A MODERN APPROACH TO SOLVING TEXT-BASED MATHEMATICAL PROBLEMS

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ABSTRACT
Solving word (text-based) mathematical problems plays a critical role in developing students' analytical thinking, problem-solving, and mathematical modeling skills. For effective instruction, this process is structured into two fundamental phases: preliminary preparation and direct problem solution. In the preparation phase, students identify relationships between given data and unknown quantities, analyze mathematical structures, and build foundational reasoning skills through visualization, didactic materials, and real-life contexts.

From a theoretical standpoint, this study integrates L.M. Fridman's classical eight-stage problem-solving framework - encompassing structure analysis, schematic representation, strategy selection, implementation, verification, investigation, formulation of the answer, and retrospective reflection - with G. Polya's problem-solving model and contemporary constructivist modeling approaches. The primary purpose of this study is to establish modern methodological foundations for teaching word problems, assess the practical applicability of Polya's framework, and demonstrate the pedagogical efficacy of structured modeling approaches over traditional teaching methods.

Utilizing a theoretical-methodological research design involving conceptual analysis, comparative evaluation, and didactic modeling, this study formulates a structured pedagogical model for mathematics instruction. The findings indicate that systematic visualization and phased strategic modeling significantly enhance students' ability to internalize quantitative relationships, structure unstructured information, and successfully tackle realistic word problems. Consequently, this research provides a comprehensive methodological framework that bridges the gap between classical problem-solving theories and modern curriculum requirements in mathematics education.
Key Words: Word problem solving, Polya's problem-solving model, mathematical modeling, didactic strategies, visual representation, mathematics education

Introduction

Problem solving is fundamental to mathematics education because it provides an important context for developing students' mathematical thinking, reasoning, analytical skills, and the ability to apply mathematical knowledge to meaningful situations. Rather than being limited to the execution of computational procedures, mathematical problem solving requires students to understand the problem situation, identify relevant information, establish relationships between quantities, formulate a mathematical representation, select an appropriate strategy, implement the strategy, and evaluate the appropriateness of the result (Polya, 1957; Schoenfeld, 1985). Consequently, problem solving is not only considered a goal of mathematics education, but also an important means of learning mathematics.

In this broader field, text-based mathematical problems, commonly referred to as word problems in the international literature, occupy a particularly important position. Such problems present mathematical relationships through verbal descriptions of situations and require students to translate contextual information into mathematical representations and determine the unknown quantity or relationship. Therefore, the process involves more than just reading and doing calculations; it requires students to interpret a situation, separate relevant information from irrelevant information, identify relationships between quantities, and construct appropriate mathematical models. Research on word problems shows that students' achievement is strongly influenced by how they interpret contextual information and the strategies they use to relate the real-world situation to its underlying mathematical structure (de Corte et al., 2000; Verschaffel et al., 2020). The relationship between word problems and mathematical modeling is particularly important. Word problems provide students with the opportunity to move between the contextual and mathematical worlds by identifying background information, introducing variables, establishing relationships, constructing representations, performing mathematical operations, and interpreting the resulting solution in relation to the original situation (Blum & Leiß, 2007; Blum, 2015). In this sense, text-based problem solving is not simply a process of finding an unknown number; it is the process of constructing and interpreting a mathematical description of a situation. This perspective is fully consistent with the modern understanding of mathematical literacy. For example, OECD (2023) defines mathematical literacy in terms of students' mathematical thinking and ability to formulate, apply, and interpret mathematics in a variety of real-world contexts. The modeling cycle that underlies this concept emphasizes the relationships between

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contextual situations, mathematical descriptions, mathematical procedures, and the interpretation and evaluation of results.

The cognitive complexity of text-based problem solving also distinguishes it from ordinary computational tasks. Students may possess the mathematical procedures needed to solve a problem, but they may still have difficulty determining which procedure is appropriate or understanding how the numerical information relates to the question. Such difficulties suggest that successful problem solving depends on strategic and metacognitive processes in addition to mathematical knowledge. Schoenfeld (1985) has emphasized the importance of resources, heuristics, control, and beliefs in understanding complex mathematical problem-solving behavior. Similarly, research shows that explicitly focusing on metacognitive processes increases students' problem understanding, planning, monitoring, and persistence during problem solving (Vorhölter, 2021; Yıldız & Özdemir, 2023). More recent research also shows that metacognitive activity plays an important role when students work on mathematical modeling problems and have to adjust their strategies throughout the solution process (Vorhölter, 2021).

In the context of mathematics education in Azerbaijan, the development of students' ability to apply mathematical knowledge to contextualized situations has also become an important component of curriculum-oriented learning. The mathematics curriculum developed within the framework of the national curriculum reform emphasizes the development of mathematical knowledge and skills through meaningful learning and application. The sequence of acquiring, consolidating, and applying new knowledge to mathematical tasks in classroom practice provides students with opportunities to use mathematical concepts in problem-solving and modeling situations. In this context, the structure of a text-based problem – the given information, conditions, relationships, and question – has a special methodological importance. As emphasized in the theory of L.M. Friedman (1989), teaching students to recognize and organize these structural elements from the early stages of mathematics education can support the transition from verbal information to mathematical representation and contribute to the development of systematic problem-solving strategies.

The structure and presentation of word problems have also been critically examined in international mathematics education research. Rather than interpreting the actual situation described in the problem, students may develop stereotypical approaches to word problems based on surface features or familiar numerical patterns (de Corte et al., 2000; Verschaffel et al., 2020). Such tendencies highlight the necessity of moving beyond purely algorithmic instruction toward approaches that encourage students to comprehend the situation, justify their strategic choices, represent relationships, and verify whether the solution is meaningful within the given context. In this regard, realistic and non-routine problems provide opportunities for students to develop flexible thinking styles and connect mathematical procedures with real-world situations (Blum & Leiß, 2007; Blum, 2015).

The classic problem-solving framework proposed by Polya (1957)-which emphasizes understanding the problem, devising a plan, carrying out the plan, and looking back - remains an essential theoretical foundation for systematic problem solving. Concurrently, subsequent research has broadened the understanding of problem solving by highlighting heuristic strategies, metacognitive regulation, mathematical modeling, representation, and interpretation (Blum et al., 2007; Schoenfeld, 1985; Verschaffel et al., 2020). Consequently, modern approaches to teaching text-based mathematical problems increasingly necessitate the integration of classic problem-solving principles with modeling-oriented and metacognitive strategies.

In this regard, purposeful and systematic teaching of text-based mathematical problems can contribute to the development of students' mathematical thinking, strategic competence, metacognitive awareness, and modeling abilities. It also helps students to make meaningful connections between mathematical concepts and real-world situations. Therefore, a modern approach to solving mathematical problems requires teaching models that organize the solution process into logically related stages, starting with the analysis and structuring of the problem situation and continuing with mathematical modeling, application, verification, interpretation, and reflection of the solution. Accordingly, the present study focuses on the methodological foundations of solving text-based mathematical problems and explores how classical and modern approaches can be integrated into a structured solution process. Special attention is paid to the role of problem analysis, representation, mathematical modeling, strategy selection, verification, and reflection. The aim of the study is to contribute to the methodological debate by providing a structured approach that can support students in understanding relationships between quantities, organizing contextual information, building mathematical models, and developing more systematic problem-solving strategies.

Research methodology and theoretical basis

The process of solving text-based mathematical problems consists of two main stages from a cognitive and methodological point of view: the stage of preparation for problem solving and the stage of direct problem solving.

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The stage of preparation for problem solving is intended for students to understand the internal logical relationship between the information (conditions) given in the text and the quantities sought and to make sense of abstract quantitative concepts. At this stage, the application of visual aids, didactic materials, tables, graphs, and schematic diagrams develops students' skills in transforming verbal (text) information into mathematical models and visualizing situations (Fridman, 1989; Verschaffel et al., 2020). Since practical calculation problems require working with physical quantities such as length, capacity, mass, time, and area, it is of particular methodological importance to explain in advance the essence of new quantities and demonstrate their interdependence in the learning process. Within the framework of the training strategy, students should be justified in choosing the appropriate mathematical operation (addition, subtraction, multiplication, division) to find the third unknown quantity based on the two known quantities given in the problem. Such a methodological approach serves to form students' analytical thinking, mathematical reasoning, and logical assimilation skills (de Corte et al., 2000; Özsoy, 2014).

In the traditional mathematics teaching methodology, solving text problems was mainly carried out in five consecutive stages:
1. Familiarization with the content of the problem;
2. Search for a solution;
3. Analytical analysis of the problem;
4. Application of the solution algorithm;
5. Verification of the obtained result (Abdullaeva, 2023).

Although this classical structure provides students with the ability to understand the content and perform mathematical calculations according to the data, modern pedagogical approaches require a deeper metacognitive and modeling-oriented organization of the problem-solving process.

While this classical structure provides students with the ability to understand the content and perform mathematical calculations in accordance with the data, modern pedagogical approaches require a deeper metacognitive and modeling-oriented organization of the problem-solving process.

The methodology for teaching mathematics problems in modern general education schools is largely based on George Polya's heuristic problem-solving theory and L.M. Friedman's structured problem-solving model. Polya (1957) systematizes problem solving into four fundamental stages:

1. Understanding the problem;
2. Devising a plan;
3. Carrying out the plan;
4. Checking the result and looking back.

This theoretical framework enables students to purposefully organize the internal structure of the problem and its progression steps (Polya, 1957; Verschaffel et al., 2020).

In the first phase (Initiation and Comprehension), the text of the problem is read carefully by the students or the teacher; the key information, given conditions, and the question (unknown) component are fully clarified. At this stage, brief notes, schemes, tables, and visual representations are widely utilized to facilitate the transition from a real-life situation to a mathematical model. Structured visualization assists students in segmenting the text and identifying logical relationships among quantities (Abdullayeva, 2023).

The planning stage is considered the most complex and critical stage of the Polya model and modern didactics. This stage requires students to be able to choose mathematical strategies, make judgments, and formulate a general solution concept. In modern teaching methodology, not only algorithmic equation building is applied at this stage, but also various modeling and heuristic selection strategies - tabulation, identification of patterns (patterns), reasoning, and trial-and-error methods (Polya, 1957; Schoenfeld, 1985).

In classical teaching, traditional forms such as writing a plan with question sentences, performing step-by-step calculations, and constructing mathematical expressions or equations were used for the written formulation of text-based problems. The innovations included in modern curriculum standards, however, highlight the whole-part model (bar model/part-whole model), organized list-keeping, and tabulation strategies that strengthen students' strategic thinking (Abdullaheva, 2023).

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The final stage of the Polya approach and modern methodology is the verification of the answer and reflection (backward look) - procedures for confirming the correspondence of the obtained result to the real context of the problem, formulating inverse problems, or re-solving the problem with different alternatives. This stage forms the skills of self-control, critical evaluation, and deepening mathematical reasoning in students (Abdullaeva, 2023; Polya, 1957).

Practical Application and Sample Analysis of Word Problem Solving Methodology

In this section, based on the theoretical and methodological principles of L.M.Fridman and G.Polya, the process of solving word problems in mathematics is analyzed step-by-step through concrete practical examples. The presented examples demonstrate the mechanism for developing students' analytical thinking, visualization, and modeling skills.

Example 1: The side of an equilateral triangle is equal to the side of a square with a perimeter of 24 cm. What is the perimeter of this triangle? (Isayev Z. et al., 2023)

In the comprehension stage, the problem is fully understood, and the figures are described (see Figures 1 and 2). The givens, conditions, and requirements of the problem are determined with the help of the students and recorded in a short written form.

Figure 1

Schematic Representation of an Equilateral Triangle

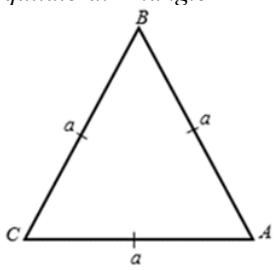
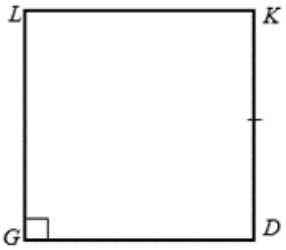


Figure 2

Geometric Model of a Square Structure



Given: Triangle ABC and square DKLG.

$AB = BC = CA$, $P_{DKLG} = 24\,cm$, $AB = DK$

Must find: $P_{ABC} = ?$

In the planning stage, it is noted that the perimeter of *a* square with side a is equal to 4*a*, and the perimeter of an equilateral triangle with side *b* is equal to 3*b*: $P_{DKLG} = 4a$, $P_{ABC} = 3b$. In the given problem, since the side of the triangle is equal to the side of the square $P_{ABC} = 3a$.

In the solution phase, the issue is resolved:

$$1)\ 4a = 24$$

$$a = 24 : 4$$

$$a = 6\,cm\,(\text{side of the square})$$

$$2)\ P_{ABC} = 3a = 3 \cdot 6 = 18\,(cm, \text{perimeter of a triangle})$$

In the verification phase, the correctness of the obtained answer is checked. Here, the answer is confirmed to be correct by solving the inverse of the given problem.

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$$18:3=6\,(cm,\text{side of the square})$$
$$6\cdot 4=24\,(cm,\text{perimeter of the square})$$

Thus, the perimeter of an equilateral triangle is 18 *cm.*

Example 1: A motorboat traveled 42 *km* downstream and 20 *km* upstream, taking 5 hours. If the river's flow rate is 2 *km/h* everywhere, find the boat's speed in still water (State Examination Center, 2019)

Understanding: At this stage, the givens, conditions, and desired items of the problem are determined:
The distance the boat traveled downstream is - 42 *km*,
The distance the boat traveled upstream is - 20 *km*,
The time spent downstream and upstream is - 5 hours,
The river's flow rate is - 2 *km/h.*
The boat's speed in still water is to be found.

Planning: The solution to the problem is planned by setting up an equation: Suppose the speed of a motorboat in still water is $x\,km/h.$ Then the speed of the boat with the current is $(x+2)\,km/h$, and the speed against the current is $(x-2)\,km/h$. The time taken by the motorboat to travel the distance with the current of the river will be $\frac{42}{x+2}\,saat$, and the time taken against the current will be $\frac{20}{x-2}\,saat$. Considering that the time spent with the current and against the current of the river is 5 hours, the following equation is set up: $\frac{42}{x+2}+\frac{20}{x-2}=5$

Solution: The equation is solved and its roots are found:

$$\frac{42(x-2)+20(x+2)}{(x+2)(x-2)}=5$$
$$\frac{42x-84+20x+40}{x^2-4}=5$$
$$5x^2-62x+24=0$$
$$x_1=\frac{2}{5}=0,4;\quad x_2=12$$

Verification: The roots are checked against the condition of the problem.

Substituting the root $x_1=0,4$ in $(x-2)$, a negative number is obtained: $x-2=0,4-2<0$. Since the speed is not a negative number, the root $x_1=0,4$ is an external root. The root $x_2=12$ satisfies the condition of the equation: $x+2=12+2=14>0$. Therefore, $x=12\,km/h.$

$$\frac{42}{x+2}+\frac{20}{x-2}=\frac{42}{12+2}+\frac{20}{12-2}=3+2=5\ (\text{hours})$$

Answer: The speed of a motorboat in still water is $12\,km/h.$

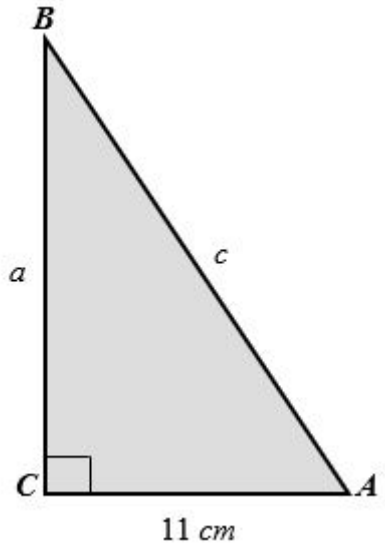
Example 3: The sides of a right triangle are expressed in integers, and one of its legs is 11 centimeters. Find its area (Aghayev et al.,1967).

Understanding: In the problem, it is known that one leg is 11 cm. Since the other data are not explicit, let's solve the problem using logical and algebraic methods (Figure 3).

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Figure 3

Geometric Representation of a Right-Angled Triangle Model



Planning: Given: $\Delta ABC,\ \angle C = 90^\circ$, $b = 11\text{cm}$

Must find: $S_{\Delta ABC} = ?$ $S_{\Delta ABC} = \frac{1}{2} AC \cdot BC$

Solution: According to the Pythagorean theorem

$$a^2 + b^2 = c^2$$

$$c^2 - a^2 = 11^2$$

By factoring the expression $c^2 - a^2$, a and c are found:

$$(c-a)(c+a) = 121 \Rightarrow \left\{ \begin{matrix} c-a=1 \\ c+a=121 \end{matrix} \right| +$$

$$2c = 122$$

$$c = 61$$

$$a = 60$$

$$S_{\Delta ABC} = \frac{1}{2} AC \cdot BC = \frac{1}{2} ab = \frac{1}{2} \cdot 60 \cdot 11 = 330\,cm^2$$

Checking: $a = 60, b = 11, c = 61$

$$60^2 + 11^2 = 3600 + 121 = 3721 = 61^2$$

Answer: The area of a right triangle is $330\,sm^2$

Discussion

The results of the study show that the solution of text-based mathematical problems does not consist of purely algorithmic calculation procedures, but involves deep cognitive, metacognitive, and modeling processes. While in the classical methodology, problem solving is characterized by more than five-stage algorithmic steps (Abdullaeva, 2023), modern approaches require the integration of D. Polyan's (1957) four-stage heuristic model and L.M. Friedman's (1989) principles of schematic-structured analysis. The practical examples analyzed in this study (Isayev et al., 2023) once again confirm that the use of visual aids, a whole-part model (bar model), and schematic representations in the "understanding" and "planning" stages of the solution process significantly facilitates the transition of students from verbal text to a mathematical model.

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Recent studies in the international literature (Verschaffel et al., 2020; Vorhölter, 2021) also support the findings of this study. Researchers emphasize that the main difficulties students face in word problems do not stem from calculation errors, but from the inability to correctly interpret contextual information in the text and from superficial (stereotypical) reading of the text (de Corte et al., 2000). As shown in the studies of Vorhölter (2021) and Özsoy (2014), the inclusion of metacognitive adjustments (planning, checking, retrospective and reverse problem setting) in the solution process deepens students' analytical thinking. In this regard, the modeling and strategic problem-solving approaches reflected in the modern mathematics curriculum of Azerbaijan (Ministry of Education of the Republic of Azerbaijan, 2013) are fully consistent with the mathematical literacy standards in the PISA and TIMSS international assessment frameworks (OECD, 2023).

Conclusion

The ability to solve text problems is one of the main components of the mathematics curriculum in secondary schools and plays a leading role in the formation of students' analytical thinking, problem-solving, and mathematical modeling skills. The main goal of each content line in the mathematics curriculum is defined as the development of students' problem-solving skills through the solution of text problems. These skills not only provide students with theoretical knowledge, but also strengthen their ability to analyze real-life situations, determine relationships between quantities, and make appropriate mathematical decisions (Abdullaeva, 2023).

The integration of the problem-solving process plays a fundamental role in the teaching of text problems. Through text problems, students develop both logical thinking and the ability to apply mathematical knowledge in different contexts. Problem solving, which is one of the areas of activity provided for the implementation of standards in the curriculum, involves the structured analysis and solution of text problems. For this reason, the solution of text problems is one of the most complex, but also the most effective parts of mathematics teaching. Practical work and exercises on examples deepen students' skills, consolidate experience, and form sustainable problem-solving strategies (Isayev et al., 2023).

Thus, solving text problems is not only a means of applying mathematical knowledge, but also a didactic mechanism that systematically develops students' analytical thinking, creative approach, and problem-solving strategies. This ensures effective teaching and learning activities in accordance with the goals of modern mathematics education.

Limitations of the Study

This study investigated the methodology of solving text-based mathematical problems within the framework of theoretical-methodological analysis and selected theoretical models (Polya and Friedman models), as well as selected practical examples from elementary/secondary school mathematics textbooks. Since the study is purely qualitative and didactic modeling in nature, it does not include the results of large-scale empirical (statistical) experiments.

Recommendations for future Research

- Empirical Evaluation: Longitudinal pedagogical experiments can be conducted with the participation of control and experimental groups to measure the impact of the proposed integrated solution model on students' academic achievement and metacognitive skills.
- Integration of Digital Technologies: The role of dynamic mathematics software (e.g. GeoGebra, Graph, etc.) and interactive learning platforms in the visualization of text-based problems can be investigated as a separate research object.
- Teacher Training: It is recommended to develop methodological tools to improve the skills of elementary and secondary school mathematics teachers in using modern modeling strategies (whole-part model, heuristic tables) in teaching text-based problems.

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