

# Pedagogical Potential of Using Geometric Figures in Developing Spatial Imagination

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**Abstract:** This article examines the pedagogical foundations and effective methods of using geometric figures to develop spatial imagination among primary school students. Spatial imagination is a key cognitive skill essential for mathematics, technology, engineering, and practical everyday tasks, and visual–geometric materials serve as a fundamental tool in its formation. The paper provides a systematic analysis of the psychological, didactic, and methodological aspects of working with geometric figures. The role of interactive methods, manipulative materials, modeling activities, the STEAM approach, and digital technologies in fostering spatial thinking is explored from a scientific perspective.

**Keys words:** Spatial imagination, geometric figures, primary education, modeling, visual representation, manipulative materials, STEAM, logical reasoning, cognitive development.

In modern pedagogical systems, the development of students' spatial imagination is regarded as one of the priority tasks not only within primary mathematics education but also within the general education framework. Spatial imagination refers to a learner's ability to perceive, interpret, and mentally manipulate the shape, size, position, motion, and spatial relationships of objects. These abilities constitute the foundational cognitive mechanisms underlying mathematics, engineering, architecture, design, physics, and various technological fields. Spatial imagination enables students to visualize complex relationships, mentally construct models, and solve problems requiring spatial reasoning—skills that play a crucial role in academic success and real-life decision-making.

The development of spatial imagination has been recognized as a significant and urgent issue in numerous national and international research studies. In J. Piaget's theory of cognitive development, the transition of a child's thinking from the sensorimotor stage to the operational stage is directly associated with visual–practical activities. According to L. S. Vygotsky's concept of the “zone of proximal development,” a child acquires new knowledge and skills initially through practical activity and manipulative experience, and only later progresses to abstract thinking. Therefore, working with geometric figures is considered one of the most effective tools for the formation of spatial reasoning.

In the context of rapid scientific and technological advancement, the expansion of the digital environment, and the dynamic development of STEM education, the importance of spatial imagination has increased even further. Significant reforms are also being carried out in Uzbekistan's education sector in this direction. In particular, the Presidential Decree PF–60 (“The New Uzbekistan

Development Strategy for 2022–2026”) emphasizes the need to enhance learners’ cognitive potential through modern pedagogical methods and the use of visual and digital learning resources. Likewise, the “Preschool and Primary Education Concept” (2021) outlines the task of developing spatial perception, manipulative activities, and modeling skills in early childhood. These policy documents confirm that improving methodological approaches aimed at developing spatial imagination is a state-level priority.

In primary mathematics education, geometric figures—such as circles, squares, triangles, rectangles, as well as spatial solids such as cubes, spheres, prisms, and cylinders—serve as essential tools for shaping students’ spatial understanding. Through these figures, learners analyze the shapes of real objects; distinguish them based on size, proportion, symmetry, and orientation; comprehend spatial relationships; develop constructive thinking through building spatial models; and learn to mentally transform, rotate, and model shapes. When spatial imagination is developed from an early age, students gain significant advantages in later studies of geometry, algebra, engineering graphics, technology, and STEAM-related disciplines.

Spatial imagination is a complex cognitive process involving an individual’s ability to form mental representations of the shape, size, proportion, position, direction, spatial arrangement, and movement of objects in the surrounding environment; to manipulate these representations mentally; and to construct models based on them. According to the scientific perspectives of researchers such as J. Piaget, L. S. Vygotsky, D. Battista, and R. Duval, spatial imagination is a foundational factor in the development of a child’s mathematical worldview, logical reasoning, and creative thinking.

Spatial imagination is essential not only for mastering mathematical knowledge but also for understanding a wide range of disciplines such as engineering, architecture, technology, graphics, physics, and chemistry, as well as for solving everyday practical problems. Learners with well-developed spatial imagination are able to visualize complex geometric models, identify spatial relationships between objects, perform visual transformations, and mentally construct various configurations.

In psychological and pedagogical literature, spatial imagination is described through the following core components:

1. **Imagery-based thinking** — the ability to form mental visual models of objects, shapes, directions, and proportions. This component determines a learner’s capacity to generate mental images and to manipulate or reconstruct them when needed.
2. **Spatial orientation** — the ability to understand and use spatial coordinates such as "up–down," "left–right," "front–back," and "near–far." This competency ensures that a child can navigate and orient independently within spatial environments.
3. **Visual modeling** — the mental process of separating, combining, rotating, resizing, and transforming geometric figures, as well as constructing mental models. This is considered one of the most complex components of spatial reasoning.
4. **Geometric reasoning** — the ability to understand, analyze, and generalize the properties, relationships, and patterns of geometric shapes based on logical principles. According to P. van Hiele’s levels, this form of reasoning develops gradually in sequential stages.

Scientific research (Clements & Battista, 1992) demonstrates that working with geometric figures is one of the most effective means of developing spatial imagination. This is because geometric shapes are clear and visually interpretable; they may have simple or complex structures; they are convenient for comparison, classification, and analytic–synthetic operations; they are suitable for manipulation; and they serve as concrete representations of spatial models. Therefore, incorporating geometric figures into the primary education process forms an essential methodological foundation for fostering students’ spatial reasoning.

The principle of visuality is one of the fundamental didactic principles of primary mathematics

education, as it facilitates the perception of abstract concepts through visual representation. Geometric figures provide an effective means of applying this principle in practice. The use of visual shapes helps learners develop the following skills: *Comparing shapes* — identifying similarities and differences between two or more geometric figures. *Identifying common and distinguishing features* — distinguishing structural elements of shapes (such as sides, angles, radius, diameter). *Decomposing shapes* — identifying the constituent parts of a figure and breaking down complex shapes into simpler ones. *Generalizing* — grouping geometric shapes into categories (polygons, solids, etc.) and recognizing their shared properties.

This process is particularly effective during J. Piaget's sensorimotor and visuospatial stages, during which children acquire abstract concepts through hands-on activities. Through visuality, learners learn to observe, analyze, internalize, and logically interpret complex spatial relationships.

**Advantages of Visual Aids:** They allow learners to study based on real objects and physical models. They help maintain active attention throughout the learning process. They accelerate logical reasoning. They enhance spatial perception and visualization. They help learners quickly understand relationships between objects.

In primary education, the use of manipulative materials is considered one of the most effective methods for developing spatial imagination. Research (Clements & Battista, 1992; Sarama & Clements, 2009) shows that children understand shapes and geometric relationships primarily through the sequence of touching—seeing—analyzing. Geometric blocks, construction sets, tangrams, mosaics, LEGO kits, and similar manipulatives create conditions that allow learners to acquire abstract concepts through hands-on activity.

In the process of working with these materials, learners engage in the following types of activities: *Assembling and disassembling shapes* — breaking complex figures into simpler components and, conversely, constructing complex compositions from basic shapes. *Creating shape combinations* — arranging geometric elements in repetitive, symmetric, or independent configurations. *Modeling* — constructing geometric models of real objects and representing their structural components. *Transforming figures in space* — performing mental operations such as rotating, flipping, enlarging, reducing, and reflecting geometric shapes.

These activities foster important cognitive skills in learners, including spatial manipulation, the perception of geometric constructions, and multi-level analytical thinking. In addition, manipulative activities contribute to the development of hand-eye coordination, logical reasoning, creativity, and constructive thinking.

**Pedagogical manipulation** refers to the process through which learners consciously understand spatial relationships by directly interacting with geometric shapes. This process aligns with Vygotsky's concept of the "zone of proximal development," as children acquire new knowledge through practical activity and gradually prepare for more complex cognitive operations.

In the 21st century, digital learning tools have opened new possibilities for the development of spatial imagination. Digital technologies allow learners not only to view shapes but also to manipulate them within virtual space—rotating, dividing, combining, and resizing them to perform complex geometric operations.

STEAM (Science, Technology, Engineering, Art, Mathematics) integration represents an innovative approach in contemporary education, aimed at cultivating complex and interdisciplinary thinking among learners. Geometric figures serve as a key component of STEAM instruction, contributing significantly to the development of engineering imagination and constructive thinking. STEAM-based activities grounded in geometric figures include: *Engineering thinking* — constructing stable structures, determining centers of gravity, and designing technical models. *Constructive imagination* — mentally modeling the internal and external structure of objects and their components. *Creative design skills* — creating models, school projects, and 3D prototypes using geometric shapes. *Practical modeling*

**experience** – solving problems and developing engineering designs using physical or virtual construction tools.

The STEAM approach not only develops spatial reasoning but also fosters the following competencies in learners: creativity, problem analysis, teamwork, experimentation and modeling, informed decision-making, practical engineering and construction skills. Activities such as constructing architectural models, building bridge prototypes, and designing robotic components based on geometric figures significantly enhance students' spatial thinking abilities.

In primary education, the use of play-based activities is considered one of the most effective and natural methods for developing spatial imagination and geometric reasoning. Games such as Tangram, Pentomino, *Geometric Lotto*, *Find the Shape*, and *Who Can Build It Faster?* not only capture learners' attention but also enable them to internalize complex geometric relationships intuitively. Through these games, students develop several key competencies: **Spatial imagination** — the ability to mentally visualize shapes, rotate and flip them, decompose them into parts, and reassemble them; **Logical reasoning** — analyzing similarities and differences between shapes and identifying cause–effect relationships; **Constructive thinking** — creating new compositions from given shapes and independently designing structural models; **Creativity** — generating artistic or technical forms from geometric elements and finding unconventional solutions. Research (Sarama & Clements, 2009) emphasizes that learning through play is one of the most effective approaches for young learners, as it integrates hands-on activity, visual perception, and cognitive processes. The use of geometric figures in teaching offers broad opportunities for students' intellectual development. According to psychological and pedagogical literature, this approach has several advantages: Through geometric figures, learners systematically and gradually acquire concepts such as shape, size, symmetry, proportion, and spatial relationships, forming the foundation of mathematical thinking. Working with figures supports the development of intellectual operations such as analysis, synthesis, comparison, generalization, and classification, thereby strengthening students' logical reasoning skills. Spatial relationships—such as “left–right,” “up–down,” “near–far,” and “inside–outside”—become easier to understand, laying the groundwork for future learning in geometry and technical disciplines. Mentally rotating, decomposing, or combining geometric shapes fosters the early development of abstract thinking, in line with Piaget's theory. As students create various compositions from geometric shapes, they begin to develop creativity, design thinking, and engineering imagination, which form a natural entry point into STEAM education.

The use of geometric figures represents a scientifically grounded, effective, and modern pedagogical tool for developing spatial imagination. This approach promotes the development of essential cognitive processes such as spatial perception, logical reasoning, analysis and synthesis, visual modeling, imagination, and abstract thinking. The integration of interactive methods, digital technologies, manipulative materials, and STEAM approaches further increases the effectiveness of instruction based on geometric figures.

Developing spatial imagination in primary grades establishes a solid intellectual foundation not only for learning geometry but also for future success in mathematics, engineering, technology, architecture, computer graphics, and the arts. Therefore, improving the didactic system for working with geometric figures is among the urgent priorities of contemporary education.

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