FORMATION OF ELEMENTARY SCHOOL CHILDREN'S VISUAL-SPATIAL PERCEPTION

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Abstract: The article deals with the results of the experimental formation of primary school children's visual-spatial perception. Research on the problem actualizes the primary educational task to teach children to recognize and reproduce the spatial properties of objects of reality. The article highlights the results of the experimental formation of the visual-spatial perception of primary school children. Visual-spatial ability as a functional unit of perception is defined, its structure and mechanism of formation are characterized. The results of the research are generalized by its purpose and tasks. Prospects for further research may consist of studying the characteristics of the perception of time and movement by younger students, distance to objects, and depth.

Keywords: Methods of examining, Pupils of elementary school, Spatial properties of objects, Spatial standards, Visual-spatial skills.

1 Introduction

Primary school is one of the periods of active formation of spatial representations. Various analyzers (kinesthetic, tactile, visual, acoustic) are involved in developing spatial concepts and methods of orientation in space. Although formed in advance, spatial concepts are considered the most difficult process than the ability to distinguish the qualities of an object [7].

The formation of spatial representations is a significant message for preschoolers' social adaptation and their subsequent education at school. The intellectual development of preschoolers directly depends on the formation of spatial concepts and orientations in space. Their lack of development by the end of preschool age is a crucial factor causing difficulties in the child's mastering of multipurpose learning skills. Similar deviations in development are expressed in pathologies of graphic activity, reading, writing, mastering operations, and more.

The formation of spatial representations determines the ability to operate with them in terms of the degree of recognition and differentiation of an object by spatial characteristics, but most importantly - at the level of mental reproduction of an object's image and changes in its position in space. It helps to place and orient an object in any frame of reference, which means understanding its position among the totality of other objects [21, 6].

The development of spatial perception in preschoolers contributes to the development of memory and attention [22]. For the transformation from visual-figurative to visual-active thinking, laborious analytical-synthetic work is required, the selection of elements, their comparison with each other, which is impossible without the presence of formed spatial representations and spatial imagination in children [4].

This article aims to describe the experimental method of forming the visual-spatial perception of primary school children. The set goal is specified in the following tasks:

- To define the ability as a functional unit of visual-spatial perception;
- To identify the levels of visual-spatial skills formed in pupils in the current pedagogical experience;
- To characterize mono- and bimodal didactic influences on the formation of visual-spatial perception;
- To evaluate the implemented didactic influences' effectiveness.

2 Literature Review

The scientific basis for solving this problem is the formation of perceptual actions concerning their neurophysiological nature theory, internal structure, and stages of internalization [3, 14, 19, 23]. Of particular importance, there are studies on children's education with visual impairments [9, 12, 17]. A strong resource for developing visual-spatial perception includes educational and methodological support for primary education, reflected in textbooks and publications for teachers [8, 11, 15, 16]. The foreign authors perform valuable researches in the following aspects:

- Application of augmented reality technologies and 3D metrics in the formation of pupil's visual-spatial abilities [1];
- Identifying the specifics of teaching visual-spatial perception in urban, suburban, remote primary education [5];
- Establishing a relationship between the effectiveness of visual-spatial perception and the success of mastering certain school subjects [10];
- Development of a criterion base for assessing pupils' visual-spatial representations [18].

Thus, the problem is multifaceted, intersectoral, and requires detailed study.

Improving the sensory sphere of primary school pupils requires the functional unit's definition that will be subject to didactic influences and the quality of which can be measured. In our opinion, such a unit should be chosen as a skilled way to perform specific actions based on acquired knowledge and skills, and in the context of our studio – visual-spatial skill.

It is logical to assume that its components – perceptual actions determine the essence of visual-spatial ability. By neurophysiological nature, such actions are circular reflex acts [3, p. 45], a continuous cyclic interaction between receptor and effector processes: nerve impulses from receptors enter the brain, are processed, return to receptors, adjust the activity of the desired motor areas, optimize information that is again transmitted to the central nervous system.

In the psychology of perception, two types of perceptual actions are exhaustively studied: introductory, aimed at finding the object, highlighting its informative features and acquaintance with them, creating a basic image of the object; cognitive, which consist in comparing the primary image with stored in memory standards (socially produced samples of spatial features), categorization and naming of the examined properties [19, p.80-83, 23, p.63, 14, p.186, p.199–200]. These perceptual actions are performed sequentially and constitute the internal structure of visual-spatial ability.

Creation of a mechanism of perceptual actions, by which scientists understand interiorization:

- First phase. The transition of external processes with material objects;
- Second phase. It occurs in sensory processes leading up to subsequent practical actions;
- Third phase. A reduction occurs due to which the external orientation develops into an ideal one [24, p.116–118].

3 Materials and Methods

In the implementation of scientific intelligence used a set of theoretical and empirical methods: analysis of scientific, educational, and methodological resources and regulations governing the content of primary education; induction and deduction, systematization and comparison, which made it possible to reveal the leading categories of research; observation, psychological and pedagogical experiment, survey, the performance of diagnostic tasks, the study of the educational and perceptual activity of products, which verified the effectiveness of the developed influences, determination of the stages of pupils' mastery of visual-spatial processes. The homogeneity of the participants' samples of the psychological-pedagogical experiment was checked with one-factor variance mathematical-statistical analysis performed through the specialized package *STATISTICA*.

The diagnostic technique is developed based on pedagogical quality: the quality of visual-spatial skills is modeled as a multilevel property consisting of less generalized features – criteria and performance indicators. The respondents' sample was sufficient, covering 312 pupils, grouped into three equivalent groups – control and two experimental.

The experimental groups' pupils were divided into four groups: with medium, sufficient, high, and consistently high levels of visual-spatial skills with a predominance of sufficient and high. The control group pupils are divided into three groups: elementary, average, and sufficient levels of mastery visual-spatial skills with a specific weight of the average.

4 Results

The expected results of mastering by pupils of many primary educational branches are:

- The ability to navigate in the plane and space;
- To recognize, classify, model, and build geometric shapes;
- To correlate real objects with their models;
- To mark and place parts of the product on the plane;
- To reproduce the shape of objects with paints, graphic, and plastic materials;
- To write in small and large handwritten letters, etc. [13].

Achieving these results becomes possible under the conditions of high-quality visual-spatial sensory processes, which actualizes the problem of their purposeful formation.

The author of the article established that children have visual-spatial skills at the secondary level at the beginning of school. A system of developmental tasks aimed at the following results:

- Systematization of spatial standards, assimilation of normative names of spatial properties (first grade);
- Development of single-modal (visual) and bimodal (visual-tactile) methods of examination of the shape, size, and placement of objects in terms of their subject combination or perceptual comparison (second and third grades);
- Individual adjustment of sensory development of schoolchildren (fourth grade).

The effectiveness of the introduced influences was revealed. A more pronounced dynamics of mastering visual-spatial skills was recorded in the experimental groups, especially in the first one compared to the control ones.

Based on the considered essential features, we detail visual-spatial ability to perform internalized cognitive-perceptual actions based on acquired knowledge about spatial features and relationships of objects (shape, size, location) and skills of applying this knowledge in the survey of reality.

5 Discussion

A qualimetric assessment model has been developed to identify the success of students' mastering of the skills being studied.

In this model, the quality of spatial perception is presented in the form of a complex property, divided into characteristics of other hierarchy levels: criteria and indicators that have particular importance (priority). The sum of the weights of one level is equal to one.

The criteria for assessing visual-spatial skills are selected:

- The accuracy of distinguishing spatial features and relationships (indicators: distinguishing simple geometric shapes by forms and size, complex shapes by the placement of elements);
- Mastering the normative names of spatial features and relations (indicators: use and understanding of the names of shape, size, placement of geometric figures);
- Awareness of classification and serial ordering of geometric objects (indicators: classification of figures by shape, serialization of figures by size in a given order);
- Reproduction of spatial features and relations (indicator: reproduction of the complex shape of objects that differ in shape and location of elements).

Regarding the importance of certain criteria, we will make some explanations. Since memorization of appropriate words is a necessary but not decisive indicator of the formation of children's perceptual ideas, the lowest weight is set for tasks to understand the names of spatial properties [20, p.14]. Among the operations of distinguishing the shape, size, and placement of objects of higher importance is given to recognizing form. It is the most informative feature in the perception of space. Other criteria and indicators are given equivalent weight (Table 1).

Table 1: The qualimetric model for assessing the quality of visual-spatial skills of primary school children

Criteria	Validity	Indication	Validity	Detection of indicators	Estimates of indicators	Estimates criteria
Distinction spatial properties (C_1)	.3	distinguishing objects by forms (D_1)	.4	K_1	$D_1 = .4\ K_1$	$C_1 = .3\ (D_1 + D_2 + D_3)$
		distinguishing objects by size (D_2)	.3	K_2	$D_2 = .3\ K_2$	
		distinguish objects by placement of elements (D_3)	.3	K_3	$D_3 = .3\ K_3$	
Assimilation of names of spatial properties (C_2)	.1	use of spatial properties names (D_4)	.5	K_4	$D_4 = .5\ K_4$	$C_2 = .1\ (D_4 + D_5)$
		understanding the names of spatial properties (D_5)	.5	K_5	$D_5 = .5\ K_5$	
Arrange objects (C_3)	.3	classification of objects by form (D_6)	.5	K_6	$D_6 = .5\ K_6$	$C_3 = .3\ (D_6 + D_7)$
		serialization of objects by size (D_7)	.5	K_7	$D_7 = .5\ K_7$	
Reproduction of spatial properties (C_4)	.3	reproduction of complex shapes of objects (D_8)	1	K_8	$D_8 = K_8$	$C_4 = .3\ D_8$
Σ	1	Quality of visual spatial skills				$C_1 + C_2 + C_3 + C_4$

Diagnosis consisted in the implementation by pupils of the following operations:

- The choice of figures identical to the sample in shape, size, and placement of elements;
- Naming the spatial properties of objects and selecting objects by the name of these features;
- Division of geometric figures into groups and arrangement of similar figures in a given order – growth, decrease in size and mixing;
- Reproduction of complex figures that differ in the shape of the elements, their mutual placement, position in the whole figure, the angle of the asymmetric detail [2, p.77-78].

The input diagnosis results showed that first-graders with absolute success (quality score – 1) distinguished between planar and three-dimensional shapes (circle, oval, triangle, rectangle, square; ball, cube, cylinder, cone). With lower performance

(0.56), pupils chose shapes by size, comparing objects of the proportional size (similar circles, triangles, and squares) more accurately than shapes that differed in two parameters at the same time (trapezoids, the same height and different lengths of bases). The results of distinguishing complex figures were even lower (0.454): respondents usually correctly chose two objects from the proposed five, without considering other positions of the parts relative to the main part and each other, the distance between them, the rotation of asymmetrical elements.

First-graders experienced significant difficulties in using the verbal notation of spatial properties (0.329). Among the plane shapes, the children accurately named a circle and a square, demonstrating poor memorization of the names of an oval, triangle, or rectangle; pupils did not mark three-dimensional figures at all. Most size relationships (even circles of different sizes, triangles of different heights, rectangles of different lengths) were characterized by the universal notions of «big/small». Spatial relationships were more accurately named in the vertical placement of figures (top/bottom) than horizontal (left/right). Simultaneously, there was a reasonably high degree of understanding of the normative designations of shape, size, and placement – the quality score (0.848) was significantly closer to absolute. The errors were caused by unstable assimilation of the names of three-dimensional figures.

The effectiveness of the classification tasks (0.614) indicates difficulties in distinguishing among geometric figures of individual sets and subsets. Pupils had to divide the presented figures into circles and polygons; polygons – into triangles and quadrilaterals; quadrilaterals – into rectangles and squares. When dividing objects into circles and polygons, the respondents correctly separated the circles, referred to the polygons as rectangles, leaving out triangles and squares; rectangles were more often considered rectangles, less often squares. The series' size did not cause many difficulties (0.784); it was wrong to place the figures mixed with different sample elements.

In reproducing the figures (quality score – 0.125), pupils had to select the desired shape constructs and place them in a given ratio. If all children completed the first task successfully, almost 50% of pupils did not cope with the second task. First-graders assumed replacement of mutual arrangement of components and position in the whole figure, convergence, or removal of details, giving an asymmetric element of the opposite direction.

Thus, when entering school, children have more formed a purely sensory stage of visual-spatial perception, sufficient to adequately distinguish between simple shapes and sizes, which varies proportionally by one parameter. Perceptual and cognitive stages of sensory processes that require analytical distinction and reproduction of complex shape, size by several parameters, naming of spatial properties, systematization of spatial standards are not finally formed. The overall quality of first-graders' visual-spatial skills corresponds to a score of 0.517 relative to the unit (ideal grade). According to the individual success of the participants of the experiment, they were divided into groups with elementary (27%), average (54%), sufficient (19%) quality levels, and the absence of children with a high level of mastery of the studied skills was recorded.

The formative experiment is organized as a contrast of two types of situations: first, the lack of input didactic influence and its presence, which involved participation in the experiment of control and experimental groups of pupils; secondly, the different degree of intensity of the input stimulus, and this required the involvement of two experimental groups of pupils. In the first experimental group, the learning-perceptual process was implemented according to option A, which was based on a combination of monomodal (visual) and bimodal (visual-tactile) directions of development of spatial perception (high degree of the input stimulus intensity). In the second group, according to option B, the learning-perceptual process aimed at the realization of only the monosensory (visual) direction of the formation of spatial perception (moderate degree of intensity of the input stimulus). No special perception development program was implemented in the control group.

The experimental effects were carried out in three stages. The purpose of the first (motivational-orientational) stage was to generalize children's existing sensory experience, the formation of new reference ideas about the shape, size, and location of objects of reality, fixation on the spatial images of normative verbal symbols. For both experimental groups, input incentives were provided under option B, the time limits of the stage covered the first year of schooling. In the performed exercises, first-graders chose objects by the name of spatial properties, called the presented objects' spatial properties. They classified shapes into planar and three-dimensional, planar into lines, segments, rays, angles, polygons, and circles. They placed and moved objects in given spatial relationships and directions. Then carried out serialization of objects in descending or increasing order of total size, length, height, thickness; circled geometric shapes with tracing paper, templates, and stencils; marked and cut out elements of applications, modeled architectural structures, made products in the technique of modeling [2, p.421–425].

The second (performing-transforming) stage, which included the second and third years of primary education, was aimed at teaching pupils rational ways to apply the learned standards in the examination of spatial qualities of objects, the gradual transfer of sensory operations from external to internal performance. The second class focuses on the development of detailed sensory comparisons of objects based on object manipulations with them; in the third class – reduction and stereotyping of sensory comparisons, their consistent transfer to the ideal plan.

Visual and visual-tactile perceptual operations were subject to improvement in the pupils of the first experimental group. In the first case, the children updated their knowledge of geometric shapes, the relationship between them in size, laid out objects on matrix cards with a given order of shapes and gradation of magnitude. They identified trapezoids by object combination (sequentially inserted figures in the «window» to the coincidence of contours), as well as based on visual comparison without alignment of objects (combined lines of the same size figures). Also recognized the given figures and their placement on reproductions of paintings, chose figures of complex shape according to the sample, comparing the main parts and small elements, selected puzzles, attaching objects to the sample, taking into account the shape, placement, and angle of details. Then reproduced the complex shape of objects, superimposing elements on the contour image or focusing on a distant sample (made geometric mosaics, compositions). Thus, children transformed the given spatial arrangements of figures [2, p. 445–448]. In the second case, pupils combined the elements of the mosaics:

- Inspected and traced with the index finger the inner contour of the recess, alternately applied inserts to it, turning them in different directions to match the contours;
- Reproduced a complex shape in the technique of plasticine – marked the contours of the figure according to the pattern, laid out silhouette lines with plasticine flagella, filled the inner plane of the image with small balls of peas made of plasticine;
- Drew geometric shapes with the index finger, the edges of the palms on the sand [2, p.464–466].

Learning and perceptual activity in the second experimental group were organized based on the formation of only visual-spatial perception.

The third (control-corrective) stage coincided with the fourth year of primary education and was focused on identifying and adjusting individual achievements in pupils' acquisition of the studied skills.

The results of the final diagnosis of the visual-spatial sensory sphere of junior schoolchildren prove positive changes in both the control and in both experimental groups, but with the highest quantitative data in the first experimental group (Table 2).

All respondents confirmed the absolute success of the distinction of a simple form, which allows us to consider the complete formation of this operation. In particular, in experimental groups, expression dynamics are illustrated by changes in geometric figures' resolution by size. It is a question of trapezoid choices that have identical height and differ in the length of bases.

Pupils of the experimental groups accurately differentiated figures in which the difference in the size of the bases was most noticeable – 2 cm.

Slightly weaker – figures with a difference in the length of the bases 1 cm. With difficulty – those figures whose bases differed slightly in size – 0.5 cm. Representatives of the control group had difficulty distinguishing any pairs of trapezoids, the latter – especially. Simultaneously, all fourth-graders recognized objects with a proportional increase/decrease in total size (similar circles, triangles, squares) correctly.

Table 2: Assessments of the quality of the visual-spatial skills of primary school children (average values)

Criteria	Validity	Indication	Validity	Detection of indicators			Estimates of indicators			Estimates criteria		
				CG	EG-1	EG-2	CG	EG-1	EG-2	CG	EG-1	EG-2
Distinction spatial properties	.3	distinguishing objects by forms	.4	1.00	1.00	1.00	.400	.400	.400	.219	.252	.250
		distinguishing objects by size	.3	.622	.712	.698	.187	.214	.209			
		distinguish objects by placement of elements	.3	.475	.754	.746	.143	.226	.224			
Assimilation of names of spatial properties	.1	use of spatial properties names	.5	.415	.763	.762	.207	.382	.381	.071	.088	.088
		understanding the names of spatial properties	.5	1.00	1.00	1.00	.500	.500	.500			
Arrange objects	.3	classification of objects by form	.5	.552	.703	.699	.276	.351	.350	.208	.232	.231
		serialization of objects by size	.5	.836	.848	.841	.418	.424	.420			
Reproduction of spatial properties	.3	reproduction of complex shapes of objects	1	.185	.613	.582	.185	.613	.582	.055	.184	.175
∑	1	Quality of visual spatial skills (final diagnosis)								.553	.756	.744
		Quality of visual spatial skills (input diagnosis)									.517	
		Dynamics of visual spatial skills quality								.036	.239	.227

The shifts in distinguishing the complex shape of objects are significant. First, the control group found children who successfully selected one, two (in 58% of cases), three, and four figures, but no one was able to choose five identical lenses. In the experimental groups of 23%, all five pairs were correctly identified, and those who made the exact choice of only one figure were not identified at all. Second, the typology of errors has narrowed. Their spectrum in the control group was the same as during the statement test: pupils did not focus on the position of the elements relative to the main part, the relative position, the distance between them, the angle of asymmetric details. In the experimental groups from this list, only two inaccuracies do not take into account the angle of the parts and the distance between them (the first occurred more often than the second).

Regarding the mastery of the names of spatial properties, we note that all control participants achieved full awareness of the normative verbal symbols. However, differences were found in the use of the corresponding words. Inaccuracies cause the insignificant dynamics of the manifestation of this criterion in the control group in naming the shape of planar and spatial figures – oval, cylinder, cone, pyramid; replacing the names of height, length, thickness with generalized options «big» or «small»; errors in determining the relationship along the horizontal axis («left», «right»). The noticeable dynamics of assimilation of verbal characteristics of spatial features in experimental groups can be explained by the ability of pupils (73% in the first and 65% in the second) to name the shape of planar figures adequately, relative size, placement on horizontal and vertical axes («left», «right», «top», «bottom»). Only the designations of three-dimensional figures – a pyramid or a cone – were wrong.

Implemented didactic influences proved to be productive in forming ideas about classification relations in spatial standards. Children in the control group were relatively successful in classifying polygons by the number of angles and separating circles from them. Still, trapezoids were often not classified as quadrilaterals or polygons. Representatives of experimental groups also made mistakes, but much less inadequate solutions were observed.

A series of geometric figures also underwent positive transformations. Fourth-graders adequately constructed rows of objects to increase (decrease) in their size gradually and did not always accurately repeat the sequence of objects laid out in a mixture. However, the contingent of students who placed the figures most successfully became more noticeable in the experimental groups – 23% in the first group and the same number in the second one versus 8% of such persons in the control group.

The strongest dynamics of change is evidenced by data on the reproduction of complex shapes of objects. In the control group, these transformations were manifested in a difference in the percentage distribution of children by the options for assembling the figure from the details («did not reproduce any object» or «reproduced one object»). The results were 26/74 instead of 50/50 during the input diagnosis. In the experimental groups, the options for performing the task were different: «did not reproduce any object», «reproduced one/two/three/four objects». The differentiation of pupils in the first experimental group by this set of options is reflected in the percentage of 4/8/42/35/11, the second group – 4/8/50/27/11. In reproducing the shape, the control section participants assumed the same errors as in its distinction is not taking into account the location of the elements relative to the main part and each other, the distance between them, the angle of asymmetrical parts. However, the intensity of incorrect design decisions in the experimental groups was much weaker than the control. Simultaneously, the inadequate reflection of the perspective of the elements and the distance between them remained quite stable.

In characterizing the methods of examining spatial properties, we will emphasize the high speed of their flow and absolute efficiency to distinguish between the simple shape and size of objects by one parameter. In the perception and reproduction of figures of complex shapes or figures that differ in size in several parameters, visual correlations were carried out by pupils more slowly and less effectively, which indicates the imperfection of their internalization. But as a result of purposeful training, these actions have a strong zone of immediate development and become effective with some help. Thus, the teacher focused the children's attention on inaccurate choice or reproduction of complex figures on the leading spatial features by the questions:

- Check whether the distance between the details is taken into account/reflected correctly?
- Is the lower right element in the selected/folded shape rotated in the same way as in the sample?

It was sufficient for the experimental groups' participants to perform more careful visual correlations, and there was no need to identify the sample and the selected/reproduced figure by superimposing them. Pupils in the control group did not notice the differences between the sample and the selected or constructed model, and if they found discrepancies, for example, in the angle of the asymmetric element, they could not correct its position even when superimposing the examined objects.

These examples show the positive impact of the implemented learning and perceptual measures on developing different ways of perceiving the spatial properties objects and, most importantly, on the ability to apply these skills in specific situations.

Measurement of visual-spatial sensory skills reflects the average level of their formation in pupils of the control group (0.553), high – in pupils of the first experimental group (0.756), and sufficient – in fourth-graders of the second experimental group (0.744). The increase in dynamics is as follows: 0.036 – in the control group, 0.239 – in the first and 0.227 – in the second experimental group. The conclusion that these groups do not belong to one general population is illustrated by the graph obtained from the one-way analysis of variance ANOVA. Since the indicator of the F-criterion > 1.00 (111.25), and the significance level of the statistical conclusion $p < 0.05$ (0.00), we can say that the average values of the samples differ: the control group is markedly different from the experimental, which are more homogeneous with each other (Figure 1).

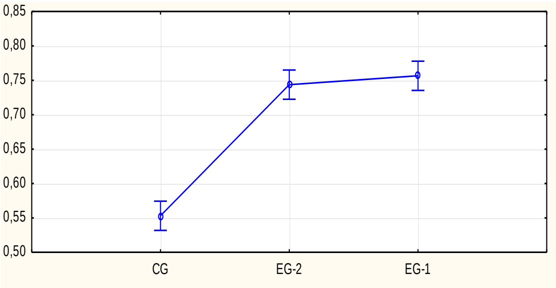

Figure 1 – Graphic model of similarity of average values of control and experimental groups

In each group of pupils were divided by qualitative levels of mastery of visual-spatial skills. In the control group, students with elementary (18%), intermediate (59%), and sufficient (23%) levels were selected; in the first experimental – with medium (12%), sufficient (46%), high (30%) and consistently high (12%) levels; in the second experimental – at the same levels, but with a slightly different distribution of persons – 13%, 48%, 27%, 12%, respectively.

6 Conclusion

This research work is allowed to define visual-spatial ability to perform internalized cognitive, perceptual actions based on acquired knowledge about spatial features and relationships of objects (shape, size, location) and applying this knowledge in the survey of reality.

In the pedagogical experience, younger pupils master visual-spatial skills in general at the intermediate level. Familiar operations related to distinguishing between the simple shape and size of objects by one parameter are more common in children; cognitive operations consist of distinguishing and reproducing a complex form, quantities by several parameters, naming spatial properties, systematization of spatial images, are less developed.

Formative didactic influences are designed according to the intergroup multilevel plan for two experimental and one control group of pupils. According to option A, which provided for a combination of monomodal (visual) and bimodal (visual-tactile) areas of improvement of spatial perception, option B aimed to implement only monosensory lines of developing spatial perception.

The positive dynamics of visual-spatial skills formation in pupils of elementary school is proved. Improving the quality of introductory and cognitive-perceptual operations and applying the acquired sensory values in the examination of objects of reality was the most powerful in the experimental groups, especially in the first of them, compared with the control group. As a result of the introduced didactic influences, the experimental groups' students mastered visual-spatial skills mainly at sufficient and high-quality levels, the control group's children – at the average level.

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