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Problem Solving Strategies in Mathematics of Students in the of Primary Level: Basis for Strategic Study Guide

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Abstract: Mathematical problem solving ability refers to the thinking ability and problem solving ability that students show in solving mathematical problems, which is a very important ability in mathematics learning. However, because traditional mathematics teaching focuses on teaching basic concepts and algorithms and neglects the cultivation of students' problem-solving skills, many students are unable to begin to apply what they have learned to real-life problems. The Chinese government attaches great importance to the cultivation of students' mathematical ability in the educational reform for students. As China's society continues to develop and progress, we are paying more and more attention to how students use their knowledge to solve problems and how students can improve their problem-solving skills at the primary and secondary school levels.

Keywords: Mathematical Problem; Problem Solving; Primary School.

1. Introduction

Mathematical problem solving ability refers to the thinking ability and problem solving ability that students show in solving mathematical problems, which is a very important ability in mathematics learning. However, because traditional mathematics teaching focuses on teaching basic concepts and algorithms and neglects the cultivation of students' problem-solving skills, many students are unable to begin to apply what they have learned to real-life problems. The Chinese government attaches great importance to the cultivation of students' mathematical ability in the educational reform for students. As China's society continues to develop and progress, we are paying more and more attention to how students use their knowledge to solve problems and how students can improve their problem-solving skills at the primary and secondary school levels.

There is a relevant discussion of mathematical problem solving in our latest elementary school curriculum standard, the National Curriculum (Primary) Syllabus (Experimental) of the People's Republic of China. This standard, which was officially implemented in 2021, is an update and refinement of the previously implemented 2001 elementary school curriculum standards. Our latest elementary school curriculum standards include mathematical problem solving as an important learning objective and focus on developing students' problem solving skills in the teaching of mathematics.

The researcher as a mathematics teacher, wanted to use this study to improve students' mathematical problem solving skills, to develop students' interest in learning mathematics, and to enable students to use mathematical problem solving strategies correctly when faced with mathematical problems.

2. Methodology

2.1. Statement of the Problem

This study aimed to determine the effectiveness of the problem solving strategies in mathematics in the primary level. Specifically, it sought answers to the following questions.

1. What are the strategies used by the students in solving mathematics problems?
2. Is there a significant difference between the pretest scores of the participants in the control group and experimental group?
3. Is there a significant difference between the pretest scores and posttest scores of the participants in the control group?
4. Is there a significant difference between the pretest scores and posttest scores of the participants in the experimental group?
5. Is there a significant difference between the posttest scores of the participants in the control group and experimental group?
6. What problem-solving study strategy guide can be drawn based on the findings of the study?

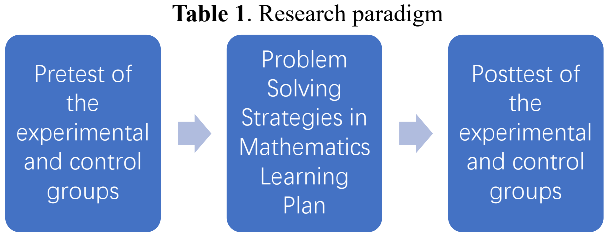
2.2. Null Hypotheses

This study tested the following null hypotheses.

1. There is no significant difference between the pretest scores of the participants in the control group and experimental group.
2. There is no significant difference between the pretest scores and posttest scores of the participants in the control group.
3. There is no significant difference between the pretest scores and posttest scores of the participants in the experimental group.
4. There is no significant difference between the posttest scores of the participants in the control group and experimental group.

2.3. Research paradigm

Table 1. Research paradigm



2.4. Research Methods

This study used quasi-experimental design, utilized natural scenes and flexibly controlled the subjects randomly assigning subjects to experimental and control groups. The whole class was assigned into two groups: the experimental group composed of 30 participants who took the pre – test and post -test after the implementation of the problem solving strategies in Mathematics; the control group composed of 20 participants who took the pre – test and post -test but no problem solving strategies implemented to them.

Both pre-test and post-test questions were derived from the Synchronous Analysis and Assessment for Grade 3, a teaching tutorial book (People's Education Press, 2021) and aligned with the standard textbook of compulsory education curriculum. This study focused on the basic mathematical knowledge and problem solving skills and strategies of Grade 3 students toward independent learning in Mathematics .

2.5. Sampling Method

This study used the purposive sampling method in selecting the participants in Grade 3 Mathematics class.

The criteria for participant selection included the following which served as profile data only but not as test factors in determining the differences:

The sampling size for the control and experimental groups is shown on Table 2.

Table 2. Frequency Distribution of the Respondents' Profile

Profile	Frequency		Percentage	
	Experimental group	control group	experimental group	control group
Sex				
Female	16	11	53.33%	55%
Male	14	9	46.67%	45%
Total	30	20	100%	100%
Age				
7years old	2	1	6.67%	5%
8years old	27	18	90%	90%
9 years old	1	1	3.33%	5%
Total	30	20	100%	100%
Subject				
Grade3 mathematics	30	20	100%	100%

As a public compulsory elementary school, the composition of the class complied with the school's class placement regulations. Table 1 shows that 53.33% of the students in the experimental group were female and 46.67% were male. In the control group, 55% of the students were female and 45% were male. The gender distribution of both groups was relatively balanced with no significant gender bias.

The data show that 90% of the students in the subject group, both in the experimental and control groups, were at the age-appropriate stage of 8 years. 6.67% of the students in the experimental group were 7 years old and 3.33% were 9 years old. In the control group, 5% of the students were 7 years old and 5% were 9 years old. This age distribution is a normal phenomenon in Chinese elementary school, which is in line with the pattern of school teaching and class placement, and the distribution is relatively balanced with no significant age difference. Both groups of students were taught third grade math in school, with the same content and speed of learning, meeting the conditions of the study.

In summary, the experimental and control groups are relatively balanced in terms of age and gender distribution. They have the basic knowledge and can further learn and master the problem solving strategies.

2.6. Data Gathering Procedure

This study involved the following stages of data collection or quasi experimentation:

Pre-test in Mathematics for Grade 3

The researcher considered basically the same daily learning situation in Mathematics class. Then, developed the pre-test for both the control and experimental groups, The scope of the pre – test was aligned with the competencies in Mathematics for the primary level as per the Mathematics Curriculum mandated by the Ministry of Education in China. The researcher administered the pre – test to both control and experimental groups.

Implementation of the Learning Plans and Integration of the Problem-Solving Strategies in Mathematics for Grade 3 - Experimentation

The researcher implemented the learning plans in Mathematics for Grade 3. She integrated the following strategies such as Arithmetic Computing, Logical Reasoning, Model Construction, Trial-and-error Method, and Graphical Representation to develop the experimental groups' problem-solving strategies.

Post-test in Mathematics for Grade 3

After the implementation of the problem-solving strategies in the experimental group, the researcher administered the post – test to both control and experimental groups. In the post – test, the researcher determined the problem-solving strategies of Grade 3 pupils in the following problem sets through their analysis and solution, compared with their problem-solving strategies in the pre – test. Each item was allotted 2 points mainly calculated according to the mathematical problem thinking process (1 point) and result presentation (1 point).

The researcher assigned anonymous codes on all tests; but the coded the experimental group and the control group separately. Then, she compared and analyzed the results of the tests of the two groups to determine whether the problem solving strategies have been effective with the experimental group.

3. Results And Discussion

3.1. Results

This chapter presents the results of the data collection, analyzed, and interpreted in light of the problem statement.

3.1.1. Differences between the Pretest Scores of the Control Group and Experimental Group

Table 3 shows the result of the test of difference between the pretest scores of the control group and experimental group. The pretest mean score of control group was 5.40; while the pretest mean score of the experimental group was 5.50. The computed t-value 0.242 is less than the critical value 2.011 and the p-value 0.810 is greater than the level of significance alpha 0.05. With these results, the null hypothesis "There is no significant difference between the pretest scores of the control group and experimental group" was not rejected. It implies that the pretest scores of the participants in the control group and experimental group did not significantly differ.

Table 3. Differences Between the Pretest Scores of the Control Group and Experimental Group.

PRETEST MEAN SCORES		Computed t-Value	Critical Value at α = 0.05	p-value	Findings
Control Group	Experimental Group				
5.40	5.50	0.242	2.011	0.810ns	There is no significant difference.

Legend: * - The difference is significant.
ns – The difference is not significant

This result shows that there is no gap between the two groups of students in the grasp of related problems in the pre-learning. The experimental group and the control group now have the same course teaching arrangement in the mathematics course, and the mathematical problem solving ability is basically at the same level, and there is no significant difference in the mathematical problem solving ability.

Wang (2020) found the importance and application significance of experimental pre-tests in third grade math problem solving experiments. The results of the study showed that through the experimental pre-test, the researcher was able to gain a comprehensive understanding of the level of mathematical problem solving ability of the students in the experimental group and the control group before the start of the experiment, which in turn provided an important reference for the experimental design.

Similarly, Yang (2019) emphasized in her study that through the experimental pre-test, the researcher could effectively understand the baseline situation of the two groups of students in terms of problem solving ability and strategy use before the start of the experiment, thus ensuring that the experimental group and the control group were comparable before the start of the experiment. This helps to improve the reliability and interpretability of the experimental results.

Wang (2020) and Yang (2019) both underscore the importance of experimental pre-tests in third grade math problem-solving experiments. Their studies highlight how pre-tests enable researchers to comprehensively assess the mathematical problem-solving abilities of students in both the experimental and control groups before the experiment begins. This understanding serves as a crucial reference point for designing the experiment. By ensuring comparability between the groups before the intervention, pre-tests enhance the reliability and interpretability of the experimental results.

3.1.2. Difference Between the Pretest Scores and Posttest Scores of the Control Group

Table 4. Difference Between the Pretest Scores and Posttest Scores of the Control Group

CONTROL GROUP		Computed t-Value	Critical Value at α = 0.05	p-value	Findings
Pretest Mean Score	Posttest Mean Score				
5.40	5.95	1.177	2.093	0.254ns	There is no significant difference.

Legend: * - The difference is significant.
ns – The difference is not significant

Table 4 shows the result of the test of difference between the pretest scores and posttest of the control group. The pretest mean score of control group was 5.40 while their posttest mean score was 5.95. The computed t-value 1.177 is less than the critical value 2.093 and the p-value 0.254 is greater than the level of significance alpha 0.05. With these results, the null hypothesis "There is no significant difference between the pretest scores and posttest scores of the control group" was not rejected. It implies that the pretest scores and posttest scores of the participants in the control group did not significantly differ.

This data shows that the control group did not use the mathematical problem solving strategies well without the specific learning training, and the mathematical problem solving ability did not improve significantly. Thus, the use of experimental pre-tests and post-tests in third grade problem solving experiments is important to better assess the actual effectiveness of the experimental intervention and to conclude that there were no significant differences between the two data groups.

Wang (2020) concluded that by administering pre- and post-tests of the experiment to the control group, the researcher was able to get a comprehensive picture of the baseline level of problem-solving skills of the students in the control group and to track how they changed after the experimental intervention. This helped to ensure that the experimental and control groups were comparable prior to the start of the experiment. It also assessed that there was no significant difference between the data of the two groups in the control group without the experimental treatment.

Zhang (2020) also argued that there was a need to administer a pre-experimental test and a post-test to the control group in a third grade problem solving experiment. By administering the pre-test and post-test to the control group, the researcher was able to better understand the starting level and changes in problem solving ability of the control group students. It was able to better assess the actual effectiveness of the experimental intervention and concluded that there was no significant difference between the data of the two groups.

According to Wang (2020) and Zhang (2020), by administering the experimental pre-test and post-test to the control group, the researcher was able to get a comprehensive picture of the baseline level of the students in the control group in terms of problem solving ability and track their changes after the experimental intervention. This practice helped to ensure that the experimental and control groups were comparable prior to the start of the experiment and assessed that there were no significant differences between the data of the two groups in the control group that did not undergo the experimental treatment. Thus, the use of experimental pre-tests and post-tests in third grade problem solving experiments is important to better assess the actual effectiveness of the experimental intervention and to conclude that there were no significant differences between the two data groups.

3.1.3. Difference Between the Pretest Scores and Posttest Scores of the Experimental Group

Table 5. Difference Between the Pretest Scores and Posttest Scores of the Experimental Group

EXPERIMENTAL GROUP		Computed t-Value	Critical Value at α = 0.05	p-value	Findings
Pretest Mean Score	Posttest Mean Score				
5.50	8.30	13.259	2.045	0.000*	There is significant difference.

Legend: * - The difference is significant.
ns – The difference is not significant

Table 5 shows the result of the test of difference between the pretest scores and posttest of the experimental group. The pretest mean score of experimental groups was 5.50 while their posttest mean score was 8.30. The computed t-value 13.259 is greater than the critical value 2.045 and the p-value 0.000 is less than the level of significance alpha 0.05. With these results, the null hypothesis "There is no significant difference between the pretest scores and posttest scores of the experimental group" was rejected. It implies that the pretest scores and posttest scores of the participants in the experimental group significantly differed.

According to the data, the scores of the experimental group changed significantly before and after the test, indicating that the experimental group could master and use mathematical strategies to solve problems to a certain extent after the experiment, and their own mathematical problem-solving ability was improved.

In both pre-test and post - test, 90% of the pupils, used logical reasoning strategies. This indicates that generally these pupils have the basic problem-solving strategies which are necessary in Mathematics for Grade 3.

Lesh and Zawojewski (2007) describe arithmetic computing as a problem-solving strategy that involves using basic mathematical rules and techniques to perform addition, subtraction, multiplication, and division operations. When solving two-digit addition problems, students apply their understanding of place value and add the corresponding digits in the ones and tens places. They may also need to carry over when the sum of the ones digits exceeds 9. By mastering the rules of arithmetic and practicing flexible calculation methods, students become proficient in solving numerical calculations involving adding two-digit numbers. Moreover, Harel and Sowder (2005）explain that logical reasoning as a strategy of using logical thinking to reason and solve problems based on known facts and conditions. By analyzing the logical relationships of problems, searching for patterns, and inferring conclusions, students can reason and solve mathematical problems rationally.

However, even though they demonstrated mastery in arithmetic computation and logical reasoning strategies in the pre-test, they were not able to fully apply these strategies in solving a problem that requires a model construction since 50% only of the pupils used it, and 78% only used graphical construction. This indicates that these pupils need more problem solving practice sets to further enhance their model construction and graphical construction strategies.

On the other hand, the pupils demonstrated mastery in arithmetic computation and logical reasoning strategies in the post-test and were able to almost apply these strategies fully in solving a problem that requires a model construction since 90% of the pupils used it, 90% used graphical construction, and nearly close that 88% used trial and error method. This indicates that these pupils have applied the five problem solving practice in the post – test which may be associated with the implementation and integration of the said five problem solving strategies in the five learning plans in Mathematics for grade 3 during the experimentation stage.

Lesh and Doerr (2003) describe model construction as a strategy of transforming mathematical problems into concrete models or graphical representations and solving problems through model construction and analysis. Students can use tools such as abstract thinking and geometry to translate problems into a visual form and then analyze and solve them.

Schoenfeld (1985) identifies trial-and-error method as a strategy for approaching the problem-solving process gradually by trying different methods and strategies, practicing and correcting mistakes repeatedly. Students can find errors and correct them through multiple attempts and reflections, thus gradually finding the correct solution. Moreover, Harel and Confrey (1994）indicate that graphical representation as the visual presentation of mathematical problems in the form of diagrams and images for better understanding of problems and problem-solving strategies. Students can present the key information of the problem by drawing charts and making graphs to further analyze and solve the problem.

Yang (2019) confirmed that through the experimental pre-test and post-test, the researcher was able to get a comprehensive picture of the starting level and changes in problem solving ability of the students in the experimental group. Further analysis showed that the experimental treatment had a significant effect on the problem solving ability of the students in the experimental group, and there was a significant difference between the two groups of data compared to the data from the experimental pre-test.

Zhang (2020) supported that through the experimental pre-test and post-test, the researcher was able to fully understand the baseline level of the students in the experimental group in terms of their mathematical problem solving ability and track their changes after the experimental intervention. Further analysis showed that there was a significant difference between the pre- and post-test data of the experimental group, indicating that the teaching of mathematical problem solving had a significant impact on the mathematical problem solving ability of the students in the experimental group.

Synthesizing the findings of Yang (2019) and Zhang (2020), it can be concluded that through the experimental pre-test and post-test, the researcher was able to get a comprehensive picture of the starting level and changes in problem solving ability of the students in the experimental group. Further analysis showed that the experimental treatment had a significant effect on the problem solving ability of the students in the experimental group. Compared to the data from the pre-test of the experimental group, the data from the post-test of the experiment showed a significant difference between the two groups. This indicates that the changes in the data between the experimental pre-test and post-test reflect the actual effect of problem solving instruction and emphasize the importance of problem solving instruction in improving the problem solving ability of the students in the experimental group.

3.1.4. Difference between the Posttest Scores of the Control Group and Experimental Group

Table 6. Difference Between the Posttest Scores of the Control Group and Experimental Group

POSTTEST MEAN SCORES		Computed t-Value	Critical Value at α = 0.05	p-value	Findings
Control Group	Experimental Group				
5.95	8.30	6.108	2.011	0.000*	There is significant difference.

Legend: * - The difference is significant.
ns – The difference is not significant.

Table 6 shows the result of the test of difference between the posttest scores of the control group and experimental group. The posttest mean score of control group was 5.95 while the posttest mean score of the experimental group was 8.30. The computed t-value 6.108 is greater than the critical value 2.011 and the p-value 0.000 is less than the level of significance alpha 0.05. With these results, the null hypothesis "There is no significant difference between the posttest scores of the control group and experimental group" was rejected. It implies that the posttest scores of the participants in the control group and experimental group significantly differed.

The results of data analysis showed a significant difference between the experimental group and the control group, and the score of the experimental group was greater than that of the control group. Because the experimental group received experimental treatment, that is, problem solving teaching, and the control group did not conduct experimental treatment. Therefore, it can explain the feasibility and effectiveness of solving the teaching of problems.

Wang (2020) found that through the experimental post-test, the researcher was able to comprehensively assess the changes in problem solving ability of students in the experimental and control groups. Further analysis showed that mathematics problem solving instruction had a significant impact on the problem solving ability of students in the experimental and control groups, and the data of the two groups were significantly different.

Zhang (2020) found that through the experimental post-test, the researcher was able to fully understand the changes in the mathematical problem solving ability of the students in the experimental group and the control group, and there was a significant difference between the data of the two groups. Further analysis showed that there was a significant difference between the experimental group and the control group in terms of mathematical problem solving ability after the experimental treatment, which further verified the effectiveness of problem solving instruction.

Wang (2020) and Zhang (2020) assessed the changes in problem solving ability between students in the experimental and control groups. Mathematics problem solving instruction had a significant impact on the problem solving ability of students in the experimental and control groups, and there was a significant difference between the data of the two groups. This further confirms the effectiveness of teaching math problem solving and provides support for the practical application of this teaching method.

3.2. Recommendations

Based on the conclusions of the study, the following recommendations are presented:

1.That math teachers in the primary level must develop and train the problem solving strategies of the pupils namely model construction, graphical construction, and trial and error method that pupils can meaningfully use in practice sets in Mathematics;

2.That students must explore and try different problem solving strategic to develop their mathematical competencies;

3.That schools and educational institutions can conduct specialized teacher training and educational seminars to help teachers better understand and apply the five mathematical problem-solving teaching strategies to improve the quality and effectiveness of their teaching;

4.That instructional materials developers must design and produce learning plans with teacher and student guide to practically integrate and implement the problem solving strategies in Mathematics for the primary level students.

4. Conclusion

1. The null hypothesis "There is no significant difference between the pretest scores of the control group and experimental group" was not rejected. It implies that the pretest scores of the participants in the control group and experimental group did not significantly differ.

2. The null hypothesis "There is no significant difference between the pretest scores and posttest scores of the control group" was not rejected. It implies that the pretest scores and posttest scores of the participants in the control group did not significantly differ.

3. The null hypothesis "There is no significant difference between the pretest scores and posttest scores of the experimental group" was rejected. It implies that the pretest scores and posttest scores of the participants in the experimental group significantly differed.

4. The null hypothesis "There is no significant difference between the posttest scores of the control group and experimental group" was rejected. It implies that the posttest scores of the participants in the control group and experimental group significantly differed.

5. Based on the results of the study, the strategic guide in Mathematics has been developed:

Strategic Study Guide in Mathematics for The Primary Level

Rationale:

This Strategic Study Guide intends to develop the problem solving strategies of the pupils in Mathematics for the primary level. This Strategic Study Guide includes five learning plans to guide the teachers and the pupils in each lesson that integrate and implement especially following problem solving strategies namely Arithmetic Computing, Logical Reasoning, Model Construction, Trial-and-error Method, and Graphical Representation.

Each lesson covers a topic and skill in Mathematics for

Grade 3 aligned with the competencies in Mathematics for the primary level as required by the Ministry of Education in China. It integrates each problem solving strategy in every lesson so that the pupils can develop/enhance the said strategy during the lesson towards independent use or application. Then, the pupils are assessed to determine whether they have acquired or developed the said strategy.

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