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A Review of Problem-Solving Skills in Mathematics and Cooperative Learning among Primary School Students

Yim Wan Sin*, Ahmad Johari Sihes and Mas Hamidon

Abstract--- *This paper review 10 published studies of Polya's problem-solving strategy and 7 published studies of cooperative learning strategies in improving students' problem-solving skills in Mathematics. Mathematics is one of the compulsory subjects in primary school curricula. The occurrence of problem solving skills in mathematics is a fundamental means of developing mathematical knowledge among students. In this review, the scope of each publication was examined thoroughly based on the effectiveness of Polya's problem-solving strategy and the cooperative learning strategies which had helped students in achieving significantly better scores in Mathematics. From this review, Polya's problem-solving strategy is one of the effective strategy in enhancing primary students' problem-solving skills. This strategy utilised the Polya's four phases of problem-solving, which starts with understanding the problem, making a plan, carrying out the plan and finally looking back at the completed solution. Cooperative learning strategies boosted primary students' learning motivation, self-confidence and improved learning attitudes. This strategy involves grouping the students into a group of 4 to 6 who share the same goals to create a conducive learning environment. This review showed that by incorporating both Polya's problem-solving strategy and cooperative learning strategies in creating an innovative teaching method, the problem-solving skills in Mathematics among primary school students could be potentially enhanced to an unprecedented level.*

Keywords--- *Problem-Solving Skills in Mathematics, Cooperative Learning, Polya's Problem-Solving Strategy.*

I. INTRODUCTION

Mathematics is an important and a compulsory subject in school. Therefore, Mathematics should be mastered by every student. Mathematics develops a generic ability to deal with numbers, logical calculations, quantities and transactions activities which simulate the applications of mathematics in real life situations. Every student should master Mathematical skills at the optimum level because Mathematical skills is an important factor in the development of a nation. In primary school, mathematics curriculum focuses on building foundation for students which are the skills of reading, writing, arithmetic and reasoning. The mathematics curriculum of primary school plays a vital role in building a strong foundation for science and mathematics subjects for students to prepare for secondary education [1]. However, by shifting the focus of the curriculum to enhance students' higher order thinking skills (HOTS) using Polya's problem-solving strategy, students will perform significantly better in solving complex problems. Mastery of individual arithmetic and reasoning skills alone are not enough, students must also be

Yim Wan Sin, Mathematics Teacher, Kulai Besar Chinese National-Type Primary School, Kulai, Johor, Malaysia.*

E-mail: wansin.yim@gmail.com

Ahmad Johari Sihes, Assoc. Prof., School of Education, Universiti Teknologi Malaysia, Johor Bharu, Johor, Malaysia.

Mas Hamidon, Teacher, Felda Pengeli Timur National Primary School, Kulai, Johor, Malaysia.

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taught to work together with each other. Kagan [2] found that cooperative learning strategies instills positive independence and individual accountability to students. It creates learning environments of equal participations and simultaneous interactions among students. This review analyses the Polya's problem-solving strategy and the cooperative learning strategies in developing primary school students' problem-solving skills in mathematics.

II. PROBLEM-SOLVING IN MATHEMATICS

Mathematics examines logical calculation of the learners. Among all, problem-solving in Mathematics is one of the most important and complex skills to learn or to teach [3]. According to O'Daffer [4], problem-solving is a process where learners use previously learned concepts, facts, and relationships, along with various reasoning skills and strategies, to answer a question or to query about a situation. Bark and Quinn [5] stated that problem-solving is defined as the ability of the learners to make use of previously acquired skills and knowledge to interpret and formulate solutions to problems. The study of Nasarudin Abdullah, Lilia Halim and Effandi Zakaria [6], reveals that mastery of problem-solving skills enabled the students to reinforce and strengthen certain aspects, such as conceptual understanding, procedural fluency, strategic competence, productive disposition, and adaptive reasoning abilities. According to Nurdan Özreçberoğlu and Çağda Kıvanç Çağanağa [7], an individual with problem-solving skills is a self-confident, creative and independent thinker who is free to overcome the problems in their daily lives. In other words, it means that students who equip themselves with problem-solving skills will enable them to solve simple questions with ease and difficult ones effectively.

There are two basic types of Problem-solving questions in Mathematics: routine and non-routine problems. The routine type problems in Mathematics are those direct questions with simple Mathematical operation and formula which only require lower-order thinking skills [8,9]. Students can solve the routine type question easily right after they use a set of prescribed or procedures such as addition, subtraction, multiplication and division to solve the problems. While non-routine problem allows individuals to think, perform reasoning, and use a mathematical language [10]. It usually related to Mathematics in real life which requires a good understanding of the language, skills in analysing the needs of the questions and the decisions of choosing the appropriate Mathematical operations and formulas. According to Felmer, Pehkonen & Kilpatrick [11], it is important to develop problem solving skills and abilities when learning and mastering Mathematics.

Suharta [12] reported that elementary school students are still not proficient in solving Mathematical problems, especially the problems that involve realistic situations which require the use of numerical operations, practical reasoning and considerations. According to Amir [13] students have difficulty in solving the non-routine problem. In line with this, Putri Yuanita and Hutkemri Zulnaidi [14] noticed that it is very common when some students who can master basic Mathematics calculation but they are not able to solve the non-routine problems which incorporated specific concepts and skills. The ability to solve non-routine problems may be influenced by the student's problem-solving skills [15].

III. POLYA'S MODEL OF PROBLEM-SOLVING SKILLS IN MATHEMATICS

George Polya is one the most influential mathematicians in the 20th century. Polya is well-known for his four

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steps in problem solving. In 1945, a popular publication entitled 'How to Solve It' was published by George Polya. George Polya introduced his 4 principles in solving Mathematical problems which is known as Polya's Model. Hensberry and Jacobbe [16] stated that Polya's Model can help students to think beyond their limits and efficiency in understanding the problem. Hence, the four steps problem-solving techniques suggested by George Polya boosted the motivations and successful thinking habits of students [11,17]. Chien I Lee [18] mentioned that Polya's Model have been recommended the most intensive method in problem-solving. This statement was supported by Mustika and Riastini [19] who stated that Polya's Model is one of the best learning models in problem solving.

From the view of George Polya, setting up of equations to solve non-routine problems in Mathematics is very important [8,17]. Polya's problem solving strategy shown that the four steps of problem-solving, which starts with understanding the problem, making a plan, carrying out the plan and looking back at the completed solution was the best strategy in enhancing students' problem-solving skills [17]. The first step in solving the problem is to read the question and concentrate on its aims. Students have to understand the problem and to see clearly what is required in solving the problem. Then, the students have to analyse and relate the variables to the data to formulate the possible solutions to the problem. Subsequently, students have to carry out the plan in order to solve the problem. Finally, students have to look back at the completed solution as well as review and discuss it [17].

The majority of the existing researches and studies concerning Polya's problem-solving strategy on the development of students' problem-solving skills in the application of teaching and learning in Mathematics are shown in the meta-analysis in Table 1.

Table 1: Analysis of Polya's Problem-Solving Strategy in Mathematics

	Title/Author	**Source**	**Issues**	**Findings**
1.	Enhancing The Learning Outcomes of Elementary School Students in Solving Problems Involving Area, Volume and Surface Area Using the Polya's Learning Model Yetti Ariani, Ary Kiswanto Kenedi [20]	Journal of Educational Inspiration	To enhance the learning outcomes of elementary school students in solving problems involving area, volume and surface area.	The four step process in Polya's Model increases the understanding of students in solving problems which involving area, volume and surface area.
2.	Polya's Strategy: An Analysis of Mathematical Problem Solving Difficulty in 5th Grade Elementary School Nunuy Nurkaeti [21]	Journal of Basic Education	To identify the difficulties that elementary school students encounter in Mathematical Problem Solving based on Polya's strategy.	The result based on Polya's steps shown that elementary school students have difficulty in understanding the problem, determining the Mathematical rules, the interrelation between concepts of arithmetical, and evaluate the exactitude of answers with questions.
3.	An Empirical Investigation Into Student's Mathematical Word-Based Problem-Solving Process: A Computerised Approach	Journal of Computer Assisted Learning	To improve the results of average to poor 2nd grade students in word-based mathematical questions that involves only addition and subtraction.	Improve the competency and proficiency of the students in solving non-routine mathematical problems by using Polya's model in combination with computer assistance at every stage of problem solving procedure.

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	Abdelhafid Chadli, Erwan Tranvouez, Youcef Dahmani and Fatima Bendella [22]			
4.	The Influence of Polya Models on Mathematics Problems in Elementary School Nanci Riastini, Pt and Agus Mustika, I Kd [23]	International Journal of Elementary Education	Investigating different performances in solving Mathematical problems.	The steps in Polya's Model educate students to actively participate in group discussion and to work systematically in solving Mathematical problems.
5.	The Evaluation Of The Problem Solving In Mathematics Course According To Student Views Esen Ersoy, Belgin Bal-Incebacak [24]	ITM Web of Conferences -2nd International Conference on Computational Mathematics and Engineering Sciences (CMES2017)	To determine the level of 3rd grade students in their Mathematical problem solving skills.	Enable students to look into a problem with a structured strategy to solve the Mathematical problems with Polya's Problem-Solving Method.
6.	Developing A Model for Problem-Solving in a 4th Grade Mathematics Classroom Susan Nieuwoudt [25]	Journal of the Association For Mathematics Education of South Africa	An empirical investigation into teaching problem-solving through developing a Problem-solving Model in a Grade 4 Mathematics classroom.	Polya's Model has improved students' cognitive levels and enabled them to solve various Mathematical problems.
7.	An Appropriate Prompts System Based On The Polya Method For Mathematical Problem-solving Chien I Lee [18]	EURASIA Journal of Mathematics Science and Technology Education	To investigate the influences of a teaching activity incorporating Polya's method.	High satisfaction among the students in the experimental group was observed when using Polya problem-Solving Method during the learning process.
8.	Polya Model Based Problem Solving and Heuristic Drawing In Pupils Year 2 Norazlin binti Mohd Rusdin [26]	School Based Project of Sultan Idris Education University	Help students to solve problems systematically based on four steps of solving problems in Polya's Model among Year 2 students.	Combination of visualisation techniques and Polya's four-step process in problem-solving was effectively used to teach non-routine problems in Mathematics.
9.	Learning Achievement in Solving Word-Based Mathematical Questions through A Computer-Assisted Learning System Tzu-Hua Huang, Yuan-Chen Liu and Hsiu-Chen Chang [27]	Educational Technology & Society	To boost the achievement of low-achieving 2nd and 3rd graders in mathematics with word-based Mathematical questions that involves addition and subtraction by developing an online instruction website.	Combination of a network instruction website with Polya's problem-solving method increases the effectiveness of students' skills in non-routine Mathematical problems.
10.	Australian Curriculum Linked Lesson Derek [28]	Australian Primary Mathematics Classroom	Examines the ability of primary school children to solve Mathematical problems in Australia.	Polya's four-step process emphasises continuous focus on tasks and activities that help to highlight the key ideas of the Australian Curriculum in Mathematics.

From the above articles' review, we can predict that Polya's Problem Solving Strategy is a suitable strategy that aims to produce students with high systematic problem-solving skills. However, this method is still insufficient for some students and disappointing in some ways and adequate practices is needed. Apart from this, some researchers combined Polya's Model with computer assistance in the process of teaching and learning problem-solving in

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Mathematics. The combination of Polya's Problem Solving Strategy with the relevant 21st century learning strategies may fix these problems and increase the effectiveness of educating students in Mathematics.

IV. COOPERATIVE LEARNING IN MATHEMATICS

Table 2 shows the reviews of the feasibility analysis of implementing cooperative learning in the teaching and learning process of Mathematics in elementary school.

Table 2: Analysis of Cooperative Learning in Mathematics

	Title/Author	Source	Issues	Findings
1.	Implementation of Cooperative Learning Model Type STAD with RME Approach to Understanding of Mathematical Concept Student State Junior High School in Pekanbaru Nurhayati and Hartono [33]	AIP Conference Proceedings	To evaluate two groups of students taught through Student Teams Achievement Division (STAD) Model incorporating Realistic Mathematics Education approach and regular learning in terms of their ability to understand the Mathematical concepts.	Students taught using Student Teams Achievement Division (STAD) Model incorporating Realistic Mathematics Education approach displayed higher ability than students taught using regular learning method.
2.	Impact of Cooperative Learning Methods on Student Achievement in Mathematics Nurulhuda Binti Ngasiman [34]	Project Reports Of Bachelor In Technical and Vocational Education, UTHM.	To identify the difficulties that elementary school students encounter in Mathematical Problem Solving based on Polya's strategy.	The result based on Polya's Strategy showed that elementary school students have difficulty in understanding the problem, determining the Mathematical rules, the interrelation between concepts of arithmetical, and evaluate the exactitude of answers with questions.
3.	Enhancing Primary School Students' Social Skills Using Cooperative Learning in Mathematics Aree Pawattana, Supapaorn Prasarnpanich, Rattana Attanawong [35]	Journal For Education and Teaching	Measuring students' achievement through STAD Cooperative Learning Model and development of social skills	Students' social skill and learning achievement in Mathematics have improved through the STAD Cooperative Learning Model
4.	Engaging with others' mathematical ideas: Interrelationships among student participation, teachers' instructional practices, and learning Noreen M, Megan L， Marsha et al. [36]	International Journal of Educational Research	To explore the correlations of the teaching practice of teachers and the participation level of the students in mathematics classroom.	Higher level of engagement and communication among students with regards to problem-solving ideas and strategies were shown to be positively impact the students' achievements (small-group discussions).
5.	Cooperative learning and Mathematics Education: A happy marriage? J.Terwel [37]	Education for Innovation: The role of Arts and STEM Education	To explore the underlying mechanisms of cooperative learning in Mathematics.	Mathematics education requires cooperative learning and guided co-constructions, which are practical and efficient instructional methodologies. Cooperative learning should not be conducted on its own as it involves other instructional approaches such as whole class introductions, in which the teacher should be in charge of as to avoid the other approaches to be left out.
6.	The effects of Cooperative Learning for Primary School Students on their attitude and achievement of Mathematics in Kuching City Koh Lee Ling, Choy Sau Kam and Lai Kim Leong et al. [38]	IPBL Research Journal	To review the effectiveness of Cooperative Learning methods on attitude and achievement in Mathematics when a trainee teacher uses it in teaching and learning of current Mathematics practise in their practicum training.	Cooperative learning is effective in improving Mathematics achievement but there is no significant difference in student attitude towards Mathematics between the treatment group and the control group.
7.	The effects of cooperative learning on Turkish elementary students' mathematics achievement and attitude towards mathematics using TAI and STAD methods Kamuran and Fikri [39]	Educational Studies in Mathematics	To compare the outcome of Team Assisted Individualisation (TAI) and Student Teams Achievement Divisions (STAD) on fourth grade students' academic achievement and attitudes towards Mathematics.	The outcome of TAI method show more significant effect in students' academic result than the STAD method, but there is no significant difference impact on students' attitudes towards Mathematics.

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According to Johnson & Johnson [29], cooperative learning is a type of group work and is defined as the instructional use of small groups to promote students working together to maximise their own and each other's learning. Cooperative learning occurs when students learn in small groups with two to six members. Each member is committed to help in order to achieve the task given [30，31]. Cooperative learning brings positive effects on academic achievement when students have same chance to socialise and share their thoughts. Students who learn through cooperative learning are more confident to verbalise their thoughts and share their ideas with the groups as they train to be more competitive and increase their potential in problem-solving Mathematics through group work. This statement is supported by Carr and Christopher Bowring [32] who mentions that students should be exposed to formative learning groups because this will help students learn to make decisions by themselves.

Cooperative learning was shown to improve the achievement scores of students in Mathematics problem-solving task compared to those using conventional learning methods [34]. Cooperative learning improves and increases the learning achievement and grades in Mathematics of elementary school students through the process of teaching and learning. Cooperative interactions promote learning and cognitive development because students teach, guide, and assist one another when solving problems and completing tasks together with their group members [40]. This shows that cooperative learning is better than conventional methods which students only receiving the knowledge passively. Apart from that, the performance of students in Mathematics is more effective when they interpret and communicate the ideas of problem-solving in Mathematics together in a group.

V. DISCUSSION

The main objective of this conceptual paper is to review the most suitable strategy in using Polya's Model to solve non-routine problems that is hypothetically more beneficial for both students and teacher in the learning and teaching process respectively. From the reviews in relation to Polya's four steps problem solving strategies, there are strong evidences in enhancing the ability in understanding Mathematics' questions as well as improving the problem-solving skills among primary school students.

Cooperative learning is also shown to be more relatable with 21st century learning environment as compared to the conventional learning environment that has been in practice for a long time. Although both cooperative learning method and conventional learning method have their respective distinct benefits, most of the present researches show that cooperative learning method can offer more advantages to learners. Cooperative learning also promotes positive relationships to be formed among students, increases students' self-esteem and intrinsic motivation. When students are being educated through cooperative learning strategy, they are given the opportunity to voice their opinions, discuss, teach, guide and assist each other. When the students are given specific task to be completed together as a team, this strategy aligns the students with common goals not only promote teamwork and active learning, it also inherently creates healthier relationships among the students.

Hence, Polya's Model of Problem-solving skills incorporated with cooperative learning strategies are hypothetically to be more effective in promoting the students to excel better in solving non-routine problems in Mathematics. In addition to that, the students' interpersonal and socialising skills can also be developed.

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VI. CONCLUSION

This review strived to ascertain the use of Polya's problem solving strategy in combination with cooperative learning strategy in improving the problem-solving skills in Mathematics among primary school students as well as enhancing the students' capabilities to solve non-routine problems in Mathematics. The effectiveness of Polya's problem-solving strategy in non-routine problem has been promoted and verified by researchers who put their efforts in developing problem-solving skills in Mathematics. Problem-solving skills can be enhanced using a learning environment where students are encouraged to support one another in the process of completing a given task. The learning is beneficial when students are actively participating in Mathematics problem-solving's discussion using the Polya's problem-solving learning process. Cooperative learning promotes students' self-esteem, motivation and stimulates their sense of responsibility and contribution to group's effort. Hence, incorporating Polya's learning strategy with cooperative learning strategy is believed to be an innovative teaching method that enhances the problem-solving skills in Mathematics for primary school students.

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