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Using Problem-Solving Methods to Improve Mathematics Learning Achievement for Primary School Students

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Abstract This study investigates the effectiveness of the problem-solving method in enhancing mathematics performance among fourth-grade primary school students in Shanghai. Integrating quantitative and qualitative research methods offers a nuanced understanding of the methodology's impact on student learning. Utilizing a rigorous mixed-methods approach, the study meticulously develops a problem-solving model grounded in the latest curriculum standards, ensuring its alignment with contemporary educational objectives. The study quantitatively and qualitatively assesses the impact of this methodology. With 80 students, including 20 in an experimental group, pre-tests and post-tests show that the method significantly stimulates learning interest, promotes logical thinking, and improves mathematics performance. Notably, the qualitative data illustrates how problem-solving pedagogy can be helpful and understandable in the primary maths classroom, revealing a shift from passive learning to active engagement. In conclusion, this study provides new perspectives and effective strategies to enhance primary school students' learning ability in mathematics, which has important theoretical and practical significance.

Keywords Problem-solving method; Maths; Mathematics learning; Maths thinking; Achievement

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Introduction

In modern educational philosophy, mathematics teaching should be student-centered and interactive, enabling students to actively discover and propose questions, analyze, and solve problems (Li, 2018). Mathematics plays a crucial role in contemporary society, influencing almost every aspect. It is a powerful thinking tool, serving as the foundation for other disciplines and a critical factor in fostering logical reasoning, problem-solving, and social progress.

Improving mathematics learning achievement is highly significant for students' development and learning. In China, scores mainly measure performance, and educators consider word problems the most effective way to help students improve their grades (Hu, 2022). The new curriculum reform requires teachers to shift from emphasizing passive learning to guiding students in independent thinking, collaborative exploration, and communicative sharing while teaching word problems.

Word problems, an important part of elementary mathematics, present challenges to many students regarding problem analysis, strategy selection, and reasoning processes. For example, they need help comprehending the meaning of the problem. Fourth-grade application problems begin to involve more complex descriptions of situations, and students may need help extracting key information from lengthy text, which requires good reading comprehension and information screening skills. There needs to be more clarity between mathematical concepts and practical applications. Although students have learned some basic mathematical concepts, they need clarification when applying them to concrete life situations. Logical reasoning ability is not. Application problems often require students to engage in a certain amount of logical reasoning, starting from known conditions and gradually deducing unknown results. This task is difficult for primary school students whose logical reasoning skills still need to be mature. Lack of problem-solving strategies:Students may need more effective strategies for solving different application problems, and the lack of these strategies can lead to efficient problem-solving or even the inability to answer correctly. Lack of interest and motivation in learning: Application problems are relatively dull; if students lack interest in mathematics f-or think that application problems are challenging to understand and uninteresting, it may lead to their lack of motivation and enthusiasm in the learning process (Hu, 2019).These difficulties negatively affect students' math learning and problem-solving skills.To deal with these problems, teachers can help students overcome their difficulties in many ways, and the problem-solving teaching method is one of the better ones to help students understand. The following teaching strategies can be adopted: Create a situation to guide understanding. Break down the problem and guide it step by step. Teach problem-solving strategies. Strengthen practical training, timely feedback and guidance. Encourage summarization and reflection.Therefore, it is necessary to conduct an in-depth study of students' performance in word problems to improve the quality and effectiveness of elementary mathematics education.

To address the above issues, scholars have proposed the problem-solving teaching method. Ministry of Education of the People's Republic of China (2022) advocates that mathematics classrooms should be a process of students learning from and supporting each other, forming a learning community under the guidance of teachers. Dewey emphasized a problem-centered approach, the problem-solving method, which involves guiding students through analyzing and solving problems. There are five main steps: posing the problem, analyzing the problem, solving the problem, summarizing the problem, and evaluations.

After reviewing relevant literature on problem-solving methods and mathematics I chose the title "Using Problem-Solving Methods to Improve Mathematics Learning Achievement for Primary School Students. The goal is to offer valuable insights and references for both students and teachers.

Methodology

Objective

In this rapidly developing era of artificial intelligence, primary education holds particular importance. As a vital component of primary education, mathematics education plays an irreplaceable role in cultivating problem-solving abilities in young students.

This study conducted experimental research by comparing two classes with similar backgrounds to validate the positive impact of the problem-solving teaching method and explore its application value in primary school mathematics education. The results demonstrate that problem-solving effectively promotes students' abilities to identify, formulate, analyze, and solve mathematical problems, facilitating their comprehensive physical and mental development. Furthermore, the research process also enhances teachers' professional expertise and development.

Relevant theoretical concepts and conceptual frameworks

Problem-solving method

Problem

In academic research on problems, researchers define problems differently from different perspectives.

Pólya (1945) explains the problem in the following way: problem means finding the right action to achieve a visible and inaccessible goal.

Zaodi Hu (2019) regarded a problem as a kind of psychological dilemma, and later, some researchers considered it a particular situation; that is to say, they viewed a problem as a situation when an individual is faced with a more difficult to achieve goal.

In summary, this paper understands problems as contradictions and dilemmas that must be studied and resolved.

Problem-solving

Indeed, when we integrate problems into specific mathematical disciplines, the perception of a mathematical problem can vary among individuals.

Zhang (2018) supposes problem-solving is a problem expressed in mathematical terms. This paper understands problem-solving as the use of mathematical language, mathematical concepts, mathematical knowledge, mathematical methods, mathematical theories, or mathematical methods of thought to resolve conflicts or difficulties in mathematics.

problem-Solving Method

The problem-solving Method is used in school teaching and learning worldwide. Still, there needs to be a uniform definition of the problem-solving Method due to differences in national and regional contexts.

Wang (2019) suggests that in the mathematics classroom, students should take the initiative to question, to ask questions, and to learn from the process of identifying problems to solving them.

Pólya (1945) was the first to introduce the concept of problem-solving in mathematics education, suggesting that an excellent strategic approach to problem-solving is to use problems to solve problems.

Li (2018) pointed out that the problem-solving method is a problem as a career; teachers and students work together to create a situation in the context of the problem, around the content of the teaching of the problem, and comply with the development of the student's mental intelligence, and then around the question of solving the actual issues in education and teaching.

Hu (2022) thinks the problem-solving mode of mathematics teaching is a comprehensive teaching method that leads students to engage in problem-solving, using problems as a carrier, enabling

students to develop in problem-solving, and realizing the interaction between teachers and students to improve the overall quality of students.

Gao (2019) believes problem-solving is a student-centered pedagogy that encourages students to learn knowledge and skills by solving real-life problems. Teachers should focus on the subjective needs of students for mathematical understanding and enhance students' awareness of learning through thought development, group interaction, and life practice.

To sum up, the problem-solving method centers around posing questions as the primary focus to guide students in analyzing problems and constructing their understanding independently. It stimulates students to explore and inquire deeply through straightforward, precise, well-structured questions, fostering self-directed inquiry.

Problem-solving method steps

Many scholars have proposed different teaching models for problem-solving method steps

Table 1 Problem-solving method steps

Author	Wang (2019)	Pólya (1945)	Li (2018)	Hu (2022)	Gao (2019)	My Research detail	
step 1	Posing problem	Understanding the problem	Problem driven	Introduction to Teaching Themes	Problem identification and definition	step 1	Posing problem
step 2	Analysing problem	Planned Solutions	Analyzing the problem	Issue Exploration	Strategy Selection and Application	step 2	Analysing problem
step 3	Solving-problem	Implementation plan	Problem-solving	Variable application	Characterization of the problem Allocation of resources	step 3	Solving problem
step 4	Summarising problem	Retrospective inspection	Rational induction		Monitoring and Evaluation	step 4	Summarising problem
step 5		Learning Summaries	Problematic applications			Step 5	Evaluations
step 6			Feedback regulation				

The table shows that the steps of the problem teaching method proposed by each scholar differ. Still, after careful study, it concludes that posing a problem, analyzing it, solving it, and evaluating it are the common elements. Based on these scholars, this paper considers the steps of a problem-solving method in light of the new curriculum standard:

Step 1: Posing problem

Creating scenarios can mobilize students' enthusiasm for learning and truly engage them in learning. Students construct knowledge through experiences, practices, and interactions with the environment. Once students are familiar with the scenarios, they actively think critically and pose questions. During the teaching process, the formation of questioning methods is not spontaneous; instead, teachers deliberately set them up to attract students into a state of active thinking. This approach to questioning methods is supported by Zhiqiang (2019).

Step 2: Analysing problem

By creating specific problem scenarios, students face certain thinking obstacles. Faced with these problems, students need to apply mathematical awareness, tap into their thinking potential, delve more profoundly, and creatively utilize their existing knowledge and experiences for learning (Zhang, 2018). This approach ensures the full development of students' various abilities. Xiaomei (2018)

emphasize that analyzing problems is a crucial step in understanding them and an essential prerequisite for problem-solving. Through thorough problem analysis in the problem-solving process, students can find multiple solutions and strategies. Teachers should provide students with appropriate guidance to encourage their active participation. During discussions, teachers should guide and encourage students, enumerate various possible problem-solving methods, and help students learn how to analyze problems, thus deepening their understanding of the problems at hand.

Step 3: Solving problem

Through activities such as research, exploration, critical thinking, and collaboration, students consciously apply the mathematical knowledge, methods, skills, and strategies acquired in the mathematics classroom to tackle the problems. Pólya emphasizes the importance of students adopting systematic approaches when solving problems rather than mechanically applying formulas and methods (Pólya, 1945). Teachers should also guide students in applying their mathematical knowledge to real-life situations, allowing students to realize that mathematics is derived from life and serves life's practical needs (Hu, 2022).

Step 4: Summarising problem

Guiding students to learn how to reflect and summarize can awaken their existing knowledge structures and exploratory abilities. If teachers only focus on whether the problem is solved without guiding students to reflect on the problem-solving process, it limits their understanding of the underlying strategies and methods used (Wang, 2019; Gao, 2019). Therefore, teachers should guide students in reviewing their problem-solving strategies. This way, students not only master the mathematical knowledge they have learned but also learn various strategies for solving mathematical problems, leading to the ability to apply these strategies in different contexts.

Step 5: Evaluations

Evaluation is an integral part of the problem-based approach to teaching and learning, which helps understand students' learning outcomes and competence development in problem-solving. An evaluation should be comprehensive and continuous, focusing primarily on students' processes and products and providing targeted feedback (Li, 2018; Gao, 2019).

Mathematics learning achievement

Achievement

Achievement can be translated into English as either achievement or performance. In China, it generally has two meanings. Firstly, it refers to the outcomes or results achieved in learning, work, etc. Secondly, it can represent an individual's performance or accomplishments in a particular task or field. In educational research, achievement refers explicitly to the test results of an individual's abilities are used to evaluate a student's academic performance, including exam scores or scores from regular assessments (Yang et al., 2022).

Mathematics learning achievement

Based on the concepts of Achievement and Mathematics Learning, Mathematics Learning Achievement refers to the ability of elementary school students to learn numbers and operations, geometry and shapes, data and statistics, and equations during their primary education. This research primarily focuses on students' learning of word problems. The teaching approach used in this study is the problem-solving teaching method, and the researchers compare the scores obtained from the performance tests before and after implementing the problem-solving teaching method.

Different versions of the Compulsory Education Mathematics Curriculum Standards have evaluated elementary school mathematics learning performance from various perspectives.

Table 2 Mathematics learning achievement assessment form

Evaluation dimensions	Assessment content	Ministry of Education of the People's Republic of China				Total
		1986 edition	2001 edition	2011 edition	2022 edition	
Numbers and Operations	Data analysis	√	√		√	3
	Computational skills		√	√	√	3
Geometry and Graphics	Spatial relations	√	√	√	√	4
	Graphic composition			√	√	2
Data and statistics	Data statistics	√	√		√	3
	Data application		√	√	√	3

According to the new curriculum standard for compulsory education mathematics (2022), the mathematics content for the first semester of the fourth grade of elementary school. For this study, the researcher selected the evaluation dimensions and components with results greater than or equal to 2 in the table above; the approach compares the changes in students before and after their lessons from three dimensions: number and algebra, geometry and graphing, data, and statistics. Test and evaluation methods: This study will use a combination of test papers, primarily Type A (objective test) and type B (question and answer test).

After the end of the problem-solving method, a test paper on mathematics in the fourth grade of elementary school was prepared. The difficulty (p) of the test paper is 0.76, and the discrimination (r) is 0.33. This was pretested among 80 fourth-grade students at New Century Primary School, In order to ensure the reliability of this test paper, the study analyzed its reliability and validity by using SPSS Statistics 26.0, and the alpha coefficient of this test paper was 0.731, for Table 3, indicating that the reliability of this test paper is high. The approximate chi-square KMO value of the test paper was 0.611 with sig<0.05 ,for Table 4, by performing the Bartlett's sphere test on the test paper, indicating that the test paper has good validity.The results of the data analysis are presented below:

Table 3 Reliability statistics

Cronbach's Alpha	Cronbachs Alpha Based on Standardized Items	N of Items
0.731	0.817	36

Table 4 KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.611
Bartlett Test of Sphericity	Approx. Chi-Square	1990.220
	df	630
	Sig.	0.000

Population and sample group

The study population was 80 students in fourth grade at New Century Elementary School; the sample group was randomized through the whole cluster sampling method, and the researcher drew 20 students with high, medium, and low levels.

Research tools

The tools used in this study include course study programs and test papers, detailed below:

The course study program uses problem-solving methods, with three programs totaling 12 hours.

To study the 2022 Core Curriculum for Basic Education (Revised 2022) and the HUE Mathematics Curriculum and to explore the integration of problem-solving pedagogy with related literature and textbooks.

The program of study is divided into three chapters each containing 12 lessons. Each lesson follows the five steps of the problem- solving methods:1) Posing the Problem. 2) Analysing the Problem. 3) Solving the Problem. 4) Summarising the Problem. 5) Evaluating the Solution .

The plan of study for the fourth-grade math program is as follows:

Table 5 Primary School Mathematics Fourth Grade Curriculum

Learning dimensions	Learning content	Specific requirements
Numbers and Operations	Knowledge and basic properties of decimals	Visualizing one-digit, two-digit, and three-digit decimals.
	Comparing the size of decimals	Compare the decimals' size and understand the meaning indicated by the number after the decimal point.
	Written calculation of division	Can perform vertical calculations to divide a four-digit number by a two-digit number.
	Recognition of weight units	Establish the concept of 1 gram and 1 kilogram weight, understand the actual weight of 1 tonne, and know the conversion factors between them.
Geometry and Graphics	Understanding Bottom and Height	Recognize the base and height of parallelograms, triangles, and trapezoids and correctly draw the heights of parallelograms, triangles and trapezoids.
	Area of the triangle	Can correctly find the area of a triangle.
	Area of the trapezoid	Can correctly find the area of a trapezoid.
	Area of Combined Figures	Can correctly find the area of a combination of shapes.
Data and statistics	Awareness of bar charts	Be able to ask and answer questions based on bar charts, identify information, and perform simple data analysis.
	Awareness of line graphs	Be able to ask and answer questions based on line graphs, identify information, and perform simple data analysis.
	Juggling game	Be able to express the likelihood of a number.
	Who Goes First Game	Intuitively recognize equal probability and the fairness of the rules of the game and identify the characteristics of uncertain phenomena.

I am testing new century elementary school fourth graders in math

Create subjective and objective tests based on learning objectives and research theories aligned with the Problem-Solving Pedagogy learning program.

The test paper consists of a subjective test of 30 multiple-choice questions and an objective test of 6 questions and answers.

Three experts assessed the content of the Improving Math Achievement test paper to check for content validity and to find the IOC (Index of Item Objective Congruence). Each IOC-aligned index for the test exceeded 0.5. The IOC applicable to the study of this test was 0.731.

The researcher taught problem-solving pedagogy to the experimental class, experimented with the students (2023 school year), and found the test results.

Check the quality of the test item. Analyze the results to determine the difficulty value (p) and discrimination value (r). Selecting tests with a difficulty value (p) in the range of 0.20 - 0.80 and a

discrimination value (r) of 0.20 or higher, the researcher analyzed the results for a test of 30 multiple-choice subjective questions and 62 question-and-answer objective questions with a difficulty value (p) of 0.76 and a discrimination value (r) of 0.33.

Check the quality of the entire math achievement test. The researcher found a confidence value using Cronbach's alpha coefficient, with a value of 0.70 or higher considered appropriate for studies (Zhao Ming & Wang Jian. 2019), The confidence level for the entire test paper was 0.731.

Table 6 The result of effect sizes and confidence intervals

	Paired Differences				
	Mean	Std. Dev.	Std.Error Mean	95% Confidence Interval of the Difference	
				Lower	Upper
Pair1 pre-test - post-test	-12	6.797	1.520	-15.080	-8.720

As can be seen from the figure, the mean of the pre-test (pre-test) and post-test (post-test), with an effect size of 57.60 - 45.70 = 11.90, indicates that the mean performance on the post-test was 11.90 units higher than on the pre-test and that the effect size (a change of 11.900 units) was significant, and that the 95% confidence intervals [-15.081, - 8.719] also indicate that this difference is reliable.

Data collection

Students were tested (pre-test) before the study.

Learning activities using problem-solving methods.

Students analyze data after the study (post-test) by combining scores after the test based on score criteria created by the researcher.

Data analysis

The researcher compared problem-solving methods before and after learning, and data were analyzed using means, standard deviations, and t-tests for samples.

Results and discussion

Research results

Twenty-fourth-grade students at New Century Elementary School were tested in math after using the problem-solving method in their math class and compared their math scores to their scores before the study as, shown in the table below:

Table 7 Mathematics Learning Achievement Before and After the Implementation based on the Problem-Solving Method

Mathematics Learning Achievement	n	perfect score	$\bar{x}$	SD.	t	p
pre-testing	20	60	45.700	9.772	-7.830	0.000
post-test	20	60	57.600	3.912		

***** Was statistically significant at .01 level (p <.01)

From the table, The 20 students in grade 4, class 2 of New Century Primary School had a mean score of ($\bar{x}$) 45.7 with a standard deviation (SD) of 9.772 in the pre-learning period. A mean score of

($\bar{x}$) 57.6 with a standard deviation (SD) of 3.912 in the post-learning period, with the post-learning scores being higher than the pre-learning period (t-test=7.830), with statistical significance at the 0.01 level, and the difference is statistically significant.

Conclusions

This study integrates the problem-solving teaching method through literature analysis, classroom observation, and testing methods. This approach aligns with the development of the new curriculum reform, offering fresh perspectives for teaching and learning in elementary school mathematics classrooms.

Throughout this study, the findings will be summarized as follows:

In traditional didactic classroom teaching, the teacher's knowledge of the main, although in the classroom there will be pictures or videos to assist education, but for some problematic mathematical knowledge, most students' understanding stays in the firm memory level; it is not accessible to feel the fun of mathematical knowledge. Problem-solving teaching method by creating a reasonable and exciting situation so that students actively integrate into the problem-solving classroom teaching, which significantly broadens their horizons, deepens their mathematical thinking, and vigorously promotes the development of the mathematics subject.

For the problem-solving teaching process focusing on the problem creation link, teachers, through the mastery of elementary school mathematics knowledge and the study of the new curriculum, put forward as much as possible in the classroom teaching mathematical problems with relevance to ensure the coherence of the learning process students learning process. By connecting mathematical knowledge with real-life situations, students are reminded to focus on the practical application of their skills. As they acquire new ideas and problem-solving methods, they are encouraged to actively consider the relationship between old and new knowledge, helping them to construct and enhance their knowledge base. In the process of internalization of knowledge, through the accumulation of knowledge, from the discovery of the problem to the problem, from the answer to a problem to the processing of the variant problem, students, through a series of divergent thinking activities, their mathematical logic ability subconsciously and subsequently enhanced. The problem-solving teaching method centers on "problem-solving," Its most significant distinction from other teaching approaches is that it considers the intrinsic connections between different concepts, enabling the integration of various elements. This approach helps improve elementary school students' mathematics performance.

In front-line teaching practice, the problem-solving teaching method promotes students' progress and drives teachers' development, reflecting its essential value and research significance.

Limitations of the research

Limitations of the sample: This study may be limited by the sample size, resulting in results that may partially represent some elementary school mathematics. Future studies may consider expanding the sample to include students and teachers from different districts and backgrounds to increase the generalizability of the study.

Differences in teaching and learning environments: There are differences in the teaching and learning environments, resource support, and teacher strengths in different schools, which may affect the effectiveness of the implementation of the problem-solving pedagogy. This study could not fully explore the specific effects of these environmental factors on teaching effectiveness, and future research could further refine the analysis of these aspects.

Evaluation of long-term effects: This study focused on the implementation effects of the problem-solving pedagogy in the short term. However, the impact on improving long-term

mathematical literacy and problem-solving ability must be further verified. Future studies could design long-term follow-up surveys to assess the long-term effects of the pedagogy.

Combination of quantitative and qualitative data: This study may have relied more on quantitative data (e.g., test scores) and should have paid more attention to the importance of qualitative data (e.g., student feedback, teacher interviews). Future research could use quantitative and qualitative methods for a more comprehensive and in-depth analysis.

Areas for future investigation

Adaptation for different age groups of students, to explore the differences in the adaptation and effectiveness of the problem-solving pedagogy among students of different age groups (e.g., lower and upper grades), and to provide more targeted recommendations for teaching mathematics to different age groups.

Interdisciplinary Applications: To study the effectiveness of problem-solving pedagogy in other disciplines (e.g., science, social science) and to explore its potential and challenges in interdisciplinary education.

Technology-assisted pedagogical innovation: With the development of educational technology, explore how to use information technology tools (e.g., intelligent teaching systems, online collaborative platforms) to optimize the implementation of problem-solving pedagogies and to improve the effectiveness of teaching and learning.

Recommendations for educators and policymakers

Strengthen teacher training; for problem-solving pedagogy, systematic training and support should be provided to teachers to help them master the pedagogy's core concepts and operational skills and improve their teaching abilities.

Creating supportive teaching environment, Schools and educational institutions should strive to create a supportive problem-solving teaching environment, including providing rich teaching resources, encouraging teacher-student interaction and cooperative learning, and establishing effective evaluation mechanisms.

Focus on individual differences. When implementing the problem-solving teaching method, teachers should focus on individual differences of students and adopt diversified teaching strategies and methods to meet different students' learning needs and development potential.

Continuous Evaluation and Feedback, A continuous teaching evaluation mechanism should be established to regularly assess and provide feedback on implementation of the Problem-Solving Teaching Approach. This allows for timely adjustments to teaching strategies and methods, ensuring the maximization of the teaching effect.

Policy guidance and incentives:The government and education departments should introduce relevant policies to encourage and support schools to adopt innovative teaching methods such as problem-solving, and provide a strong guarantee for education reform.

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