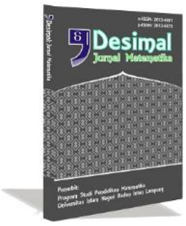
Desimal: Jurnal Matematika Vol 8 No 1 (2025) 87-100

Contents lists available at DJM

DESIMAL: JURNAL MATEMATIKA

p-ISSN: 2613-9073 (print), e-ISSN: 2613-9081 (online), DOI 10.24042/djm

http://ejournal.radenintan.ac.id/index.php/desimal/index



Teaching and learning mathematics with problem solving approach: Learning activities and instructional practice

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ARTICLE INFO

Article History
Received : 14-01-2024
Revised : 08-03-2024
Accepted : 21-04-2024
Published : 30-04-2024

Keywords:
Instructional Practice;
Mathematics Education;
Problem-Solving Approach;
Real-World Problems.

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Doi:
10.24042/djm.v8i1.26004

ABSTRACT

This study examined the implementation of problem-solving-based learning in mathematics education within schools in Victoria, Australia. It aimed to evaluate its effectiveness in enhancing students' critical, logical, and creative thinking skills while identifying challenges in integrating this approach into the curriculum. A qualitative descriptive method was employed, involving literature review, classroom observations, and informal interviews with teachers and students. Data collection focused on exploring instructional practices and their alignment with curriculum objectives. Results indicated that problem-solving activities fostered conceptual understanding and practical application of mathematics in real-life scenarios. Examples, such as measuring distances using average steps and solving optimization problems, demonstrated increased student engagement and comprehension of mathematical concepts. However, challenges included teachers' limited understanding of problem-solving strategies, insufficient resources, and language barriers in interpreting real-world problems. Despite these obstacles, integrating structured activities and diverse instructional strategies proved to be a promising method for improving mathematical learning outcomes. These findings underscore the importance of aligning pedagogical practices with curriculum goals to enhance mathematics education.

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INTRODUCTION

Traditional approaches to teaching mathematics, a long-standing component of formal education, often emphasize memorization and the mastery of abstract concepts but frequently fail to establish meaningful connections to real-world situations. As a result, students often struggle to apply mathematical knowledge in everyday life. In contrast, mathematics education should start from problem situations that are meaningful to students, offering them opportunities to attach meaning to the mathematical constructs they develop while solving problems (Heuvel-Panhuizen & Drijvers, 2020). The study by Palm (2008) indicated some level of disconnection between the students' mathematics learning and how it applied to real-world problems. This disconnection may lead to a struggle by students to understand mathematics (Arthur, Owusu, Asiedu-Addo, & Arhin, 2018).

Problem-based learning (PBL) approaches can lead to greater conceptual understanding (Mustaffa, Ismail, Tasir, & Said, 2016; Shishigu, Hailu, & Anibo, 2017) and problem-solving skills (Ferreira & Trudel, 2012; Pratiwi, Cari, Aminah, & Affandy, 2019). Unfortunately, the implementation of this approach in the classroom is often suboptimal due to a lack of PBL knowledge and skills (Sakir & Kim, 2020), limited teaching materials (Putranti, 2024), and students' low active involvement in the class (Sari, Adnan, & Hadiyanto, 2019). This poses a major challenge in aligning curriculum objectives with classroom learning practices.

However, in practice, mathematics learning is often limited to mastering abstract concepts (Anireddy, Mantri, & Kaur, 2022) and applying routine procedures (Prendergast et al., 2018), which makes it difficult for students to see the relevance of mathematics in real life (Kikomelo, 2024). By connecting mathematical concepts to practical, everyday scenarios, educators can bridge the gap between abstract theory and real-life relevance (Zhu, 2023).

To bridge this gap, a problem-solving approach is an effective solution. Problem solving not only allows students to understand concepts in depth but also provides a real and relevant context so that they can connect their learning with its practical applications (Guo, Yao, Wang, Yan, & Zong, 2016). Through this approach, students are invited to identify, analyze, and solve problems that do not have direct answers so that their critical, creative, and analytical thinking skills develop optimally.

Problem-solving is a cornerstone of mathematics education. It represents not just a skill but also a means to explore, understand, and apply mathematical concepts in real-life scenarios. According to Groves & Stacey (1990), problem-solving in mathematics is to describe what happens when a person or a group tackles a task for which they know no solution or obvious means of finding one, and the solution of which involves the use of some mathematics. Despite its importance, problem-solving often presents challenges, including misunderstandings and the need for foundational terminology, as suggested by Shibata (1998). This article explores the role of problem solving in mathematics education, its integration into curricula, and the strategies to improve its instructional practice.

Although there has been much research that acknowledges the importance of problem-solving in mathematics learning, most studies focus more on theoretical aspects and less on exploring how problem-based learning strategies are applied in real situations (Amalia, Surya, & Syahputra, 2017; Gorghiu, Drăghicescu, Cristea, Petrescu, & Gorghiu, 2015). In addition, there are few studies that specifically assess the effectiveness of this approach in the context of mathematics in Australia (David Clarke, Goos, & Morony, 2007). This study connects education policy with the reality on the ground to create more relevant and contextual learning for students.

This study aims to explore the implementation of problem-solving-based learning in mathematics teaching, identify the challenges faced, and evaluate its effectiveness in improving students' skills.

METHOD

This research method uses a qualitative descriptive approach with the aim of analyzing the implementation of problem-solving-based mathematics learning. The research was conducted through a literature review of various official documents, books, and relevant academic articles, as well as informal interviews and observations in the context of mathematics learning. The subjects of the study consisted of teachers and students in schools in Victoria, Australia, focusing on their understanding of the concept of problem-solving and its implementation in the classroom. This study involved students from various grade levels, ranging from Grade 8 to Grade 11, and was not limited to a specific educational level. In addition, data were collected through observations of classroom learning activities and discussions with students and teachers regarding their experiences.

Data collection focused on exploring direct experiences and instructional practices that support students' mastery of problem-solving skills. The instruments used included field notes, informal interviews, and analysis of relevant examples of mathematical problems. The data obtained were then analyzed descriptively to identify the effectiveness of the problem-solving approach in improving students' logical, analytical, and creative thinking skills. This analysis also includes an evaluation of the role of the curriculum, learning strategies, and teacher-student interactions in supporting mastery of mathematical concepts through the context of real-world problems.

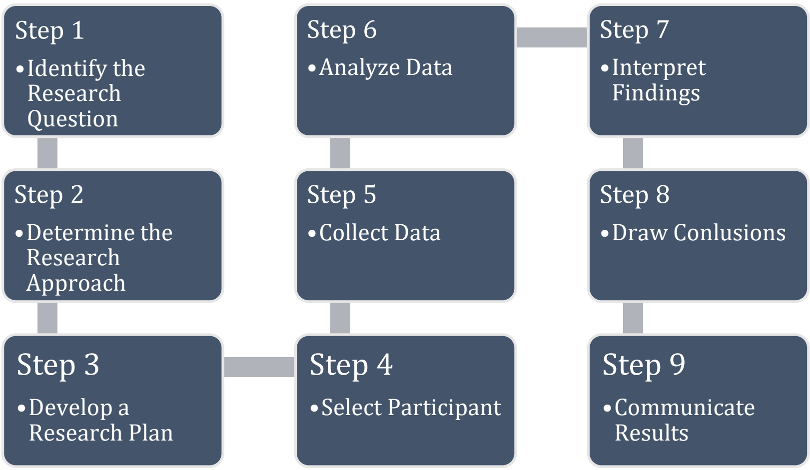

Figure 1. Research Design Process

RESULTS AND DISCUSSION

Problem-Solving Approach in Mathematics Learning

Example 1: Measuring Distance Using Average Steps

In this activity, students work in groups to measure the distance to the canteen using the average step length. They use a simple linear formula, $D = k \times N$, where D is the distance, N is the number of steps, and k is the average step length. The final output is a report showing the steps taken and a rule that can be applied in other situations. This approach encourages collaboration and understanding of the concept of distance.

Example 2: Solving the Problem of Two Consecutive Numbers

Students are faced with a problem involving two consecutive numbers. They use strategies such as trial and error, guessing, or an algebraic approach by writing equations. This approach trains students to break down problems into smaller parts and analyze the results.

Example 3: Finding the Intersection of Two Lines

This problem asks students to use construction skills to determine the intersection point of two lines on a diagram.

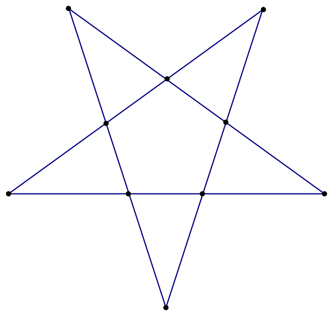

Figure 2. Pentagram

This activity helps students master geometric concepts and develop logical skills in visualizing solutions. It is suitable for students from year 8 and onwards. Based on this result, teachers may set up another task for students to complete, such as finding the value of each of the interior angles in a regular pentagon, as well as the value of the angles at the points of the star.

Conceptual Learning through Practical Activities

Example 4: Understanding the Concept of Quadrilaterals

Students are reminded that a quadrilateral is a two-dimensional shape with four sides. This activity supports the mastery of basic geometric concepts.

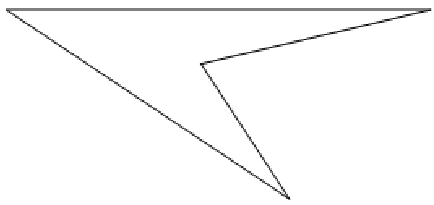

Figure 3. 2-D Shape with 4 Sides

Example 5: Solving Equations in the Wagon and Bicycle Problem

Students are tasked with calculating the number of wagons and bicycles sold based on the total number of wheels. The wagons have 4 wheels each, the bicycles 2. A total of 12 items are sold on that day. They are taught to use value tables for *w* and *b*, substitution methods, or other strategies to solve linear equations. Also, they may use the guess-and-check method to find the unknown values.

Example 6: Maximum Area of a Paddock

This problem asks students to calculate the maximum area of a paddock that can be fenced using 200 meters of wire. They are encouraged to use formulas, draw diagrams, and analyze results.

Example 7: Freeway Exit Location to Minimize Distance

Students are asked to determine the optimal location for a freeway exit to minimize the total road length. This activity utilizes geometry and value analysis to find solutions.

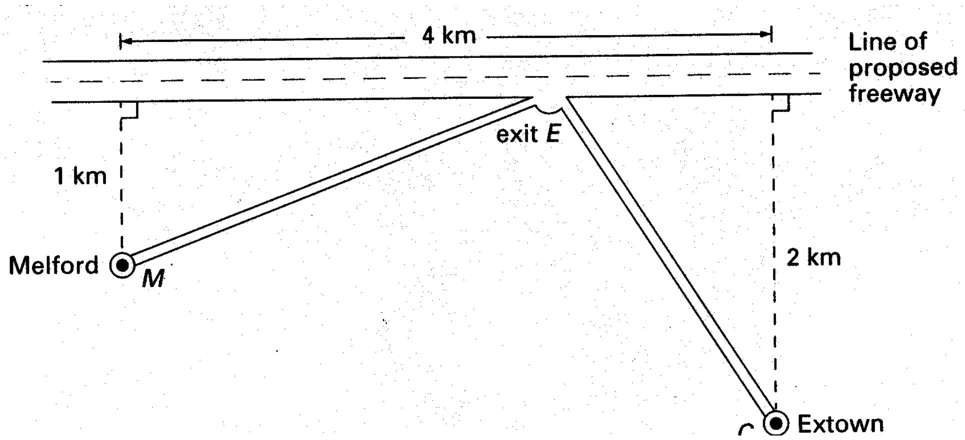

Figure 4. Freeway Exit Design Melford - Extown

For both examples 6 & 7, students are to read the problem carefully, analyze the given information, and choose a suitable strategy to solve it. They need to draw diagrams, set up tables of values, use correct formulas, analyze results, and make decisions. Information technology using Excel or "Geometer's Sketchpad" programs is very useful in these situations.

Problem-solving remains a central component of mathematics education in Victorian schools, as outlined in official documents like the CSF II Maths (Victorian Curriculum and Assessment Authority, 2000), VCE Maths study design (Victorian Curriculum and Assessment Authority, 1999), and VELS Maths (Victorian Curriculum and Assessment Authority, 2005). These documents highlight that students should develop the ability to apply mathematical knowledge to solve problems in a variety of contexts, from well-defined to open-ended situations. The curriculum aims to ensure students gain essential mathematical and numeracy skills, particularly for employment, and to solve real-world problems.

To facilitate these goals, textbooks in Victoria dedicate substantial space to problem-solving activities, including investigations, technology applications, and practical scenarios. For instance, "the Maths Quest textbook Vic offers full color with simulated photographs and graphics to support real-life applications and carefully graded exercises with many skill and application problems". Although no exact percentages are mentioned, the text underscores the significant presence of problem-solving in curriculum-aligned resources.

The CSF II document outlines the expectations for mathematics students at all levels, which include building knowledge of facts and technical skills, enhancing conceptual understanding, and developing systematic approaches to non-routine problems. Teachers are encouraged to help students apply what they have learned in real-world scenarios, engage in investigations, and develop logical reasoning. However, before implementing learning activities, teachers need to carefully consider the content to be pre-taught, assessment criteria, and any unfamiliar language or vocabulary that may hinder students' understanding.

Mathematics textbooks often present various strategies for problem-solving, but teachers must focus on how to effectively use and teach problem-solving skills. Posamentier & Smith (2020) propose that problem-solving can be viewed in three ways: as a subject for study, as an approach to mathematical ideas, and as a teaching method. The value of problem-solving activities lies in what students are expected to achieve and how these activities align with the concepts being taught. As Clarke & McDonough (1989) emphasize, problem-solving is most effective when it provides structure for learning.

Problem-solving remains a critical concern globally in mathematics education. Posamentier & Smith (2020) stress that it should be the cornerstone of any successful mathematics program. Mathematics education enables students to solve practical problems and apply mathematical concepts to real-world situations, thereby fostering both academic skills and critical thinking. Teachers play a crucial role in nurturing students' problem-solving abilities by encouraging the use of appropriate strategies and mathematical tools. This focus on problem-solving not only improves students' attitudes toward mathematics but also enhances their overall skills and abilities, making problem-solving an essential tool for enrichment in the subject.

Utilizing Non-Routine Problems for Enrichment

Example 8: Birthday Financial Patterns

This problem introduces number patterns and sequences, where a grandmother gives her grandson birthday gifts that double in value each year. Students are asked to create a value table, identify patterns, and derive a formula.

Example 9: Transporting Melons with a Camel

In this problem, we are tasked with transporting watermelons from one place to another using a camel that can carry 1000 melons at a time. The camel consumes one melon per kilometer traveled, which complicates the task of getting the melons from Melbourne to Sydney, a 1000 km journey. Initially, a direct trip of 1000 km seems unfeasible since the camel would consume all the melons along the way. A trip of 500 km also fails for the same reason, as the camel would eat the melons before reaching the destination.

Therefore, the solution lies in breaking the journey into smaller segments, ensuring the camel carries the melons over shorter distances. The main challenge is to minimize the camel’s walking distance while still maximizing the number of melons transported. In order to achieve this, trips must be planned to optimize the camel’s load and the number of trips back to the starting point. Minimizing the number of trips and the walking distance is key to ensuring the transport is effective.

The primary goal is to ensure that the camel transports as many melons as possible by making multiple trips while minimizing the melons consumed during the journey. The camel needs to carry the maximum load possible at each stage of the journey, and careful planning of intermediate stops is necessary. At each stop, the number of melons being carried will decrease as the camel eats along the way, so the task is to ensure that the camel walks as little as possible with each trip.

A simplified version of this problem involves a boy transporting 30 melons over a 10 km distance, with the same conditions on carrying capacity and melon consumption. This version of the problem serves as a task for year 11 students to explore the mathematics behind optimizing transport under these constraints. It allows for a manageable approach to the larger problem, helping students grasp the concepts of optimization and resource management in a practical context.

Table 1. Travel Recap

Length of trip (km)	Number of trips	Number of melons
1	26	4
2	13	4
3	$9\frac{1}{3}$	2
4	$6\frac{1}{2}$	4
5	6	0

Our analysis of the results revealed several key findings. First, there was no discernible pattern or relationship between the length of the trip and the number of melons remaining at the end of the journey. However, we observed that the number of melons left at the destination could be expressed as 30 minus the total number of trips made. Interestingly, a relationship was identified between the length of the trip and the number of trips, represented by the equation $y = a \times x^b$, specifically $y = 25.5x^{-0.9}$. These findings were verified using both a graphics calculator and Excel, which also facilitated the creation of a representative graph to illustrate this relationship.

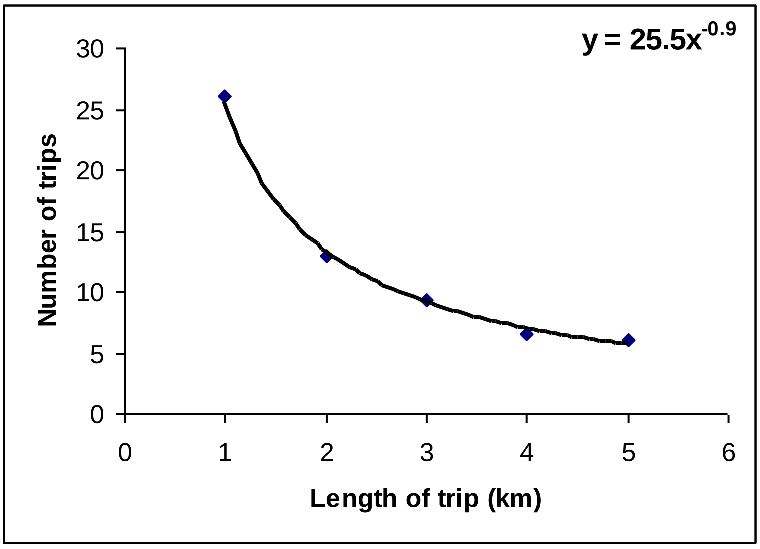

Figure 5. Relation between the Length of Trip and the Number of Trips

The handling of mathematical problems, both inside and outside the classroom, requires thoughtful consideration of several key factors to ensure effective learning. The way an activity or problem is presented plays a critical role in engaging students and shaping their problem-solving experience. Teachers must provide sufficient information as well as clear and concise instructions to guide students effectively. Additionally, the choice of strategy for solving the problem can significantly influence students' understanding and approach, emphasizing the importance of aligning the problem-solving method with the students' needs and abilities.

Other important considerations include providing adequate time for students to explore and work through the problem, particularly when dealing with word problems that may pose language difficulties. Special attention should be given to ensuring students comprehend the problem fully. Furthermore, allocating time for discussion and feedback fosters deeper understanding, encourages collaborative learning, and allows students to reflect on their problem-solving processes. These factors collectively create a supportive environment that enhances mathematical exploration and critical thinking.

Language challenges can significantly hinder students' ability to solve mathematical problems, as real-world contexts in such problems often require a basic level of reading comprehension. Students with difficulties in understanding written information are at a disadvantage. Effective problem-solving necessitates diverse strategies, depending on the desired learning outcomes. It is often more beneficial to demonstrate multiple approaches to solving a single problem rather than limiting students to one method for solving many problems. Clarke & McDonough (1989) highlight strategies such as restating the problem, organizing data systematically, experimenting, identifying patterns, trying simpler cases, and working backward from an assumed solution. Similarly, Diane Painter emphasizes a four-step method involving understanding the problem, selecting an appropriate strategy, solving it, and revisiting the problem to verify the solution.

Additional resources, such as strategy boards and visual aids, further support students in approaching problem-solving effectively. For instance, Randall Charles and Frank Lester developed structured plans displayed in study areas, which guide students through stages like understanding the problem, planning a solution, acting it out, and checking results. These approaches incorporate tools like diagrams, tables, or simpler related problems to make problem-solving more accessible. Their method includes the following components: context.

Table 2. A Guide of Steps and Strategies for Solving Mathematical Problems

How To Solve A Problem		**Strategy Board**	
See & Understand	Do I understand the problem	Guess & Check	Look for a pattern
Planning	- Select a strategy or strategies from the board - Plan how you intend solving the problem	Act it out	Draw a picture or Graph
Doing it	Try out your idea	Solve a simpler related problem	Use a sum or number sentence
Check it	Did it work out? - If so, reflect on the activity - If not, go back to step one.	Make a model	Make a list or table
		Try all possibilities	Work backwards

Source : (Charles & Lester, 1982)

Teachers play a pivotal role in selecting and crafting engaging problems that stimulate interest and foster logical thinking. By incorporating diverse strategies and structured resources like the ones above, students are better equipped to develop critical thinking skills and handle non-routine mathematical challenges effectively.

Developing Logical Skills and Mathematical Connections

Example 10: Calculating the Number of Handshakes

In this activity, students calculate the total number of handshakes in a class using various methods, such as value tables or combinations. This activity strengthens mathematical connections and pattern skills.

First Method: This approach involves a hands-on classroom activity where students simulate the handshake scenario. Starting with a small group of students, the activity is repeated with increasing group sizes. The number of handshakes is recorded for each case, and the results are tabulated. Students are encouraged to analyze the data to identify a pattern. The key observation is that the number of handshakes follows a recursive relationship, given by $t_{n+1} = t_n + n$, where t_n represents the total number of handshakes for n individuals.

Second Method: Using geometrical visualization, this method connects the handshake problem to properties of 2-D shapes. Students consider the handshakes as the total number of line segments formed in a polygon. Each handshake corresponds to either a side or a diagonal of the polygon. The total number of handshakes can thus be calculated as the sum of the number of sides (n) and the number of diagonals, using the formula $\frac{n(n-1)}{2}$. This approach leverages students' geometrical reasoning and provides a visual understanding of the relationships between points, sides, and diagonals.

Third Method: For a more abstract approach, students may apply combinatorial reasoning by calculating the number of 2-combinations from n individuals, denoted as $\binom{n}{2} = \frac{n(n-1)}{2}$. This method highlights the fundamental principle of counting combinations and introduces students to a key concept in discrete mathematics.

Each method offers a unique pathway to understanding the problem, encouraging students to explore recursive patterns, geometrical visualization, and combinatorial techniques while developing critical thinking skills in mathematics.

Teachers should become familiar with these strategies and practice them before beginning to present them to students. In this way, teachers can develop facility with the basic tools of problem solving (Posamentier & Smith, 2020).

However, how mathematics problems are presented and worked on in class is still an issue. Results from the TIMSS 1999 video study showed that some mathematics educators and psychologists argued that emphasizing the connections between mathematics and real-life situations can distract students from the important ideas and relationships within mathematics. Others have claimed significant benefits of presenting mathematical problems in the context of real-life situations (Hiebert, 2003).

Also, the TIMSS report mentioned that the ways in which mathematics is presented and the ways in which teachers and students interact about the mathematics are direct indicators of the nature of teaching and the nature of learning opportunities for students in various countries. In some outdoor activities, take some mathematical concepts with you. It is going to be very engaging and very helpful in solving certain real-life situations.

Example 11: Measuring River Width

Students are tasked with measuring the width of a river without getting wet. They use basic measurement and geometric concepts to determine distances that cannot be measured directly.

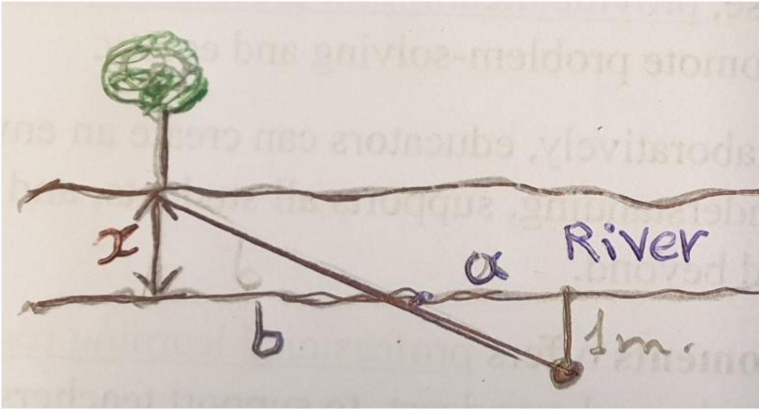

Figure 6. Width of the River

Example 12: Estimating Fish Population in a Lake

Using tagging and sampling methods, students estimate the fish population in a lake. This approach introduces concepts of probability and proportion.

Example 13: Estimating the Number of Grass Blades

Students are asked to count the number of grass blades in a home garden using a small sample area. This activity teaches them how to generalize results from sample data.

To foster collaborative learning and strengthen the connection between parents and children, parents were invited to participate, assist, and support their children in solving this problem. While some parents might initially perceive the activity as trivial or even humorous, most view it as a valuable opportunity to engage in problem-solving alongside their children.

A suggested approach involves starting with a small, tangible task, such as selecting a small square area in a garden—e.g., a 10 cm by 10 cm square—and counting the number of grass blades within this defined space. From this localized count, children and parents can work together to extrapolate the total number of grass blades in the entire garden, applying mathematical concepts of scaling and estimation. This activity not only enhances mathematical thinking but also encourages collaboration and practical application of problem-solving in everyday contexts.

Discussion and Evaluation

Each lesson ends with a discussion session where students share their experiences, evaluate the learning process, and receive feedback. Teachers use this moment to encourage reflection and improve teaching methods. Problem-solving activities relevant to daily life have proven to increase students' interest and understanding of mathematics.

These results show that problem-solving approaches, both routine and non-routine, can be effective learning tools to enhance students' logical, conceptual, and applicative skills in mathematics. This finding emphasizes the importance of both types of problem-solving approaches in enhancing students' understanding of mathematical concepts and their ability to apply knowledge in diverse situations.

This research aligns with previous findings that indicate problem-solving approaches play a crucial role in mathematics learning. For example, Mariani, Mustaji, & Dewi (2025), in their study, demonstrated that the use of problem-solving strategies can enrich students' learning experiences. However, this study places greater emphasis on the differing impacts of routine and non-routine approaches and how both can complement each other in building more comprehensive skills in mathematics.

While previous studies have largely focused on the effectiveness of a single type of problem-solving approach, the findings of this research offer a new contribution by demonstrating that a combination of both routine and non-routine approaches is more effective in enhancing students' logical, conceptual, and applicative skills. In other words, routine problem solving can help students grasp the fundamentals of mathematics, while non-routine problem solving develops their ability to think creatively and solve problems in more complex contexts.

CONCLUSIONS AND SUGGESTIONS

Problem-solving is the way that we (teachers, students, and people) use to handle a problem that requires a numerical or non-numerical solution. However, teachers still have to help students to gain knowledge and develop skills that will be necessary for them to tackle tomorrow's problems. For so many mathematicians, problem-solving is a way of teaching as well as a tool to assess students' knowledge and skills progress.

Future research could expand the quantitative evaluation to measure the long-term impact of the problem-solving approach on students' mathematical skills. Content analysis of mathematics textbooks could be enriched by incorporating teachers' perspectives and support for diverse learning styles. Research on problem-solving strategies could be deepened by observing students from different cultural or social backgrounds. The integration of technology could explore the use of AI-based applications for personalized learning. All of these approaches aim to enrich and deepen the understanding of problem-solving in mathematics education.

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