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THE METHODOLOGY OF USING VISUAL MODELS IN FORMING MATHEMATICAL CONCEPTS FOR YOUNG LEARNERS

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Annotation : This article examines the methodology of using visual models in the formation of mathematical concepts among young learners. It analyzes psychological and pedagogical foundations that justify the use of visual tools such as ten-frames, number lines, bar models, manipulatives and digital representations in primary mathematics education. The article emphasizes how visual models support conceptual understanding, reduce cognitive load, enhance motivation, and promote meaningful learning through the Concrete-Pictorial-Abstract (CPA) approach. Research-based evidence demonstrates that visual tools improve number sense, problem-solving ability and long-term retention of mathematical ideas. Methodological recommendations are provided to guide teachers in effectively integrating visual models into mathematics instruction.

Keywords : visual models, young learners, mathematical concepts, CPA approach, number sense, bar model, ten-frame, manipulatives, visual thinking, primary mathematics

The development of mathematical concepts in early childhood education is a fundamental prerequisite for children's cognitive growth, academic readiness and later success in STEM-related disciplines. Contemporary educational psychology emphasizes that young learners do not acquire abstract mathematical notions automatically; rather, the construction of such knowledge occurs through concrete actions, visual impressions, manipulation of objects, symbolic representations and gradually internalized schemes. Therefore, the use of visual models—pictures, diagrams, number lines, manipulatives, geometric shapes, bar models, ten-frames and digital visualizations—plays a decisive methodological role in forming mathematical understanding in primary school. This article examines the pedagogical, cognitive and methodological foundations of using visual models for developing mathematical thinking, analyzes their efficacy based on empirical findings, and provides methodological guidelines for teachers to employ visual tools effectively.

Early mathematical instruction must address the child's developmental characteristics. According to Piaget's theory, children aged 6–10 remain in the concrete operational stage, meaning that learning is most effective when linked to observable, tangible and manipulable representations. Vygotsky's sociocultural perspective further highlights the significance of external symbolic tools—such as diagrams and models—in supporting the transition from concrete to abstract reasoning through the Zone of Proximal Development. Bruner's representation modes (enactive–iconic–symbolic) similarly suggest that visual models function as a bridge between action-based cognition and symbolic mathematical thought. Modern research in cognitive psychology confirms that dual-coding (verbal + visual processing) significantly increases memory retention, reduces cognitive load, and enhances problem-solving abilities. These theoretical foundations demonstrate that the use of visual models is not optional but a central methodological strategy in teaching mathematics to young learners.

Visual models help children conceptualize quantities, relationships, operations and mathematical structures that are otherwise difficult to grasp abstractly. For example, number bonds illustrate decomposition and composition of numbers, which is essential for mastering addition and subtraction. Ten-frames provide structured visual cues for understanding base-ten concepts and number magnitude. Bar models support relational thinking, proportional reasoning and early algebraic skills. Number lines promote linear representation of quantity, fostering an intuitive grasp of sequencing, directionality, intervals and measurement. Manipulatives such as counters, cubes, pattern blocks and fraction circles offer tactile-visual experiences that enable children to build mental images of mathematical ideas. When these tools are used consistently, systematically and developmentally appropriately, they contribute to conceptual understanding rather than rote memorization.

The methodology of using visual models requires thoughtful planning. Teachers must identify which mathematical concept is being introduced, determine the most effective visual tool, and ensure the model is introduced gradually—from simple to more complex representations. The introduction typically begins with a concrete, hands-on phase in which students manipulate objects to explore patterns or operations. This is followed by a semi-concrete or pictorial phase, where the same relationships are shown through drawings, diagrams or structured visual layouts. Finally, students transition to the abstract phase where they use symbols, numbers and equations once conceptual understanding is secure. This progression aligns with the CPA (Concrete-Pictorial-Abstract) model widely adopted in modern mathematics pedagogy.

For young learners, visual models reduce anxiety and increase engagement in mathematics. Numerous studies indicate that children exposed to visual tools demonstrate higher levels of motivation, improved problem-solving abilities, and more positive attitudes toward mathematical tasks. Visual models provide immediate feedback, making errors visible and correctable. They support linguistic development by helping students articulate mathematical relationships, describe patterns, and explain their reasoning. Furthermore, visual models promote inclusivity: students with diverse learning styles, language backgrounds or special educational needs benefit from supports that make abstract ideas accessible.

The use of bar models has been particularly effective in teaching early arithmetic and word problem solving. Bar models allow children to visualize part–whole relationships, comparison scenarios and change situations, which are foundational schemas in arithmetic word problems. By representing the quantities as rectangular bars, students can “see” the structure of the problem before attempting a computational solution. This encourages relational thinking, strategic reasoning and metacognitive awareness. Research conducted in Singapore and other high-performing educational systems reveals that bar model instruction significantly improves students’ mathematical performance.

Ten-frames are another highly effective visual tool that shapes number sense. Their structured 2×5 arrangement mirrors base-ten concepts and enables children to recognize numbers without counting individual objects. Through repeated use, students develop an internalized benchmark understanding of 5 and 10, enabling them to perform mental calculations more efficiently. Ten-frames also support subitizing, pattern recognition, the concept of missing addends, and the early development of addition and subtraction fluency.

For operations such as addition and subtraction, number lines provide dynamic visual representations of jumps, distances and directional movement. Children learn to understand addition as moving forward on the number line and subtraction as moving backward. This prevents the common misconception that operations are purely symbolic procedures detached from meaning. Moreover, number lines lay the groundwork for future concepts such as negative numbers, fractions, measurement, and graph interpretation.

Fraction learning in primary school is notoriously challenging. Visual fraction models—fraction circles, area models, length models, and partitioned rectangles—dramatically reduce the cognitive difficulty by enabling children to compare sizes, understand equivalence, recognize fractional units, and connect symbolic fraction notation with its visual meaning. Visual fraction bars foster proportional reasoning by showing how units relate to each other, helping children see equivalence rather than memorize rules.

Digital visual models are increasingly essential in modern classrooms. Interactive number lines, virtual manipulatives, geometric apps, and digital graphing tools make visualization dynamic, accessible and engaging. They allow instant manipulation, change of variables, and real-time feedback. Technology-enhanced visual models also support differentiated instruction: students who need more scaffolding can adjust difficulty levels or repeat tasks, while advanced learners can explore extended representations. When integrated responsibly, digital tools complement physical models rather than replacing them.

Despite their advantages, visual models must be used strategically. Overreliance on visual aids without conceptual guidance may lead to superficial understanding. Teachers must explicitly connect the visual representation with the underlying mathematical idea. For example, when using counters for subtraction, it is essential to highlight the principle of "taking away" or "finding the difference," not merely moving objects. When using number lines, children should verbalize their reasoning by describing jumps and explaining directionality. When using bar models, teachers must prompt students to identify relationships among quantities rather than immediately translating diagrams into equations.

Another methodological consideration is ensuring that visual models are developmentally sequenced. Introducing overly complex diagrams can hinder learning instead of facilitating it. A well-designed learning sequence gradually reduces visual support as students gain proficiency, promoting independent reasoning. Teachers should avoid presenting multiple models simultaneously unless the instructional objective is to compare them. The clarity and simplicity of the model are crucial for minimizing cognitive load and ensuring comprehension.

Teachers need professional preparation to use visual models effectively. Many educators rely heavily on symbolic instruction because they were taught that way themselves. Professional development programs must train teachers to recognize the conceptual foundations behind visual tools, analyze student responses, diagnose misconceptions, and adjust instruction accordingly. Collaboration among teachers—such as lesson study, peer observation, and shared resource development—also strengthens the methodological use of visual tools.

Assessment strategies should incorporate visual models as well. Diagnostic tasks can require students to illustrate their understanding using diagrams, number lines or drawings. This allows teachers to identify conceptual gaps that may not appear in procedural tasks. Formative assessment based on visual reasoning encourages deeper reflection and more accurate teacher intervention. Summative evaluations may include visual-model-based problem solving to ensure alignment with instructional methods.

The cumulative impact of visual-model-based instruction extends beyond early mathematics. Students who develop strong conceptual understanding show improved performance in advanced topics such as algebra, geometry and data analysis. They demonstrate greater flexibility in problem solving, stronger reasoning skills, and higher levels of metacognitive awareness. Visual models thus serve as foundational intellectual tools that support lifelong mathematical literacy.

In conclusion, the use of visual models in forming mathematical concepts for young learners is a scientifically grounded, pedagogically effective and developmentally appropriate methodology. It enables children to build meaningful, durable and transferable mathematical understanding. Visual models bridge the gap between concrete experience and abstract reasoning, align with the natural cognitive development of young learners, and support inclusive, engaging and conceptually rich instruction. When implemented thoughtfully—using the CPA progression, aligning models with learning goals, providing conceptual scaffolding, and integrating both physical and digital tools—visual models become transformative instruments that elevate mathematical learning. For teachers, deliberate and reflective use of visual models is not merely a technique but a fundamental component of high-quality mathematics education. Strengthening methodological competence in this area is essential for developing the next generation of confident, capable and mathematically literate learners.

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