DEVELOPING ALGORITHMIC THINKING THROUGH PROBLEM-BASED LEARNING IN MATHEMATICS EDUCATION

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Abstract: This article examines the development of algorithmic thinking in students through the application of problem-based learning in mathematics education. Algorithmic thinking is regarded as an essential cognitive skill that enables learners to analyze problems systematically, construct solution strategies, and apply logical reasoning in sequential steps. The study emphasizes that traditional formula-based instruction is often insufficient for developing deep analytical abilities. Therefore, the proposed methodology integrates problem-solving activities with algorithmic modeling to enhance students' independent thinking and decision-making skills. The article discusses theoretical foundations of algorithmic thinking, describes algorithmic models used in mathematical problem solving, outlines a methodological framework based on structured learning stages, and highlights practical classroom applications. The advantages, challenges, and educational opportunities of this approach are analyzed, and its contribution to modern mathematics education is justified.

Keywords: Algorithmic thinking, problem-based learning, mathematical modeling, logical reasoning, step-by-step analysis, methodology, education, decision-making.

Introduction: In modern education, the rapid development of technology and information systems has significantly changed the requirements for learners' cognitive skills. Students are no longer expected only to memorize formulas or perform routine calculations; instead, they must be able to analyze complex situations, identify relevant data, and construct logical strategies for problem solving. One of the most important competencies in this context is algorithmic thinking. Algorithmic thinking involves the ability to decompose a problem into logical steps, recognize patterns, determine cause-and-effect relationships, and design an effective sequence of actions leading to a solution.

Mathematics plays a central role in the development of algorithmic thinking because it provides a natural environment for structured reasoning. Mathematical problems contain conditions, operations, and logical relationships that resemble the structure of algorithms used in computer science. However, in traditional mathematics instruction, students often focus on applying ready-made formulas without understanding the underlying reasoning process. As a result, they may successfully solve standard exercises but struggle when faced with non-routine or complex tasks.

Problem-based learning is considered one of the most effective pedagogical approaches for overcoming this limitation. It encourages learners to actively engage in the learning process, explore multiple solution paths, and reflect on their reasoning. By integrating problem-based learning with algorithmic modeling, teachers can guide students to perceive mathematical problem solving as an organized and logical process. This article aims to explore how problem-based learning can be used to develop algorithmic thinking in mathematics education and to present a methodological framework for its practical implementation.

Main Part

1. The Role of Problem-Based Learning in Algorithmic Thinking

Problem-based learning is an instructional approach in which students acquire knowledge and skills through the process of solving meaningful and challenging problems. Unlike traditional teacher-centered instruction, problem-based learning places the learner at the center of

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the educational process. The teacher acts as a facilitator who guides students' thinking rather than providing ready-made solutions.

Through problem-based learning, students develop several important abilities related to algorithmic thinking. First, they learn to analyze a problem situation and identify what is known and what must be found. This stage requires careful reading and comprehension, which forms the basis for subsequent reasoning. Second, learners are encouraged to break complex problems into smaller parts. This process of decomposition allows them to focus on manageable elements and construct a structured solution path. Third, students must choose appropriate strategies and methods depending on the nature of the task, which strengthens their decision-making skills.

Mathematical problems inherently contain algorithmic elements such as conditional statements ("if–then"), repetitions, and ordered operations. For example, solving a word problem involving several steps requires identifying intermediate results and organizing calculations in a logical sequence. This mirrors the logic of algorithms used in programming and computational thinking. Therefore, problem-based learning not only enhances mathematical understanding but also prepares students for future studies in computer science, engineering, and data analysis.

2. Algorithmic Models in Mathematical Problem Solving

Problem-solving activities can be represented using different algorithmic models that reflect the logical structure of reasoning processes. These models help students visualize and organize their thinking.

2.1. Sequential Algorithm Model

The sequential algorithm model is based on a fixed order of actions. In many arithmetic and algebraic problems, students follow a clear sequence: they read and understand the problem, identify known and unknown quantities, write relevant equations, solve them step by step, and check the result. This linear structure forms a simple but powerful algorithm that reinforces the idea of systematic reasoning.

For in   stance, when solving a linear equation, students first isolate the variable, then perform inverse operations, and finally verify the solution. By explicitly describing these steps, learners become aware of the algorithmic nature of their actions and gain confidence in their ability to control the problem-solving process.

2.2. Conditional Algorithm Model

Some mathematical problems require different solution paths depending on certain conditions. This leads to the conditional algorithm model, which includes branching logic. For example, when solving an equation with parameters, students must consider various cases depending on the value of the parameter. If one condition is satisfied, one method is applied; otherwise, an alternative approach is chosen.

This type of reasoning introduces students to decision-making processes that are central to algorithmic thinking. It teaches them that not all problems have a single universal solution method and that careful analysis of conditions is necessary to select an appropriate strategy.

2.3. Recursive Algorithm Model

Recursive thinking appears when a problem can be reduced to smaller versions of itself. This model is often observed in the study of numerical sequences, series, and patterns. For example, when defining a sequence in which each term depends on the previous one, students learn to apply a repeating rule that generates the entire structure.

Recursive algorithms strengthen abstract reasoning because learners must understand the relationship between successive steps. They also promote the idea that complex systems can be

constructed from simple repeated operations. This insight is valuable not only in mathematics but also in computer programming and logical modeling.

3. Methodological Framework for Developing Algorithmic Thinking

The proposed methodology for developing algorithmic thinking through problem-based learning consists of several structured stages. Each stage corresponds to a specific cognitive activity and contributes to the overall development of logical reasoning skills.

Stage 1. Problem Comprehension

At this stage, students focus on understanding the problem statement. They identify the main goal, determine what information is given, and recognize any constraints. Teachers may encourage learners to rewrite the problem in their own words or create a simple diagram to clarify the situation.

Stage 2. Decomposition

The problem is divided into smaller logical parts or subproblems. Students analyze which steps must be completed first and which depend on previous results. This stage develops the ability to structure complex tasks into manageable components.

Stage 3. Algorithm Design

Students construct a sequence of steps or decision rules required to reach the solution. This algorithm may be expressed verbally, symbolically, or in the form of a flowchart. The focus is on planning rather than immediate calculation.

Stage 4. Implementation

Each step of the algorithm is executed carefully and logically. Students perform calculations, apply formulas, and follow the designed sequence. This stage emphasizes accuracy and consistency.

Stage 5. Generalization

Learners formulate a general method that can be applied to similar problems. They identify patterns and common structures, which allows them to transfer their knowledge to new situations.

Stage 6. Reflection

Students analyze the effectiveness of their algorithm and consider possible improvements. They discuss alternative strategies and evaluate which approach is more efficient. Reflection strengthens metacognitive skills and deepens understanding.

4. Practical Application in Mathematics Education

The proposed methodology can be applied in various educational contexts, including school mathematics lessons, discrete mathematics courses, and introductory programming classes. In algebra, for example, students can use algorithmic models to solve equations and systems systematically. In geometry, problem-based learning can be used to analyze construction tasks and proofs by organizing reasoning steps.

For instance, when solving quadratic equations, students first determine the type of equation, then select an appropriate solution algorithm such as factorization or the quadratic formula. By explicitly outlining these steps, learners become more aware of the structure of the solution process.

In word problems, algorithmic thinking helps students translate real-life situations into mathematical expressions. They identify variables, establish relationships, and construct a sequence of operations that leads to the answer. This approach reduces guesswork and increases confidence in problem solving.

5. Advantages, Challenges, and Opportunities

Advantages

The integration of problem-based learning and algorithmic thinking offers several educational benefits. It enhances logical and critical thinking, encourages independent problem

solving, and integrates mathematical reasoning with algorithmic concepts. Students develop skills that are useful for programming, data analysis, and scientific research. Moreover, this approach increases motivation by making learning more meaningful and interactive.

Challenges

Despite its advantages, the methodology also presents challenges. Students may initially resist non-formula-based approaches because they are accustomed to routine procedures. Complex problems may cause cognitive overload if learners are not adequately prepared. In addition, teachers require methodological training to implement problem-based strategies effectively.

Opportunities

These challenges can be addressed through gradual introduction of algorithmic methods and continuous support for both students and teachers. The approach offers opportunities for improving analytical abilities, strengthening conceptual understanding, and increasing interest in mathematics. It also contributes to better preparation for technological and engineering disciplines.

Conclusion

The development of algorithmic thinking through problem-based learning represents a powerful pedagogical strategy in mathematics education. By guiding students to analyze problems systematically, construct solution algorithms, and reflect on their reasoning, this methodology promotes deeper understanding and intellectual independence. Integrating algorithmic principles into mathematical problem-solving activities strengthens students' logical structure of thinking and prepares them for further studies in computer science, engineering, and data-driven fields.

The harmony between theory and practice achieved through this approach contributes to innovative and effective education. Future research may focus on experimental validation of this methodology in different educational contexts and on the development of digital tools that support algorithmic learning.

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