Preliminary study to enhance mathematical creativity in non-routine mathematics problem solving among primary school students

Chandra Sinniah
University of Technology, Malaysia
Skudai, Johor, Malaysia

Abdul Halim Abdullah
University of Technology, Malaysia
Skudai, Johor, Malaysia

Sharifah Osman
University of Technology, Malaysia
Skudai, Johor, Malaysia

Abstract. The aim of this study is to find out the level of achievement of non-routine problem in Geometry and level of mathematical creativity among primary school students. In the study, quantitative and qualitative data were collected through tests and interviews with teachers. This study is a part of research design to develop a learning strategy that can enhance mathematical creativity in non-routine mathematical problem solving among primary school students. A sample of 15 students of Year Five participated in this study. The researcher of this study developed a mathematical creativity test and non-routine problem solving test. Apart from this, an interview was conducted on three experienced mathematics teachers. A descriptive analysis of data reveals that the level of mathematical creativity and non-routine problem solving are below the average level. From the teacher's perspective, students can't perform well when solving non-routine problem solving due to lack of creative thinking in mathematics.

Keywords: mathematical creativity, non-routine, mathematical problem solving.

1. Introduction

Mathematical education in secondary schools is based on the continuity of knowledge and skills learned at primary school level. The curriculum of mathematics in primary and secondary schools has been restructured to provide students a higher level in line with the national curriculum with higher achievements in international assessment. Thus, the primary school curriculum is a milestone to build students with creative and critical thinking. Among the objectives of KSSR (Primary School Standard Curriculum) are to form a high-level thinking, critical, creative, innovative, mathematical embedding and exploring in everyday life and using knowledge and mathematical skills to apply and adapt to various strategies to solve problems (MOE, 2015). It is very important that the emphasis is given to solving non-routine mathematical problems at primary school level.

According to National Council of Teachers of Mathematics (NCTM), non-routine problems could be unfamiliar for primary level students. Non-routine mathematical problems usually do not have a clear strategy to solve them and can be solved in various strategies and ways. The use of non-routine problems in mathematics learning in the classroom is very helpful to improve students' ability to think at a higher level than ordinary level of thinking in routine questions. For example, the following two problems represent routine and non-routine problems, respectively: (1) Round 336 to the nearest hundred; (2) What are the numbers that can be rounded to 300? Both problems test the same concept but the second question requires higher thinking skills. The first routine problem has only one definite answer while the second non-routine problem has multiple answers.

The non-routine problem is more complicated because the strategy to get a solution may not be immediately visible and the problem requires creativity or originality (Lenchner, 2005). To solve these non-routine problems, one of the important components identified is the

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mathematical creativity (Plucker, Beghetto & Dow, 2004). Mathematical education should focus on creative thinking where students are free to try their own original solutions. Mathematics is inseparable from creative elements because the ability of students to present new ideas and diverse solutions to problems in mathematics is considered an indicator of creativity in mathematics (Liljedahl & Sriraman, 2006). Laycock (1970) describes mathematical creativity as the ability to analyse certain problems in a variety of ways, view patterns, differences and similarities, generate a variety of ideas and choose appropriate methods to deal with unusual mathematical situations. With this mathematical creativity opening up space for a new analysis of problems, approaches and new solutions that can lead to high-level education.

However, the definition of mathematical creativity in the classroom is more focused on non-routine problem solving. Hence, in this study, mathematical creativity should be enhanced among students in developing potential non-routine problem solving successfully. Haylock (1987) suggested that there was a need for mathematics teachers to identify, encourage and improve creative mathematical capabilities at all levels. Therefore, it is necessary to pay more attention in designing and implementing an educational environment that promotes creativity in mathematics. A suitable learning approach is essential to improve mathematical creativity among primary school pupils. In this study, a preliminary study was carried out to investigate level of mathematical creativity and achievement in non-routine problem solving. The results will help the researcher to design and developed learning strategy to enhance mathematical creativity and non-routine problem solving.

2. Background

Problem solving plays an important role in mathematical curriculum because pupils gain experience in solving problems by using knowledge and skills through the learning process. In mathematical education, students constantly face new situations and problems that drive them to not only to know and use various strategies but also to be flexible (Baroody, 2003). The flexibility of the student determines whether he can adapt to new problems or non-routine problems. Non-routine problems occur when students face situations but do not know how to solve problems directly. Non-routine problems have no direct way of dealing with the question, but require the creative thinking and application of several strategies to understand the problem and find the best way to solve this problem (Pantziara, Gagatsis & Elia, 2009). Therefore, non-routine mathematical problems are more complex and more complicated than routine problems.

The main issue of this study is focused on students' achievement in solving of non-routine mathematical problems. The UPSR (Primary School Achievement Test) 2016 results showed poor results. This condition may occur because the pupil involved is the first cohort to follow the Primary School Standards Curriculum (KSSR) since its introduction in 2011. The forms and methods of assessment are based on KSSR where mathematical questions are very challenging as they require creative and critical thinking which are the elements in HOTS. Based on the analysis of study by A. H. Abdullah, Rahman and Hamzah (2017) to determine the performance of non-routine problem solving, it is found that students' performance levels are still at low levels. The researcher believe that creative thinking in mathematics is very important and most related to non-routine problem solving performance.

Based on previous studies, it was found that the emphasis on Mathematical Creativity was less attentive during teaching and learning especially among primary school pupils. Teaching and learning practices are still based on teachers and are traditional in nature. (Zakaria & Iksan, 2007; Lim, Fatimah & Tan, 2002). The mathematics teacher emphasizes on the results of the examination and focuses on the syllabus that needs to be fulfilled according to the planned syllabus period. Tammadge (1979) stated that there was a need for mathematics teachers to identify, encourage and improve Mathematical Creativity capabilities at all levels. This supports his opinion that mathematical teaching is dominated for a very long time by thought models that emphasize on cumulative learning based on existing knowledge (Haylock 1987).

By the definition of Sriraman (2004), some researchers believe that creativity in mathematics is generally associated with solutions or problem posing at school level (Chamberlin & Moon, 2005; Silver, 1987; Sriraman, 2004; Liljedahl & Sriraman, 2006; Ellwood et al., 2009; Posamentier, Smith & Stepelman, 2010; Haylock, 1987). To cultivate Mathematical Creativity at

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school level, students should be given the opportunity to solve challenging or complicated problems that enable and encourage students to continue to solve problems and find new, appropriate and relevant solutions (NMAP, 2008). In a study conducted by Kwon, Park and Park (2006), mathematical teaching and learning approaches which used unstructured problems or open problems had a positive impact on fostering divergent thinking skills within the Mathematical Creativity. At primary school level, pupils need to be prepared with a selection of problems that are easily matched with their interests, level of understanding of conceptuality and skill levels. Their Mathematical Creativity can be nurtured through a suitable learning strategy based on non-routine problems because Mathematical Creativity and non-routine problem solving are connected and dependent on each other.

There have been several studies on Mathematical Creativity using non-routine mathematical problems (Kattou, Kontoyianni, Pitta-Pantazi, & Christou, 2013; Leikin, 2009; Sriraman, Haavold, & Lee, 2013). The study's result shows that the use of non-routine problems are the most effective way to improve students' Mathematical Creativity. Levenson (2011) proposed Mathematical Creativity as the creation of new knowledge and the ability to solve problems. However, non-routine problems and Mathematical Creativity are interconnected where Mathematical Creativity can improve the non-routine problem solving capabilities besides the use of non-routine problems in teaching and learning can improve the Mathematical Creativity. Kwon et al. (2006) suggests two main components of mathematical creativity: the creation of new knowledge and the ability to solve flexible problems. This suggests that solving open problems is useful for improving the proficiency of creative thinking in mathematics. Chamberlin and Moon (2005) suggest that creative talented students have an incredible ability to produce new and useful solutions for non-routine problems.

Usually, non-routine mathematical problems are planned or constructed based on various solutions or various strategies and arguments (Levav-Waynberg & Leikin, 2012; Silver, 1987). Therefore, Mathematical Creativity is ideally associated with solving non-routine mathematical problems due to Mathematical Creativity's characteristics that emphasizes fluency, flexibility and originality. To develop Mathematical Creativity and problem-solving skills, pupils need to be exposed to non-routine mathematical problem solving. Mathematical Creativity can be enhanced through activities that require exploration, investigation, discussion and problem solving through new findings (Leikin, 2009). In solving non-routine mathematical problems oriented with various answers and various potential strategies to improve Mathematical Creativity especially the skills of fluency, flexibility and originality (Nohda, 2000; Milgram & Livne, 2005; Levav-Waynberg and Leikin, 2012). Therefore, it is important to cultivate Mathematical Creativity among school students to improve the solving of non-routine mathematical problems

3. Methodology

This preliminary study was carried out to answer the first research question of main study which is to find out the early stage of mathematical creativity and non-routine problem solving performance. The study involved 15 pupils from Standard 5 in a primary school. This result will support the previous study and also will help the researcher to develop suitable learning strategy to enhance mathematical creativity and non-routine problem solving abilities. This study is a part of analysis phase in ADDIE model. Analysis of information is related to the mathematical creativity and achievement in non-routine mathematical problem solving through document analysis, mathematical creativity test, non-routine problem solving test and interviews.

3.1 Mathematical Creativity Test

Researcher will analyse data from Mathematical Creativity Test to determine the mathematical creativity level among primary school pupils. The instrument consists of five items built based on the description of the KSSR (Primary School Standard Curriculum) Year 5 syllabus. The number of items are limited to five as it requires pupils to give a variety of solution and is suitable for primary school level. The recommended time for this test is 40 to 50 minutes. Items in the mathematical creativity test are open response items that will be measured through indicators of fluency, flexibility and originality. Individual scores for fluency are determined by the number of relevant and correct answers given by pupils to a particular item.

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Example:

Item II
Draw any shapes: square, rectangle, triangle that contains area of 12 units² using the space given below.

Pupils need to draw as many solutions as they can for this question on the grid space given. The scores are given based on table below.

Table 1: Mathematical Creativity Measurement

	Fluency	**Flexibility**	**Originality**
High	4 and more	3 and more	2 and more
Medium	2-3	1-2	1
Low	0-1	0	0

3.2 Non-Routine Problem Solving Test

This instrument is used to collect preliminary data on achievement of mathematical non-routine problem solving among primary school pupils. This instrument consists of five items constructed based on Test Specification Table and the description of the KSSR Mathematics Year 5 syllabus. The items in this test are non-routine problem solving. Scores are given based on the UPSR (Primary School Performance Test) scoring schema where each item is allocated five marks. The achievement level measures as below.

Table 2: Non-Routine Problem solving Level

Level	**Score**
High	16-25
Medium	6-15
Low	0-5

3.3 Interview with Mathematics Teachers

The initial study collected qualitative data based on interviews with three teachers who taught Mathematics for more than 10 years. This interview is important to get an early picture of the mathematical creativity level and achievement in non-routine mathematical problem solving. This interview will be conducted separately between one teacher and another teacher. The estimated time for the interview is between 30 to 40 minutes. The focus of this interview is to find out the current teaching and learning scenario in mathematics problem solving. Further investigation is about the problem faced by teacher when teaching non-routine problem solving. In addition, this interview also aims to obtain information about students' creative thinking in mathematics and its importance in non-routine problem solving.

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4. Results and Discussion

This preliminary research was done to support researcher's document analysis on mathematical creativity level and non-routine problem solving performance. The results were presented by tests and interview that guided this study as follows:

4.1 Mathematical Creativity Test

The measurement of this test is based on fluency, flexibility and originality. Fluency here refers to the number of solutions that can be produced. Flexibility on the other hand, refers to the number of solutions of various variations while originality is the unique solution for a problem. Table 3 shows the level of pupils in Mathematical Creativity.

Table 3: Mathematical Creativity Level

	Fluency	Flexibility	Originality
Low	4	12	14
Medium	10	3	1
High	1	0	0

Table above shows that fluency is in moderate levels (67%). Pupils can give more than one solution but are still limited. For example, Item II in this test requires pupils to draw solutions for area of 12 unit². Figure 1 shows a sample of pupil's answer for Item II. Only one student can give four solutions for this item.

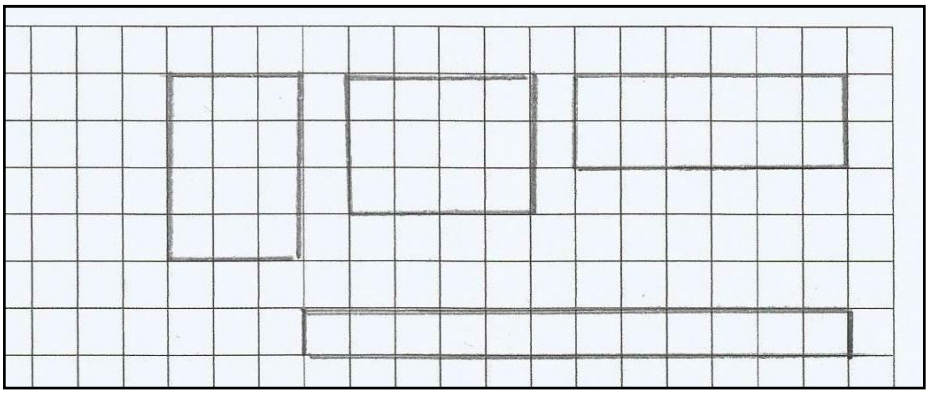

Figure 1: Pupil's Answer

Apart from that, the flexibility level also still low. Certain number of pupils can only modify the solution to other solution. Only three pupils (20%) reached medium level in flexibility. A very small number of students gave unique solution that represent originality. Only one out of fifteen has shown medium level in originality. Overall, from the table above, mathematical creativity level among these pupils has still not reached satisfactory level. Pupils showed a better performance in fluency compared to flexibility and originality. This student (Figure 1) is able to give four solutions but could not give a unique solution. This student has never used triangle shape. Table 3 clearly shows that student's creativity level in originality aspect is very low.

4.2 Non-Routine Mathematical Problem Solving Test

The score given to this test based on UPSR marking scheme. Graph below shows the achievement of the pupils on Non-Routine Mathematical Problem Solving Test. Figure 1 shows the performance in this test and grouped in three level of achievement.

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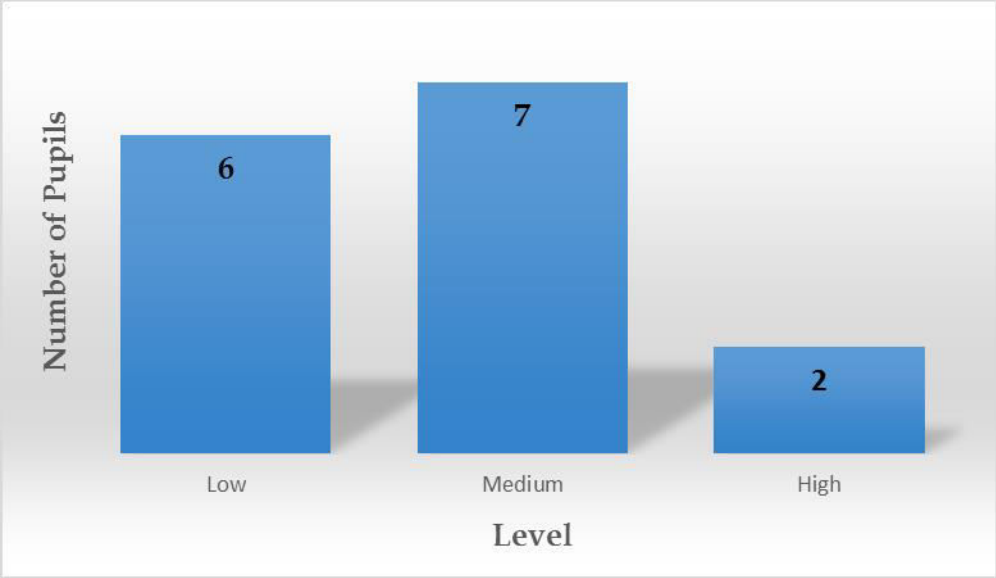

Figure 2: Non-Routine Mathematical Problem Solving Performance

Based on Figure 4.1, it was found that the achievements of most pupils were in low and medium level. Almost half of the pupils involved in this study show average performance in this test.

4.3 **Interview with Mathematics Teachers**

The table below is an analysis of the needs of teachers obtained through interviews to answer the questions raised.

Table 4: Findings of the Interview

Consumer Needs Analysis	**Teacher Feedback**
Existing teaching and learning practices in solving mathematical problems.	• Most problem solving practices follow Polya's steps. • Have different understanding of difficult problems (non-routine problems).
The problems faced in teaching and learning non-routine mathematical problem solving.	• Pupils lack of understanding of the question's need. • Pupils seldom use various methods in solving problems. • Lack of exposure to non-routine mathematical problems.
The level of creative thinking in mathematics among primary school pupils.	• Lack of creative thinking in math.
The importance of mathematical creativity in solving non-routine mathematical problems.	• Mathematical creativity can help pupils use various methods while solving non-routine mathematical problems.
Usage of technology in teaching and learning mathematics problem solving	Seldom use of technology in teaching and learning mathematics. If technology is used, it may be possible to help improve mathematical creativity.
Recommendations on material requirements or teaching and learning strategies to enhance mathematical creativity.	• Using strategies that emphasize mathematical creativity in non-routine mathematical problem solving.

From the analysis of the interview, it was found that problem solving is a very important element in mathematics. For teaching and learning practices implemented in the classroom, teachers use Polya steps in solving mathematical problems. However, students solve problems according to their own understanding of the problem. Pupils try to solve difficult problems using basic procedures and concepts learned.

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Among the problems faced by students in teaching and learning non-routine mathematical problem solving is that the students have difficulty in understanding the requirements of the question, lack of knowledge of various methods and also less exposure to non-routine mathematical problems. Referring to Table 5 in the Year 6 Mathematics Primary School Standard Curriculum, non-routine mathematics problems are classified in Proficiency Level 6. It was found that most of the students were able to master up to Proficiency Level 4 but were less prominent in solving non-routine mathematical problems.

Table 5: Competency Level and Interpretation

Competency Level	**Interpretation**
1	Know the basic knowledge of mathematics.
2	Know and understand the basic knowledge of mathematics.
3	Know and understand basic mathematical knowledge to perform basic mathematical operations and basic conversions.
4	Know and understand mathematical knowledge to perform computational steps in solving daily routine problems.
5	Master and apply mathematical knowledge and skills in solving daily routine problems with a variety of strategies.
6	Master and apply mathematical knowledge and skills in solving daily non-routine problems creatively and innovatively.

According to teachers, students experience this difficulty because they are too guided by certain procedures and work steps. They can't think outside the box where there are some strategies that can be used to solve the problem. According to these teachers, students have the potential to solve non-routine math problems if they are regularly guided to solve these problems. Based on interviews with teachers about the level of creative thinking in mathematics, it was found that students are less prominent in solving non-routine mathematical problems. This difficulty arises when students think less creatively in mathematics. This is because students are too dependent on the teacher's teaching and try to solve problems with an understanding of concepts they have learned before. Only a small number of students can use different methods.

From the teachers' feedback, all three teachers interviewed stated that they do not use any technological aids in teaching and learning apart from teaching and learning due to COVID-19 situation. According their opinion, the use of technology may be able to help to improve the students' creative thinking in mathematics to improve the achievement of non-routine mathematical problem solving.

Overall, teachers suggested that learning and teaching should emphasize on non-routine mathematical problem solving. According to them, it was found that students' achievement in solving non-routine problems still has not reached the satisfactory level. Therefore, it is important to place greater emphasis on mathematical creativity to generate various ideas or methods in solving non-routine mathematical problems. In addition, the teachers interviewed were of the opinion that the learning and teaching activities would be more effective if applied with current technology. It may even help to boost mathematical creativity and make learning fun.

5. Conclusion

The main conclusions of this study indicate that the student's performance on mathematical creativity is not at the appropriate level. Of the three indicators used to measure mathematical creativity, it was found that fluency showed moderate levels. For flexibility and originality, they are still on the lower level. The same goes for the achievement of non-routine mathematical problem solving. Most of the pupils in this study are in the moderate level. From the teacher perception, it shows that the main issues when solving non-routine problem are lack of understanding of the problem, usage of various and low exposure to non-routine problems. Another issue is the lack of creative thinking in mathematics (mathematical creativity) among

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primary school pupils. This indicate that there is a need to improve mathematical creativity to develop divergent thinking in solving non-routine problems. According to the teachers, they seldom use technology in teaching and learning mathematics but they assume if well planned strategy is developed using technology, it may enhance mathematical creativity. This finding will be useful for the researcher to develop a suitable strategy integrated with technology to enhance mathematical creativity in non-routine problem solving among primary school pupils.

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