Learning Strategy Development for Solving Non-routine Problems Through 5E Model in Mathematics Learning: A Proposal

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Abstract---*This study aims to develop a learning strategy of solving non-routine problems to overcome the difficulties that students face in problem-solving. The methodology of design and development research pioneered by Richey and Klein[1] was applied using three phases of the study. The data of the first phase needs analysis, was obtained by administering tests and conducting interviews with students who had difficulty in solving non-routine problems. The research data will be thematically analyzed, including open coding and axial coding that will generate themes. Next, the data onthe design and development stages will be collected using the Fuzzy Delphi technique. Data from expert interviews will be transcribed and through the coding process to generate themes for developing the questionnaire that will be answered by 30 experts in mathematics, including those interviewed earlier. The analysis based on expert responses to the questionnaire using the Fuzzy Linguistic Likert scale. Threshold value 'd' will be calculated to obtain expert consensus on all items included in the questionnaire. The third phase uses a quasi-experimental method to evaluate the effectiveness of the learning strategies developed. Two groups of 30 students each will involve in this phase. A comparison of achievements between treatment and control groups will be performed through pre-test and post-test. This learning strategy will emphasize the social interactions of a student with peers or students with the teacher to find solutions. By using this strategy, students will be able to learn problem-solving better and improve their problem - solving skills.*

Keywords---*Non-Routine Problem, Problem-Solving, Mathematics Learning.*

I. INTRODUCTION

Analysis of the public examination results shows that the percentage of failed candidates every year has increased since higher-order thinking skills were included in the SPM examination in 2014[2]. The Malaysian Examination Board also reported that students face difficulties in problem-solving was because they are not mastering the concept. The students are also uncertain about which strategies to use. It is even more frustrating when 60% of 15-year-old Malaysian students who participated in PISA 2012 failed to achieve a minimum level of proficiency in mathematics.

These scenarios are closely related to the problem-solving approach adopted in the school. The Ministry of Education in its report[2] expressed concern that teaching and learning in schools in the past did not pay enough attention to the development of higher-order thinking skills and problem-solving skills. Traditional approaches in

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which teachers give lectures and demonstrate all the procedures needed to solve problems are still widely practised in mathematics learning[3]. Such a learning approach is no longer relevant to learn problem-solving in the 21st century. Therefore, a new learning strategy needs to developed to help students improve their non-routine problem-solving skills.

II. NON-ROUTINE PROBLEMS IN LEARNING MATHEMATICS

2.1 What is Non-Routine Problem?

Problem-solving ability refers to students' ability to solve mathematics problems that include routine and non-routine problems[4]. Routine problems refer to simple problems that are often repeated and can usually be solved by direct calculations or algorithms that have been learned. When confronted with them, students know how to solve them by keyword[5]. Non-routine problems refer to complex problems, where mathematical ideas cannot be seen directly.

Finding solutions to non-routine problems requires the development of techniques and challenges one to think to understand the concepts involved[5]. One of the properties of a non-routine problem is that it involves complex cognitive, has more than one correct solution, can be solved with more than one strategy, involves real-life situations and requires mathematical thinking process[6].

Non-routine problem solving involves many problem-solving processes and requires higher-order thinking skills. It can be categorized as a high-level skill that can only be acquired after the basic concepts and solutions of the routine problem are mastered. In solving non-routine problems, the thoughts and approaches used in the solution process are more important aspects of attention than just reaching the right answers[7]. In other words, how the results are achieved, the strategies used and the logical thinking about the solution are more important. Non-routine problems require the use of skills and knowledge in extraordinary ways. In solving such questions, self-correction must be made when necessary, metacognition is used, and the solution process is carried out in a controlled manner[8].

Many research studies have shown that students are unsure and lack the skills needed to solve mathematics problems, especially non-routine problems[9]. Furthermore, a non-routine that reflects the relationship between mathematics and the reality of life rarely presented in the classroom. Thus, when they faced a complicated problem situation, they encounter unusual. Most students do not use strategies such as drawing diagrams, formulas, or tables as appropriate. Usually, students look at the problem and try to figure out what to do with the numbers in the given problem. Classroom activities that do not provide students with the opportunity to investigate, reason, or solve the problem-solving process can contribute to unwanted attitudes towards mathematics learning outcomes and problem-solving [10].

2.2 Why Solving Non-Routine Problems in Mathematics Learning is Important?

The use of routine problems alone would raise obstacles in the development of skills because the routine problems can be solved using algorithms, a limited to a strategy or memorization alone without the need for higher-order thinking skills. For this reason, students should be exposed to non-routine problems that require students to use

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higher-order thinking such as analyze, synthesize, correlate, to reason, to make assumptions and create a formula[11,12].

Recognizing the fact that real problems in everyday life are not as easy and well-organized as the problems often presented in textbooks, various efforts include introducing non-routine problems in teaching and learning mathematics that solve real-life problems in stages. Although students and teachers consider non-routine problems to be difficult, studies of mathematical problem-solving indicate that non-routine problems are the most appropriate problem for developing HOTs[13]. Polya's assertion that non-routine problems provide opportunities for students to formulate in the process of understanding, analyzing, exploring, and applying mathematical concepts[14]. In addition to formulating critical and analytical thinking, solving non-routine problems can give students a better conceptual and mathematical understanding if they are implemented correctly in the classroom.

2.3 Difficulties in Solving Non-Routine Problems

Non-routine problem solving requires students to examine a variety of information for non-routine problems usually have a stimulus in the form of diagrams, tables, or text. The ability to choose relevant information and to ignore other information requires critical thinking skills. Students are having difficulty understanding the problem[15,16] given because they are unable to identify relevant information in the problem. They were unable to identify the exact relationship of the problem to a non-routine problem. They were eventually confused by the information provided[17], despite having read the problem statement repeatedly due to the questions given in the form of long sentences have too much information to consider[18]. A study conducted by Kaur in Singapore found that difficulties in understanding problems prevented students from taking further steps in problem-solving.

The difficulty in understanding this problem is closely related to the failure of students to access existing knowledge or skills that they have acquired. Researchers[19,20] have shown that difficulty in solving problems often results from the ineffective activation of knowledge that impedes learning and achievement. Understanding problems is a vital process because if students misunderstand the problem or situation they are addressing, they may be making the wrong assumptions and then making mistakes for the rest of the problem-solving process. The findings of the above studies show that difficulty in understanding non-routine math problems is a universal problem not limited to Malaysia alone and has contributed to students' failure to solve non-routine maths problems.

When students do not understand the problem presented, they will have difficulty making an appropriate mathematical representation of the problem. Research by A. Stillman & L. Galbraith[21] also shows that students spend more time in problem-solving because students have difficulty understanding and converting information from ordinary sentences to appropriate mathematical representations[22]. The mathematical process is known as formulating situations mathematically process[23]. Students were found to be more likely to translate verse by sentence than to grasp the entire problem[17]due to the lack of exposure to non-routine problems.

Besides, students often fail in solving problems because there are no fixed procedures for solving all problems. Every non-routine problem is unique and different. When solving non-routine problems, practical knowledge of a situation is essential. Students need to carry out the process of collecting and analyzing information, using solution strategies and other activities to implement the proposed solution plan[24]. The study conducted by Johari, Nor

Hidayah, Nor Hasniza and AbdHalim[25], who found that the majority of students failed to master problem-solving skills because they were unable to do strategic planning is in line with this situation. Besides, students were found to be too rigid with one strategy without considering another strategy even though the strategies used did not work[17,24]. De Corte and Somers[26] observing that a lack of knowledge of problem-solving strategies in their student groups has led to poor performance in non-routine problem-solving. Students' difficulty in designing and implementing problem-solving strategies shows that students are less skilled at managing problem-solving strategies.

Students are also seen as less analytical and reflective of each decision made during the problem-solving process. They not only do not check the final answer they receive, whether they meet the requirements of the question or not but are satisfied with the solution without considering the appropriateness of the strategy used and not reviewing each solution.

2.4 Problem Solving Approach in Learning Mathematics

The Polya 4-Step Model Approach was introduced from the elementary level. According to Polya[5], the mathematical problem-solving process is generally divided into four main steps namely (i) Understanding Problems, (ii) Planning Strategies, (iii) Implementing Strategies and (iv) Reviewing. This 4-Step Polya model is a standard model used in the study of mathematical problem solving not only in Malaysia but throughout the world. Although Polya has explained the guidelines and hierarchies of their implementation, it is still too general. It gives too much meaning[7], so that every student can not thoroughly follow the sequence of problem-solving processes proposed by Polya.

Besides, the textbook approach commonly used to solve problems does not provide details of the learning activities that need to be implemented. The problem usually found in textbooks also only cover routine matters that require students to use the settlement procedure has been known to only[27]. Each example of a solution in Form Two mathematics textbook includes four troubleshooting steps as suggested by Polya. However, the phases of problem-solving are no longer emphasized in the Form Four Mathematics textbook. When only the calculation procedure is shown, encourages upper-middle-class students to memorize a simple procedure for solving almost identical problems without understanding the solution.

Previous studies have shown that the use ofthe 5E Learning Model is widely practised in science, but today it is an important model where studies in mathematics also use this model[28]. 5E Learning Model has been widely used in international mathematics education to study its effects on students' scientific process skills[29]. The use of 5E Learning Model in mathematics learning improves achievement and ability in problem-solving [30,31], increases flexibility and accuracy in problem-solving [32], enhances logical thinking[33]and develops critical thinking[34]. While there are numerous studies on 5E Learning Model in other countries such as Indonesia[3,27,30,33,34], Turkey[31,35] and Taiwan[36], in Malaysia these studies are very limited, and only a few educators practice them. Such efforts are still an optional approach and are not in the form of a structured integration with Polya's 4-Step Model.

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As previously stated, students are often confused by the information provided in the question and cannot relate it to the knowledge they have learned in the past. This scenario may be overcome by applying the 5E Learning Model in problem-solving as active involvement in learning is an essential feature of this model. The 5E Learning Model is under social constructivism that emphasizes learning through social interaction. When students are actively involved in learning activities and interacting with more knowledgeable others, such as teachers or peers, they can seek guidance and help build mutual understanding. Indirectly, their existing knowledge can be activated to connect with the problem that needs to be resolved.

Students' difficulty in constructing representations or formulating situations mathematically may be reduced when students are allowed to investigate, explore possible information and solutions and share ideas with friends or teachers to come up with new ideas. Buschman[37], suggested that teachers can encourage students to solve problems in their way rather than demonstrate all the solution and students copy the solution only. Thus, by engaging in judgment during the problem-solving process, students will be able to deepen their understanding. Therefore, teachers need to act as facilitators that will encourage students to think about solving problems.

According to Bybee[29], students also need to be allowed to explain their understanding and solving them to others. Among their peers, there may be people who are more knowledgeable and more skilled at solving problems. Teachers can guide students towards accurate and in-depth understanding. Therefore, by describing the solutions made and comparing them to the solutions made by the other partners will enhance their knowledge and problem-solving skills. Approaching Model 5E, students will interact with other people or parties both at the level of explanation and Description to provide opportunities for students to enhance their knowledge and guidance, creating a light and evaluate measures and decisions taken during the process problem-solving. Indirectly, students can learn the skills of strategic planning, information management, evaluating, and justifying every decision made during the problem-solving process. These are the learning potential offered by Model 5E to complement the problem-solving model. After conducting a detailed study of the cognitive domain of each of the 5E Model learning activities, the researchers found the potential and space to combine these two models to develop a non-routine math problem-solving learning strategy. By exploiting each phase in Polya's 4-Step Model and applying the appropriate activities, it is hoped that it will be able to overcome the difficulties in solving non-routine math problems more effectively.

III. RATIONALE OF THE STUDY

Solving problems is an essential skill for students to master in the 21st century to ensure that the country can compete and thrive in today's innovation-driven economy. Students need to master problem-solving skills as a practical exercise that is very useful for their daily lives and careers.

Recognizing the fact that real problems in everyday life are not as easy and well-organized as the problems often presented in textbooks, various efforts include introducing non-routine problems in teaching and learning mathematics that solve real-life problems in stages. Although students and teachers consider non-routine problems to be problematic, studies of mathematical problem solving indicate that non-routine problems are the most appropriate problem for developing HOTs. Polya's assertion that non-routine problems provide opportunities for students to formulate in the process of understanding, analyzing, exploring, and applying mathematical concepts[5].

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In addition to formulating critical and analytical thinking, solving non-routine problems can give students a better conceptual and mathematical understanding if they are implemented correctly in the classroom.However, this ambition does not seem to be fulfilled when the public examination results show that the percentage of failures has increased year after year since the HOTs element has been included in the 2014 Certificate of Education (SPM) examination since 2014.

An analysis of the past SPM 2017 results revealed that only 27% of candidates had the highest level of HOTs. They have mastered the skills of applying at a high level, but the skills of analyzing, evaluating, and creating are still at a moderate level[2]. It is even more frustrating when 60% of 15-year-old Malaysian students who participated in PISA 2012 failed to achieve a minimum of mathematics proficiency. Comparison of the scores also shows that Malaysian students aged 15 missed three years of schooling than their peers in Singapore, South Korea, Hong Kong, and Shanghai. The situation probably gives risk to the Malaysian students to leave the school with no math skills required in their lives, whether in the workplace or higher education. Therefore, this phenomenon cannot be tolerated as it may be the cause of a more significant problem in the future.

Based on the unsatisfactory results of these public examinations and international assessments, there is a concern that teaching and learning in schools in the past did not pay enough attention to the development of higher-order thinking skills and problem-solving skills[38]. The traditional mathematical learning practice in which teachers give lectures and demonstrates all the procedures needed to solve problems is no longer relevant to 21st-century learning intentions.

Because of the difficulties mentioned above, most Malaysian students still have severe difficulties in solving mathematical problems, especially non-routine problems. They face almost every step of the solution proposed by Polya. The 4 Step Polya Model is general and does not outline the details of the learning activities that need to be performed, especially the specific activities that can help students overcome the difficulties described above. Therefore, the researcher believes that the 4-Step Polya Model adopted in Malaysia should be complemented by the construction, selection, and implementation of appropriate activities to overcome such dominant difficulties. After conducting detailed research on the cognitive domain at each level of Model 5E learning and its associated difficulties with it, the researchers found the potential and space for developing and developing problem-solving learning strategies that incorporate the 4-Step Polya Model and 5E Model to be more effective in improving non-routine math problem-solving skills.

IV. EXPLORATION: THE PATH TO WALK

4.1 Purpose of the Study

The purpose of this study is to design a non-routine problem-solving learning strategy to overcome the difficulties students face in solving problems. For that purpose, this study will first explore the difficulties faced by students and understand how this can be done. In turn, this study will seek recommendations for designing learning strategies to overcome these difficulties. Further testing of the effectiveness of the learning strategies to be developed will be carried out.

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V. METHODOLOGY

The design of this study takes the approach of the study design and development or DDR (*Design and Developmental Research*) to generate the learning strategy of non-routine problem-solving. The rationale for using this design is because it is a specific product development process that involves the entire design and development process, namely analysis, design and development, implementation, and evaluation as documented by Richey and Klein[39]. In general, they emphasize that this method comprises three systematic phases, namely the needs analysis phase, the design phase of development, and the evaluation phase, and the usability testing intervention.

5.1 Research Phases and Participants

In the First Phase, the problem-solving test (PST) containing non-routine items will be administered to a few fourth-grade students to detect difficulties encountered while students solve problems. Some students will be selected from all students who pass the test to participate in the Needs Analysis. They will be interviewed to understand how these problems can occur and how they relate to learning in the classroom. So, user requirements can be met. The criteria for the students to be interviewed for is that they are having difficulty in solving the given problem and can clearly describe their experience.

In Phase II, researchers will use the *Fuzzy Delphi* technique to design non-routine problem-solving learning strategies. The expert's views and consensus will determine the objectives, content, and learning activities that are appropriate for use. In the *Fuzzy Delphi* technique, two-step processes need to be done. In the first step, the expert's interview will be done to find the theme for the questionnaire is made. In the second step, the questionnaire will be answered by 30 experienced and experienced experts in teaching math and non-routine problem-solving. Experts interviewed in the first step also responded to the questionnaire.

In phase III, the researcher conducted a quasi-experimental study with a pre-post test. Student achievement was recorded before and after the 6-week intervention session.

5.2 Data Collection Method

The Phase I study involved the administration of tests and interviews with fourth-grade students. Test administration is designed to identify students who are having difficulty solving problems through their answer scripts. They will be selected for an interview to understand how these difficulties can occur and be associated with problem-solving learning in the classroom.

In Phase II, this study uses two steps in the *Fuzzy Delphi* technique. *Delphi's* instrumentation will use a semi-structured interview technique of five experts in the first step. Then in the second step, the questionnaire generated as a result of the expert interview will be answered by 30 experts, including the interviewees in the first step. The total number of experts used in designing this curriculum is 30 people

In Phase III, the researcher evaluates the effectiveness of the learning strategies developed using the quasi-experimental study approach. The first step in this phase is to define two treatment and control groups. A treatment group is an experimental group that uses learning strategies developed for solving non-routine problems involving algebra. In contrast, the control group is the group using the existing teaching approach, which is the textbook and paper 2 of SPM Mathematics examination.

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5.3 Data Analysis

In the analysis phase, the data obtained from the student interviews will be transcribed for thematic analysis, including *open coding* and *axial coding* to generate themes of difficulty encountered and related to existing learning practices. The Nvivo12 software will be used to help researchers manage their data more systematically.

In the design and development phase, after the *Delphi* technique interview conducted on a few experts, the themes of the interview will produce questionnaire instruments. The questionnaire will be provided to 30 experts. The Fuzzy Delphi techniques used shall be: (i) Determination of Expert or Number of Experts Involved; (ii) Linguistic Scale Selection; (iii) Obtaining Average Value; (iv) Determining Threshold Value ' d '; (v) Consensus 75%; (vi) Get Fuzzy Evaluation; and (v) Defuzzification.

The quantitative data of phase III were obtained from the answer script provided by the students in the Non-Routine Problem Solving Test. The data will be analyzed descriptively using SPSS initialization to show the percentages, mean, and standard deviation. Subsequently, the data were analyzed by inference to see the difference in achievement between the control group and the experimental group. Pre- and post-test achievement will be compared to study the effect of learning strategies that would be developed on non-routine math problem-solving skills.t-Test and Mancova will be used to analyse the data.

VI. EXPECTED BENEFITS

In addition to exposure to non-routine problems, this study enables students to explore the problem-solving process in a more systematic way to improve problem-solving skills. Indirectly, the emphasis on these non-routine issues creates individuals who are creative, critical, logical, and innovative. Students' perceptions that each problem can be solved with just one strategy will change with exposure to non-routine problems as some non-routine problems can be solved by incorporating several strategies.

This study is also expected to help teachers improve the level of student thinking in terms of critical and creative thinking. Also, by identifying the difficulties encountered in solving non-routine problems, teachers can assist students by providing appropriate treatment if their students face the same difficulties as the sample in this study. Besides, using the learning strategies developed, teachers can also monitor the development of knowledge and problem-solving skills among students more systematically.

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