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DEVELOPING PRIMARY SCHOOL STUDENTS' MATHEMATICAL THINKING THROUGH PROBLEM-SOLVING ACTIVITIES

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Abstract: This theoretical and methodological article examines how systematically organized problem-solving activities can develop mathematical thinking among primary school students. The study synthesizes established research on mathematical proficiency, heuristic reasoning, metacognition, classroom discourse, representation, and formative assessment. A qualitative integrative review was used to identify principles that are both supported by research and applicable to everyday primary mathematics lessons. The analysis shows that problem solving is most productive when it is treated not as an additional exercise after explanation, but as a central means of learning mathematical concepts. Effective tasks permit more than one representation or strategy, connect mathematics with meaningful situations, and require pupils to explain, compare, verify, and revise their solutions. The teacher's role is to maintain cognitive demand while providing timely prompts, visual models, and structured peer discussion. The article proposes a five-stage instructional cycle—understand, plan, solve, explain, and reflect—and offers practical criteria for task selection and assessment. It concludes that regular engagement with appropriately challenging problems strengthens conceptual understanding, strategic competence, mathematical language, persistence, and independent reasoning in the primary grades.

Keywords: primary mathematics education; mathematical thinking; problem solving; reasoning; metacognition; classroom discourse; formative assessment

1. Introduction

Mathematical competence in the primary grades is broader than the accurate performance of arithmetic procedures. It includes understanding quantities and relations, recognizing patterns, selecting representations, constructing arguments, and using mathematics to interpret unfamiliar situations. These capacities begin to develop when children are invited to investigate a question rather than merely reproduce a demonstrated algorithm. For this reason, problem solving occupies a central position in contemporary mathematics education.

The importance of this orientation is reflected in major accounts of mathematical proficiency. Kilpatrick, Swafford, and Findell (2001) describe proficiency through interconnected strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Problem-solving activity can coordinate all five strands because pupils must interpret a situation, choose and execute a strategy, justify the result, and evaluate whether the answer is reasonable. Similarly, the OECD mathematics framework emphasizes mathematical reasoning and the processes of formulating, employing, and interpreting mathematics in context (OECD, 2023).

In many classrooms, however, a 'problem' is still understood as a short word exercise placed after the teacher has explained the required operation. Such exercises may support practice, but they do not automatically produce mathematical thinking. A genuine problem creates a purposeful intellectual obstacle: the learner understands the goal but does not immediately possess a memorized

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route to it. The educational question is therefore not simply how many problems pupils solve, but what kinds of reasoning the tasks elicit and how the teacher organizes discussion around them.

The purpose of this article is to synthesize research-based principles for developing primary school students' mathematical thinking through problem-solving activities and to translate those principles into an applicable lesson cycle. The guiding questions are: (1) which features of tasks stimulate mathematical thinking; (2) which forms of teacher support preserve productive struggle; and (3) how can pupils' reasoning be assessed during and after problem solving?

2. Literature Review

Pólya's four phases—understanding the problem, devising a plan, carrying out the plan, and looking back—remain a useful foundation because they make the normally invisible stages of solution visible to learners (Pólya, 1945). Yet later research shows that successful problem solving is not a simple linear application of heuristics. Schoenfeld (1985) demonstrates that mathematical performance also depends on the learner's knowledge resources, control of decisions, and beliefs about mathematics. For primary pupils, this means that teaching a list of strategies is insufficient unless children also learn when to use them, how to monitor progress, and why a strategy is valid.

Conceptual understanding grows when pupils connect different representations. Objects, drawings, number lines, tables, symbols, and verbal explanations allow children to see the same relationship from several perspectives. Research synthesized by Carbonneau, Marley, and Selig (2013) indicates that concrete manipulatives can support mathematics learning, especially when instructional guidance helps learners connect the material model to abstract mathematical ideas. Manipulatives are therefore not an end in themselves; their value lies in the meanings pupils construct and articulate.

Classroom discourse is another decisive condition. When pupils compare two correct strategies, locate an error, or defend a claim, they encounter mathematics as a system of reasons rather than a collection of answers. Hiebert et al. (1997) argue that classrooms designed for understanding allow students to make connections and reflect on methods. The teacher must select and sequence pupil responses so that discussion reveals important mathematical relationships. Questions such as 'How do you know?', 'Can you represent it another way?', and 'What stays the same?' shift attention from answer production to reasoning.

The literature also distinguishes unsupported discovery from guided problem solving. Minimal guidance can overload novice learners who lack relevant knowledge structures (Mayer, 2004). At the same time, explaining every step removes the need for strategic thought. The meta-analysis by Alfieri et al. (2011) supports guided discovery in which learners investigate while receiving scaffolds, feedback, worked examples, or prompts. In primary mathematics, productive support may include clarifying vocabulary, reducing irrelevant numerical complexity, offering a diagram, or asking a focusing question without revealing the entire procedure.

Metacognition enables pupils to regulate their work. Children need routines for predicting, checking, and revising: What is known? What is unknown? Does the representation match the story? Is the answer possible? Could another method confirm it? Such reflection develops gradually through teacher modeling and repeated use of mathematical language. The 'looking back' phase is therefore not optional; it is where a completed calculation becomes a reusable insight.

3. Methodology

The article uses a qualitative integrative review and pedagogical design approach. Foundational monographs, research syntheses, international frameworks, and peer-reviewed studies concerning problem solving, representation, guidance, discourse, and assessment were examined. Sources were selected for their relevance to primary or general mathematics learning and for their contribution to an actionable instructional model. The evidence was coded under four categories: task design, learner

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activity, teacher mediation, and assessment. Recurring principles were then combined into a five-stage classroom cycle. This approach does not report an original experiment and makes no causal claims beyond the reviewed evidence; its purpose is to develop a theoretically grounded model that teachers can adapt and test in local classrooms.

4. Results and Discussion

The synthesis identified five mutually reinforcing stages. First, pupils understand the problem by retelling it, identifying the goal, distinguishing relevant information, and representing the situation. A teacher may ask pupils to act out the context or draw a bar model before choosing an operation. This prevents superficial reliance on keywords such as 'altogether' or 'left,' which can be misleading.

Second, pupils plan by considering possible strategies. In the early grades, a shared strategy bank may include making an organized list, drawing a model, using manipulatives, finding a pattern, working backward, simplifying the numbers, or testing a conjecture. The strategy should be chosen because it fits the mathematical structure, not because it is the most recently taught method.

Third, pupils solve and monitor. Productive struggle is valuable only when learners remain intellectually engaged. Teachers should observe whether pupils can enter the task, then adjust support through graduated prompts. A light prompt might direct attention to a relationship; a stronger prompt might offer a partial representation. Direct demonstration should be reserved for cases in which prerequisite knowledge is genuinely missing. This graduated approach balances learner agency with cognitive accessibility.

Fourth, pupils explain and compare. Selected solutions should be displayed in a purposeful order—for example, from a concrete model to a diagram and then to an efficient symbolic method. Comparison questions can reveal equivalence: Why did both methods produce the same result? Which method makes the structure clearest? Would the method work for larger numbers? Even an incorrect solution can be useful if discussed respectfully as evidence of a specific misconception.

Fifth, pupils reflect and generalize. A short exit prompt may ask learners to name the key idea, verify the answer by a second method, or create a related problem. Generalization transforms a single episode into mathematical knowledge. For example, after solving several sharing problems, pupils may express that equal groups can be represented by repeated subtraction, multiplication, or division depending on the unknown quantity.

Task quality determines whether this cycle generates meaningful thought. Effective primary tasks have an accessible entry point, a clear mathematical purpose, and sufficient openness for alternative representations or methods. Openness does not require ambiguity. A task may have one numerical answer while still allowing several pathways. Teachers should also control linguistic complexity so that the reading demand does not obscure the intended mathematics, especially for multilingual learners.

Assessment within problem solving should document reasoning as well as correctness. A concise analytic rubric can attend to four dimensions: understanding of the situation, appropriateness of representation and strategy, accuracy and completeness, and explanation or verification. Formative evidence may come from observation notes, pupil talk, annotated work, mini-whiteboards, and exit tickets. Black and Wiliam (1998) show the importance of feedback that helps learners close the gap between current and desired performance. In this context, feedback should identify the next reasoning action—for example, 'Show how the two quantities are related'—rather than simply mark the answer wrong.

A practical lesson sequence can begin with a short launch that clarifies the context without prescribing a method, continue with individual thinking and paired work, and culminate in a whole-class synthesis. Individual think time protects every pupil's opportunity to reason; collaboration then

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exposes learners to alternative perspectives. The final synthesis is essential because activity alone does not guarantee that the intended mathematical idea becomes explicit.

The model also has implications for differentiation. Instead of assigning entirely different low-level tasks to struggling pupils, teachers can preserve a common mathematical goal while varying representations, number size, prompts, or recording requirements. Advanced pupils can justify a generalization, investigate an additional condition, or create a counterexample. This maintains participation in a shared mathematical community while responding to different levels of readiness.

5. Practical Recommendations

Primary teachers should include a meaningful problem in every instructional unit and plan in advance which mathematical idea the discussion will foreground. Problems should be piloted for clarity and solved through more than one method before the lesson. Teachers should anticipate likely misconceptions, prepare a sequence of prompts from least to most explicit, and decide which pupil strategies could be compared in the synthesis. Pupils should routinely use drawings, manipulatives, symbols, and oral or written explanations. Assessment criteria should reward reasoning, representation, and verification alongside computational accuracy. Finally, classroom norms should communicate that uncertainty, revision, and respectful disagreement are normal components of mathematical work.

6. Conclusion

Problem-solving activities develop mathematical thinking when they are embedded in a coherent pedagogy rather than treated as occasional enrichment. The central instructional movement is from interpreting a situation to selecting a strategy, monitoring a solution, explaining relationships, and generalizing the result. Carefully designed tasks, connected representations, purposeful discourse, graduated guidance, and formative feedback together strengthen conceptual understanding and learner independence. The proposed five-stage cycle offers primary teachers a practical structure, but its effectiveness should be examined through classroom-based studies that consider grade level, curriculum content, language background, and local teaching conditions.

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