

Pedagogical Model for Developing Spatial Representations in Primary School Students: Theoretical and Methodological Foundations

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Abstract: The development of spatial representations in primary school students is an important component of contemporary elementary education, as spatial thinking contributes to mathematical reasoning, visual perception, problem-solving, modelling, and the understanding of relationships among objects in the surrounding environment. This study examines the theoretical and methodological foundations of a pedagogical model designed to develop spatial representations in primary school students. The study employs theoretical analysis, comparative analysis, systematization, generalization, modelling, and pedagogical design methods. The proposed model is based on a system of complementary didactic principles, including connection with real life and practical orientation, learning through play, multisensory learning, consideration of individual and age-related characteristics, learner activity, and independence. The methodological framework incorporates integrative, activity-oriented, learner-centered, developmental, synergetic, and constructivist approaches. The model consists of five interconnected components: target, motivational-preparatory, content-based, practical-activity, and reflective-assessment components. The analysis demonstrates that the development of spatial representations should not be limited to isolated geometric exercises but should be organized as a systematic and progressively structured pedagogical process involving visual, practical, constructive, graphical, and digital activities. The study concludes that the integration of these methodological approaches creates favorable pedagogical conditions for the gradual development of spatial perception, spatial representation, visual-imaginative processing, mental rotation, and spatial reasoning in primary school students.

Keywords: Spatial representations, spatial thinking, primary school students, pedagogical model, didactic principles, methodological approaches, visual modelling, mental rotation, constructivist approach, activity-oriented learning, elementary education.

Introduction: The development of students' cognitive abilities has become an increasingly important priority in contemporary primary education. Alongside subject-specific knowledge, modern educational systems emphasize learners' abilities to visualize, model, compare, transform, reason, and apply knowledge in unfamiliar situations. Within this context, the development of spatial representations constitutes an important component of primary school education.

Spatial representation refers to the ability to perceive, mentally reconstruct, transform, and apply information

concerning the shape, size, position, direction, distance, orientation, and spatial relationships of objects. It is closely related to spatial thinking, which involves the mental manipulation and interpretation of spatial information. Spatial abilities are relevant not only to mathematics and geometry but also to science, technology, engineering, art, design, and everyday problem-solving.

The development of spatial thinking is particularly significant during the primary school years because children gradually move from direct manipulation of

concrete objects toward increasingly abstract forms of mental representation. Piaget and Inhelder (1967) demonstrated that children's understanding of space develops through the interaction of perception, movement, and increasingly complex cognitive operations. This perspective suggests that spatial concepts should be introduced through concrete experience and gradually transformed into mental and symbolic representations.

From a sociocultural perspective, learning does not occur independently of interaction and pedagogical guidance. Vygotsky (1978) emphasized the importance of mediated activity, communication, and instructional support in the development of higher psychological processes. Applied to spatial learning, this perspective highlights the role of teacher guidance, collaborative problem-solving, verbal explanation, and appropriately structured learning tasks.

Yakimanskaya (1980) examined the development of spatial thinking among schoolchildren and emphasized the importance of spatial images in educational activity. Spatial images allow learners not only to recognize objects but also to mentally transform, compare, reconstruct, and operate with them. Consequently, spatial representation should be regarded as a dynamic cognitive resource rather than as a static knowledge of geometric figures.

Recent research further supports the developmental nature of spatial abilities. Uttal et al. (2013), in a meta-analysis of 217 studies, reported a moderate overall effect of spatial training, demonstrating that spatial skills are responsive to educational intervention. Their findings are particularly relevant to primary education because they indicate that spatial abilities should not be treated solely as fixed individual characteristics but can be developed through appropriately designed learning experiences.

At the same time, the pedagogical development of spatial representations requires more than the introduction of individual spatial exercises. The effectiveness of instruction depends on the systematic coordination of educational objectives, content, methods, learning activities, instructional resources, reflection, and assessment.

Therefore, the central problem addressed in this study is the theoretical and methodological justification of a

pedagogical model for developing spatial representations in primary school students.

Purpose of the study

The purpose of this study is to identify, systematize, and theoretically substantiate the methodological approaches and didactic principles underlying a pedagogical model for developing spatial representations in primary school students.

Research objectives

The study seeks to:

1. clarify the pedagogical and psychological meaning of spatial representation;
2. identify and systematize the major didactic principles relevant to spatial development;
3. determine the functional role of methodological approaches in developing students' spatial abilities;
4. substantiate the structural components of the proposed pedagogical model;
5. identify pedagogical mechanisms for integrating visual, practical, constructive, graphical, and digital activities into spatial learning.

METHODS

The study employed a set of complementary theoretical and methodological research methods, including theoretical analysis, comparative analysis, systematization, generalization, modelling, and pedagogical design.

Theoretical analysis was used to examine psychological, pedagogical, and methodological literature concerning spatial representation, spatial thinking, visual imagery, mental rotation, constructivist learning, developmental education, and activity-oriented instruction.

Comparative analysis was applied to identify common and distinctive features of different methodological approaches to the development of spatial abilities. The results of the analysis were subsequently systematized to establish the conceptual foundations of the proposed pedagogical model.

The modelling method was used to construct a coherent pedagogical framework that connects educational objectives, motivational preparation, instructional content, practical activities, reflection,

and assessment.

The pedagogical model was designed as an interconnected system consisting of five principal components:

Target component → Motivational-preparatory component → Content component → Practical-activity component → Reflective-assessment component → Expected outcomes.

The target component determines the overall educational purpose and specific objectives related to the development of spatial representations.

The motivational-preparatory component is intended to develop students' interest, readiness, and positive attitudes toward spatial tasks. It incorporates play-based activities, problem situations, visual stimuli, and tasks connected with students' everyday experiences.

The content component determines the knowledge and concepts that students are expected to acquire, including spatial position, direction, distance, shape, size, volume, orientation, and relationships among objects.

The practical-activity component provides opportunities for students to manipulate objects, construct models, interpret drawings, complete visual tasks, perform mental transformations, and use digital representations.

The reflective-assessment component enables learners to analyze their own activities, identify errors, explain solutions, and evaluate their progress.

RESULTS

1. Conceptualization of spatial representation

The analysis indicates that spatial representation should be understood as a multidimensional cognitive ability involving perception, storage, reconstruction, transformation, and application of spatial information.

For primary school students, this process can be represented as a gradual transition:

perception → recognition → comparison → mental representation → transformation → modelling → application.

At the initial stage, students perceive the spatial characteristics of concrete objects. They subsequently recognize and compare objects according to their position, shape, size, direction, or orientation. At more

advanced stages, learners mentally reconstruct objects that are not directly visible, transform their orientation, and apply their spatial knowledge to new situations.

For example, when a student observes a three-dimensional cube, the initial task involves visual perception. When the student identifies the hidden side of the cube, mental representation becomes involved. When the student predicts the appearance of the cube after rotation, the task requires mental transformation and spatial reasoning.

Thus, spatial representation develops through increasingly complex cognitive operations and should therefore be supported by appropriately sequenced instructional activities.

2. System of didactic principles

The theoretical analysis identified six interrelated principles that provide a didactic foundation for the pedagogical model.

Connection with real life and practical orientation

Spatial concepts become more meaningful when they are connected with students' everyday experiences. Classroom objects, furniture, toys, buildings, routes, natural objects, and familiar environments can serve as authentic contexts for spatial learning.

Tasks such as identifying the position of an object relative to another object, describing a route, determining direction, or comparing distances allow students to connect abstract spatial concepts with concrete experience.

Learning through play

Play-based learning provides opportunities to engage students in spatial tasks while maintaining their interest and active participation. Tangrams, puzzles, mosaics, construction blocks, mazes, graphic dictations, and visual completion tasks can be used to support spatial development.

However, play should not replace the educational objective. Rather, it should function as a pedagogically purposeful means of achieving the intended learning outcomes.

Multisensory learning

Spatial representations can be strengthened through the coordinated use of multiple sensory and cognitive channels. Seeing, touching, moving, rotating,

constructing, describing, and drawing an object can provide complementary forms of spatial information.

Therefore, a multisensory approach creates opportunities for students to transform concrete sensory experience into stable mental representations.

Individualization and consideration of age-related characteristics

Primary school students differ in their spatial experience, visual memory, attention, reasoning strategies, and learning pace. Consequently, spatial tasks should be differentiated according to students' levels of preparation and cognitive development.

Differentiation may include varying task complexity, providing visual support, allowing additional manipulation of concrete objects, or introducing more open-ended modelling activities for advanced learners.

Learner activity and independence

Spatial representations cannot be effectively developed through passive reception of information alone. Students need to manipulate objects, construct models, compare alternatives, predict transformations, draw representations, and explain their reasoning.

The teacher therefore acts primarily as a facilitator who creates learning situations, asks guiding questions, and provides appropriate support rather than simply presenting ready-made solutions.

3. Methodological approaches underlying the model

Integrative approach

The integrative approach connects spatial learning across mathematics, technology, visual arts, science, and STEAM-oriented activities.

For instance, geometry lessons may focus on spatial relationships, technology activities may involve constructing three-dimensional models, visual arts may develop understanding of composition and position, while science activities may use maps, diagrams, and models.

Such integration enables students to perceive spatial knowledge as a coherent system rather than as isolated concepts belonging to a single subject.

Activity-oriented approach

The activity-oriented approach emphasizes learning through purposeful action. Students develop spatial knowledge by directly manipulating concrete objects,

geometric models, drawings, construction materials, and digital representations.

A task such as constructing a cube, rotating it, observing different sides, and drawing the resulting view provides a richer spatial experience than simply observing a static illustration.

Learner-centered approach

A learner-centered approach positions students as active participants in the educational process. Spatial tasks should therefore take into account students' individual learning needs, interests, prior experience, and levels of preparedness.

Differentiated tasks can be organized according to three broad levels:

- **basic level** — identifying and naming spatial forms and relationships;
- **intermediate level** — transforming and reconstructing given spatial representations;
- **advanced level** — creating models and proposing alternative spatial solutions.

Developmental approach

The developmental approach focuses on stimulating new cognitive operations rather than merely reproducing previously learned information.

Questions such as "What changes when the object is rotated?", "What might be hidden behind this figure?", "How would the shape look from another viewpoint?", and "Can you construct the same object in another way?" encourage students to engage in higher-order spatial reasoning.

Synergetic approach

The synergetic approach provides a theoretical basis for understanding the interaction of different components of the pedagogical system. Motivation, content, practical activity, visualization, reflection, and assessment do not function independently; their interaction contributes to an integrated educational effect.

For example, an engaging visual problem can increase motivation, motivation can stimulate active participation, practical manipulation can facilitate the construction of a spatial image, and reflection can help students recognize and correct errors.

Thus, the pedagogical outcome emerges from the

interaction of interconnected components rather than from a single instructional technique.

Constructivist approach

The constructivist approach views learners as active constructors of knowledge. Students develop spatial understanding through direct experience, manipulation, experimentation, discussion, and reflection.

Within spatial learning, this means that students should have opportunities to construct shapes, rearrange parts, rotate objects, test hypotheses, compare models, and explain their conclusions.

Consequently, the instructional sequence can be organized as:

problem situation → independent exploration → hypothesis → practical verification → reflection → conclusion.

This structure supports meaningful learning because students construct spatial knowledge through experience rather than simply memorizing definitions.

DISCUSSION

The findings indicate that spatial representation is a complex educational construct that cannot be adequately developed through isolated geometric exercises. Its formation involves the interaction of perception, visual memory, imagination, movement, language, modelling, and reasoning.

The theoretical positions of Yakimanskaya (1980) emphasize the role of spatial images in school learning. Piaget and Inhelder (1967) demonstrate the relationship between spatial understanding, perception, and action, while Vygotsky's sociocultural perspective highlights the importance of mediated learning and instructional support.

The findings are also consistent with the meta-analytic evidence reported by Uttal et al. (2013), which demonstrates that spatial skills can be improved through structured training. This provides an important theoretical justification for developing systematic pedagogical interventions aimed at strengthening spatial abilities in primary school students.

An important implication of the present model is that spatial learning should proceed from concrete experience toward increasingly abstract mental operations. Consequently, students should initially

manipulate real objects and models, then interpret visual and graphical representations, and finally perform mental transformations without direct physical support.

Visual and practical tasks are particularly important in this process. However, the pedagogical value of a visual task depends not merely on the presence of an image but on the cognitive operation required from the learner.

For example, identifying a familiar shape primarily involves recognition. Determining the missing part of a figure requires visual analysis. Predicting the result of a rotation requires mental transformation. Constructing a new object from several components requires spatial modelling and reasoning.

Accordingly, spatial tasks should gradually increase in cognitive complexity:

recognition → comparison → reconstruction → transformation → rotation → modelling → transfer to a new situation.

The proposed model also suggests that spatial development should be assessed multidimensionally. Five interrelated developmental indicators can be identified:

1. **Spatial perception** — the ability to accurately perceive the position and spatial relationships of objects;
2. **Spatial representation** — the ability to mentally reconstruct objects or relationships that are not directly visible;
3. **Visual-imaginative processing** — the ability to compare, transform, and graphically represent visual images;
4. **Mental rotation** — the ability to mentally predict the appearance of an object after rotation or change of orientation;
5. **Spatial reasoning** — the ability to analyze, generalize, transform, and apply spatial relationships in new contexts.

These indicators can provide a theoretical basis for the development of diagnostic instruments and assessment criteria in subsequent empirical research.

CONCLUSION

The study theoretically substantiates a pedagogical

model for developing spatial representations in primary school students. The analysis demonstrates that spatial development should be organized as a systematic, purposeful, activity-oriented, and progressively structured educational process.

The proposed model integrates five interconnected components: target, motivational-preparatory, content-based, practical-activity, and reflective-assessment components. Their interaction provides a coherent framework for planning, implementing, and evaluating spatial learning.

The theoretical analysis identified connection with real life and practical orientation, learning through play, multisensory learning, individualization, consideration of age-related characteristics, learner activity, and independence as major didactic principles supporting the model.

The methodological foundation of the model is provided by integrative, activity-oriented, learner-centered, developmental, synergetic, and constructivist approaches. Their combination creates conditions in which students can move from direct perception and manipulation of concrete objects toward mental representation, transformation, modelling, and spatial reasoning.

The findings further indicate that visual-practical activities, geometric modelling, construction tasks, tangrams, puzzles, graphical exercises, mental rotation tasks, and digital modelling can serve as important instructional resources for developing spatial representations.

The proposed theoretical framework provides a basis for subsequent empirical investigation of the effectiveness of the pedagogical model. Further research should focus on developing a structured system of spatial tasks, establishing diagnostic criteria and levels, implementing the model in primary school settings, and statistically evaluating changes in students' spatial abilities.

Thus, the theoretical and methodological foundations presented in this study provide a conceptual basis for designing an evidence-informed system for the systematic development of spatial representations in primary education.

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