the third phase is the implementation and evaluation. However, only the first phase and the second phase were conducted in this study. In second phase, the Fuzzy Delphi Method (FDM) was the main method used to obtain expert consensus. FDM is an appropriate method to be used as a tool to obtain expert agreement (Mohd Ridhuan & Nurulrabihah, 2020). According to Mohd Ridhuan and Nurulrabihah (2020), in FDM, there are three conditions that can be used in verifying whether a component, item or element developed is agreed upon by a group of experts, namely:

(i) Requirement 1: using the value of Threshold, d (Chen, 2000; Cheng & Lin 2002).
The Threshold value, d determined by using this formula:

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

If $d \leq 0.2$, the item is accepted. If $d > 0.2$, the item is not accepted or a second round need to be done with experts who disagreed.

(ii) Requirement 2: According to Delphi Tradisional method (Chu & Hwang, 2008; Murray & Hammons, 1995). This requirement states that an item will be accepted if the percentage of the expert consensus is ≥ 75%.

(iii) Requirement 3: Based on α-Cut (Tang & Wu, 2010; Bodjanova, 2006).
The α-Cut value is the middle value or the median between the *fuzzy* (0 – 1) number. This means the value of α-Cut is 0.5. If the value score *fuzzy* (A_{max}) is more than 0.5, then the item is accepted based on the expert consensus.

In this study, a total of 15 experts in Mathematics education were appointed. This is based on the recommendation of Adler and Ziglio (1996) who states that the appropriate number of experts to be appointed in the Delphi method is between 10 to 15 people if a high level of

agreement with each other can be reached by the experts. The profiles of the appointed experts are shown in Table 1.

Table 1. Profile of appointed experts

Expert Category	Numbers
Mathematics Lecturer at the University	3
Mathematics Lecturer at the Teaching College Institute	3
Excellent Teacher in Mathematics	3
Experienced Teacher in Mathematics	6
Total	**15**

2.2. Research Instrument

In this study, two instruments were used which is structured interviews and questionnaire. Through FDM, the process of obtaining expert agreement was done in two rounds, namely a structured interview (round 1) and an expert validity questionnaire (round 2). Structured interviews were administered to 7 experts in advance to identify what components should be present in NMOPSF in the form Of HOTS through Bar Model Strategy. At the same time, a literature review was also conducted to further strengthen the arguments for the selected components. Through the interviews conducted, an expert validity questionnaire was developed based on the components that had been identified. This questionnaire was adapted from the questionnaire proposed by Mohd Ridhuan and Nurulrabihah (2020). The developed questionnaire was referred back to the 7 experts for confirmation. A validated expert validity questionnaire was administered to all 15 experts in the second round to obtain their agreement on the components contained in the NMOPSF in the form Of HOTS through Bar Model Strategy.

2.3. Data Analysis Method

Structured interviews finding was analyzed using thematic analysis. The finding from the questionnaires was analyzed through Fuzzy Delphi Method. As discussed earlier, in FDM, there are three conditions that can be used in verifying whether a component, item or element developed is agreed upon by a group of experts.

3. RESULTS AND DISCUSSION

Findings from the structured interviews have identified four main components in NMOPSF in the form Of HOTS through Bar Model Strategy namely (i) concept, (ii) procedure/algorithm, (iii) representation and (iv) strategy. There is one item under the procedure/algorithm component which is the Polya Model, and one more item under the representation component and the strategy component which is the Bar Model Strategy. These four items will be covered by two special component which is Value and Cybergogy. Cybergogy is a framework for creating engaged learning online (Wang & Kang, 2006). Through cybergogy, pupils can discuss online with their teachers or friends in order to solve HOTS mathematical problems.

Table 2 shows the three components (Concept, Prosedure/Algorithm and Representative) that have been identified through interviews with experts. Table 3 shows the two more components (Strategy and Value) that have been identified through interviews with experts. Cybergogy components are identified based on three factors, namely (i) the views of experts who were interviewed, (ii) literature studies that have been conducted and (iii) through the experiences of teachers and students when our country was hit by a pandemic and the movement

control order came into force. Table 4 shows the items that have been identified through interviews with experts.

Table 2. The three components that have been identified through interviews with experts

Component	**Some Highlights of Expert Feedback**
Concept	i) Pupils also have to understand the concept. If you understand the concept, it is easier for pupils to answer question (K1/Sl/02). ii) If you understand the concept, the basic skills are also good, so pupils can solve math problems well (K1/Az/04). iii) If the student does not understand the concept, how can the student solve the Math problem? He must have suffere (K1/Sh/09).
Prosedure/ Algoritm	i) In solving a problem, if we want it to be easy, we first train pupils to use the correct steps. (K2/Zm/11). ii) Regardless of the pupil's level in the class, if he knows and remembers the procedure to solve a problem, it helps a lot to solve Mathematical problems (K2/Hr/09). iii) Actually, solving this problem has an algorithm that we have to follow. This is the first one that we need to train the pupils (K2/Sh/15).
Representative	i) Often we will use a diagrammatic representation as the first stimulus (K3/Hp/01). ii) Our process to help pupils understand this math problem has various methods. We can use diagrams, pictures and more (K3/Az/08). iii) In problem solving, if we want pupils to understand and easily interpret questions, we train them to make representations. There are many ways. The easiest way to train pupils to draw pictures (K3/Hr/09).

Table 3. The two more components that have been identified through interviews with experts

Component	Some Highlights of Expert Feedback
Strategy	i) As teachers, we have to diligently explore what strategies are most effective to help pupils (K4/Hp/03). ii) The pupils also have to have a strategy on how to answer math problem solving questions (K4/Sl/04). iii) Pupils have to know strategies to solve math problems. We can use many strategies (K4/Hr/07).
Value	i) Those are actually values that we also need to cultivate indirectly (K5/Hp/03). ii) For me, the PAK21 element is very good. It emphasizes 4K 1N. We apply the value element there as well (K5/Az/08). iii) Now many people are talking about PAK21. In that there is 4K 1N. There is an element of value in it. So actually if we want to train students to answer problem solving questions, we cannot stay on that value. Take care too (K5/Sh/12).

Table 4. The items that have been identified through interviews with experts.

Items	**Some Highlights of Expert Feedback**
Polya Model (under the Procedure /Algorithm component)	i) I think this Polya model is the most effective for guiding students to answer problem solving questions (I1/Sl/04). ii) If we talk about the models for solving this problem, the common, the popular, the simple, the effective is none other than the Polya model (I1/Zm/09). iii) In my opinion, the Polya model contains steps that are appropriate to help students (I1/Az/05).
Bar Model Strategy (under the Representative and Strategy component	i) I have seen this Bar Model. For me it is very helpful for students, especially students at medium and weak level (I2/Sl/04). ii) If you look at the example, this Bar model looks good. We teach students to draw square pictures. From that picture, the student can sort of work out what he wants to do (I2/Zm/09). iii) I am interested in this Bar model. For me it is good and I think it can help students (I2/Az/06).

All components and items have been identified through the guidance of a senior lecturer in Mathematics education who is also one of the expert panels who have been interviewed. This selection is further strengthened through a literature review that has been carried out.All of these components and items have secured expert agreement in the second round of FDM. The findings from the questionnaire conducted in second round of FDM are shown in Table 5.

Table 5. Fuzzy Delphi method analysis for expert validity questionnaire form

Component & Item	Requirement 1 Treshold Value, d	Requirement 2 Percentage of Expert Concensus (%)	Requirement 3 Fuzzy score (A)	Expert Consencus
Concept	0.076	100	0.920	Accept
Procedure/ Algorithm	0.068	100	0.933	Accept
Polya Model	0.092	100	0.902	Accept
Representative	0.068	100	0.933	Accept
Strategy	0.093	93.33	0.916	Accept
Bar Model Strategy	0.060	100	0.940	Accept
Value	0.094	93.33	0.909	Accept
ICT (Cybergogy)	0.076	100.00	0.920	Accept

Based on Table 5, the value of Threshold, d for each component and item ≤ 0.2, the percentage of expert agreement for each component and item is ≥ 75% and the value of α-Cut (Fuzzy score) for each component and item ≥ 0.5. The overall findings from Table 5 show that all three conditions in the FDM have been met. This means that all components and items in the NMOPSF in the form Of HOTS through Bar Model Strategy have obtained expert consensus, have satisfactory validation, acceptable and can be used. Figure 1 show the final framework of the NMOPSF in the form Of HOTS through Bar Model Strategy.

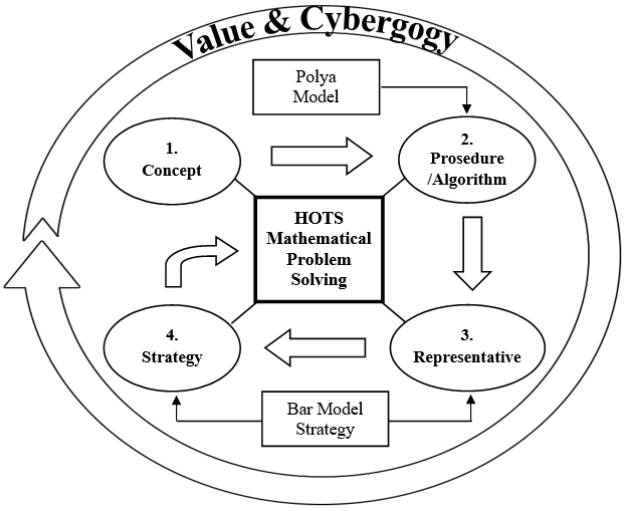

Figure 1. NMOPSF in the form of HOTS through Bar Model Strategy

NMOPSF in the form Of HOTS through Bar Model Strategy which has been developed and has gained expert consensus will be tested for its effectiveness through a quasi-experimental method (TnL sessions in the classroom) in the third round of DDR.

4. CONCLUSION

Problem solving which is the main objective and focus in learning mathematics has been given more serious attention through PPPM 2013-2025. This curriculum transformation has put

HOTS as its main agenda. However, at this time, the performance of students in solving Mathematics problems, especially those in the form of HOTS is still unsatisfactory and has not reached the desired level. This problem also occurs in international assessments such as TIMSS and PISA. This causes the target that our country set in TIMSS and PISA still cannot be achieved. Therefore, teachers must play a significant role to explore a strategy to help pupils answer the problem -solving questions that involved HOTS elements in Mathematics well.

Through the research carried out, the use of the Bar Model Strategy is able to improve the achievement of students in solving HOTS Mathematical problems. However, to date, not many HOTS-shaped mathematical problem-solving frameworks, models or modules that apply the Bar Model strategy have been developed. There is no specific guide that teachers can use to help them apply the Bar Model strategy effectively in their TnL. Therefore, a study to develop a NMOPSF in the form Of HOTS through Bar Model Strategy needs to be done and needs to have high validity by obtaining expert consensus. To achieve this goal, 15 experts in Mathematics Educations have been appointed to evaluate the framework that has been developed. As a result all experts have agreed that the framework developed is of high validity and suitable for use. This is evident when all three conditions of the expert agreement in FDM have been met.

NMOPSF in the form Of HOTS through Bar Model Strategy that has been developed is seen as a comprehensive framework that will be able to provide guidance to teachers to help their students answering problem solving questions involving HOTS elements in Mathematics well. After obtaining expert agreement, NMOPSF in the form Of HOTS through Bar Model Strategy that has been developed will be tested for its effectiveness through a quasi-experimental method in the third round of DDR.

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