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Effectiveness of Development of Spatial Thinking in Schoolchildren of Junior Classes by Application of Plane and Spatial Modeling of Geometric Figures in Didactic Games

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Abstract

The use of planar and volumetric geometric figures in the form of didactic games and exercises, the participants in the experiment showed a significant improvement in the results of the level of spatial representation compared with the control group.

The methodology of the use of didactic games and exercises with geometric figures showed the statistical significance of differences in students in the control and experimental groups and significantly improved the quality of their knowledge and skills.

The study proves that didactic games can be used at different stages of learning, starting with an explanation of new material, its consolidation, repetition, control. Didactic games on plane modeling allow you to fully solve the educational tasks of the lesson, activate mental activity, increase the cognitive interest of students. The technique helps to convey difficult material in an accessible form.

We believe that in the process of research, the neurophysiological abilities of mental activity increased, holistically perceive objects, operate with a large number of signs, abstract certain properties of objects of the surrounding world, the ability to represent three-dimensional figures, perform actions with them (Madiyarov et al., 2017).

Keywords: spatial representation, mathematics, primary classes, methods of development spatial representation.

1. Introduction

1.1. The relevance of the problem

The possession of spatial representations and the presence of spatial imagination is one of the problems of mathematical education associated with the study of geometric material. In the process of studying the mathematical content of elementary schoolchildren, methods of mental activity are formed: analysis and synthesis, comparison, classification, abstraction and

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generalization (Arginskaya, 2003; Bantova, Beltjukova, 1984; Istomina, 2001, Totikova et al., 2019; Madiyarov et al., 2017). The success of spatial ability building is largely developed through spatial activity and training (Baenninger, Newcombe, 1989).

A multiple increase in the information load in the modern world gives an impetus to the development of interest in the problem of development the spatial representations in mathematics lessons with primary school children. Since the period of primary school age, mathematics provides real prerequisites for the development of spatial representations, contributes to the development of memory, thinking, attention, imagination, the of development of reasoning ability, and the sufficiency of the volume of mathematical material and well-chosen special tasks contributes to the full development of the intellectual sphere of students.

According to E.S. Trotskaya (Trotskaya, 2017) at present, the modern people are required to have high social activity, the ability to analyze continuously incoming information, to think in abstract concepts. Spatial thinking goes beyond its original evolutionary function and ceases to be just an instrument of orientation on the ground. It allows a person to develop his intellectual abilities and improve in the professional sphere, for example, to understand diagrams, read and create maps, build visual models of phenomena and abstractions (Dvoynin, 2008; Dvoynin, 2012; Ponomarenko et al., 2016).

J.M. Blaut & D. Stea (Blaut, Stea, 1974) note that this kind of thinking begins to from the age of three. Already at this age they are able to distinguish between simple images and create their own. Therefore, it is advisable to develop spatial thinking in a child during the period of active formation of cognitive processes such as perception, memory, thinking, speech, imagination (Trotskaya, 2017).

H.J. Kell, D. Lubinski, C.P. Benbow & J.H. Steiger (Kell et al., 2013) describe the fundamental role in the scientific discoveries and innovations of spatial thinking and skills necessary for everyday activities such as remembering the location of objects and events, also when moving from one place to another.

The questions of the study of spatial thinking were raised by scientists many times and have different directions. Scientists B.B. Velichkovsky (Velichkovsky et al., 2019); O.I. Galkina (Galkina, 1961); N.Ya. Semago, M.M. Semago (Semago, Semago, 2004); Vânia Carlos (Vânia et al., 2017), T. Bartoschek (Bartoschek, 2013) studied the ways of forming spatial representations. S. Olkun, G.G. Smith, H. Gerretson, Y. Yuan, J. Joutsenlathi (Olkun et al., 2009) investigated the dependence of the mathematical abilities of students on their level of development of spatial thinking. T. Goksun, S. Goldin-Meadow, N. Newcombe, T. Shipley (Goksun et al., 2013), studied the role of gestures and language in solving spatial problems. The structure and foundations of the development of spatial thinking were widely considered in the works of I.Ya. Kaplunovich (Kaplunovich, 1980), I.S. Yakimanskaya (Yakimanskaya, 1980). A. Frick, M.A. Hansen and N.S. Newcombe (Frick et al., 2013).

Research Results M.S. Terlecki, N.S. Newcombe & M. Little (Terlecki et al., 2008), Frick, Mohring & Newcombe (Frick et al., 2014); Hawes, LeFevre, Xu & Bruce (Hawes et al., 2015); Levine, Huttenlocher, Taylor & Langrock (Levine et al., 1999) show that preschool children are able to demonstrate spatial thinking, visualization, and mental transformations.

Ensuring the creation of spatial images and operating them in the process of solving various practical and theoretical problems is an indicator of intellectual development and the level of development of human spatial thinking (Rozov et al., 2007; Yakimanskaya, 1980).

The skill of spatial visualization can be improved through training and provide evidence of the usefulness of interactive computer visualizations in this training (Cohen, Hegarty, 2007).

Many studies have shown that dynamic software and model-specific activities can provide many opportunities for improving spatial skills (Uygan, Kurtulus, 2016; Baki et al., 2011; Cohen, Hegarty, 2007; Güven, Kösa, 2008; Sundberg, 1994; Weidemann, 1990; Yessaliyev et al., 2018). Therefore, to improve spatial capabilities began to be widely used activity-target designs, including virtual dynamic models, made manually or programmatically.

The effectiveness of planar modeling in working with children was studied by G.A. Repina (Repina, 2008) and L.V. Wenger (Wenger, 1982). Using this technique, in a short time, you can create many different models or come up with different assembly options for one model. The method helps the child learns to reason and strive to independently find ways to solve problems. Children by this age already have ideas about geometric shapes and the possibilities of their transformation, create mental images of geometric shapes using spatial memory and spatial visualization, recognize and represent shapes from different positions, mentally combine and separate two- and three-dimensional shapes (spatial visualization) (Hawes et al., 2017). They develop visual-figurative thinking, which is why it is very important to further develop the geometric representations of children in space and on the plane, to generalize the signs of geometric shapes, to divide them into parts, to project in space. The construction on the plane of modified images of objects from various flat geometric figures contributes to the development of geometric representations in children, it is aimed at the development of figurative thinking with the help of spatial images and volumetric figures. In the process of development and developing of spatial representations in younger schoolchildren, purposeful mastery of objective actions takes place. The student learns to independently solve problems in stages from simple to complex.

Actions aimed at improving spatial thinking and children's academic achievement in mathematics can be especially important given the fundamental importance of spatial thinking and mathematics for subsequent academic and professional success (Battista, 1990; Guay, McDaniel, 1977).

1.2. The objectives and tasks of the research

Given these prerequisites, this study was carried out, the purpose of which was to promote the development of spatial thinking and visualization during the experimental introduction of the method of planar and volumetric modeling, as a means of forming a spatial representation in younger students in the process of teaching mathematics.

To achieve this goal, the following research objectives were identified:

1. Identification of the level of forming the spatial representations in primary school students.

2. To study the dependence of the success of development the spatial representations of elementary schoolchildren on the use of didactic games of planar and 3D modeling of geometric figures.

3. Experimentally check the effectiveness of the developed methodology of development and development of spatial representations in the practice of teaching mathematics to primary school students.

1.3. Object of study

To conduct experimental work to identify the level of development of spatial representations of younger schoolchildren, children from grades 1 to 3 of the school-gymnasium № 47 in Shymkent and the secondary school № 49 of the village Konyr Tobe in the Saryagash district of the Turkestan region were chosen as an object of the study. A total of 363 students from grades 1 to 3 were enrolled, including 184 in experimental and 179 in control classes.

The choice of schools was based on the principle of determining localization in urban and rural areas.

The experimented students were selected according to the observation criteria: an age, an academic performance, and school curriculum development. The experimented students were selected as average matching among students of the same general education schools. The experimented students were also randomly assigned to experimental or control groups. This determined the limitations of the samples. All parents gave informed consent for their children to participate in the current study.

In order to exclude significant differences between the experimental and control groups, the preliminary independent T-tests were performed to identify the levels of spatial representation.

To study the features of the forming the spatial representations of students during the experiment, the indicators of younger students were compared. The control groups continued to study according to the traditional program and in the experimental group according to the system of developing training.

The teachers of mathematics with long experience and high qualifications in teaching mathematics in primary grades were selected for participating in the study. Having practical experience with educational materials for the development of spatial representation of children of primary school age. Teachers were additionally acquainted with the psycho-physiological process of the forming the cognitive skill and the manipulation of mental images as a means of a more thorough study of the spatial thinking of children.

Teachers of the experimental groups underwent advanced training in teaching spatial thinking.

Talks were held with the parents of schoolchildren from experimental groups about the study and written consent was obtained for their child to participate in the study.

1.4. Research methods

For the diagnostics of forming the spatial representations the followings were used:

• Test of spatial representations – to identify the level of development elementary spatial representations (Semago, Semago, 2005);

• Identification of the level of development of spatial representations using the methodology of M.A. Gabova (Gabova, 2016);

• Test of spatial thinking – to identify the ability to create a spatial image and operate in a way (Yakimanskaya et al., 1991);

• To assess the degree of reliability of differences between the studied parameters in the control and experimental groups, a mathematical statistics method such as the student's paired t-test was used;

• The Spearman correlation coefficient was used to identify the relation between the indicators of the level of forming the spatial representations of students and the success of mastering knowledge in mathematics;

• Statistical analysis was performed using SPSS version 19.0 (IBM, SPSS Software, Armonk, new York, USA). StatSoft Statistica 10;

• All values of quantitative variables in each group were expressed as mean values and standard deviations (M ± SD). The differences were considered significant at $p > 0.05$;

• When studying the test results, the standard normal distribution of the obtained data was revealed.

1.5. Development of tasks for the forming of spatial representation

When developing tasks for the development of formations and the development of spatial representation, the methods of I.S. Yakimanskaya, I.Ya. Kaplunovich, A.E. Simanovsky, A.I. Savenkova.

The program developed 15 tasks, which consisted of:

- image objects (flat and three-dimensional geometric figures, images of geometric figures and their images, images of figures in space and on the plane, an image (drawing), which includes several geometric figures, images of a three-dimensional object, structures from two geometric bodies, drawings in three types);
- The spatial arrangement of the figures (in a row, rotated relative to the usual arrangement in the images, relations and directions such as to the left of, to the right of, above, below, between, under, inside, outside, etc.);
- Geometric figures;
- The tasks were set (definition, generalization, construction, etc.)
- Graphic skills (building a graphic image by hand or using graphic tools, reading a graphic image, building according to the model, according to a given condition).

Assessment of the development levels of spatial representations of primary school children was carried out according to the following criteria:

• determination by the student of the spatial direction;

• relations between objects in both real and imaginary three-dimensional and two-dimensional space;

• difficulties in determining and naming the shape of objects and their parts, in dismembering objects and reconstructing them from parts in real and mental terms, in generalizing objects according to their shape and spatial arrangement;

• freedom of expression in speech of the result of the activity and the way to achieve them;

Low level – with difficulties;

The average level – with minor difficulties;

High level – not experiencing difficulties.

As indicators of the success of younger students in mastering academic knowledge and skills, each question was rated at 1 point and recalculated into the arithmetic average grade point.

To reveal the connection between the success of mastering knowledge and skills in mathematics by younger students and the development of spatial representations, the Spearman correlation coefficient was used.

In order to avoid the effect of consistency when applying these techniques, the method of their positional equalization was used.

2. Discussion and results

Assessment of the formation of spatial representations is one of the basic prerequisites for the child's mental activity. It was evaluated in the framework of a general psychological study of primary school children, where the level of spatial thinking provides orientation in the visible or imaginary space.

To identify the formation of spatial representations in younger schoolchildren, a pre- and post-test of spatial thinking was used (Yakimanskaya et al., 1991). The test is based on operating with spatial images and their initial content (reflection in the image of the geometric shape, size, spatial distribution of objects). Each student from the experimental group was given two types of tasks to identify the process of creating an image (tasks in which it is necessary to create an image of work with the sizes of objects and their shape), and three types – to fix the types of operating the image (leading to a mental modification of the position of the object, its structure, to a simultaneous change in the spatial position and structure of the image).

Preliminary selection and analysis of data

To determine the absence of significant differences between the experimental and control groups, preliminary independent T-tests were conducted by groups of revealing the levels of spatial representation. The test results of the control and experimental groups showed a standard normal distribution of the obtained data (Figure 1).

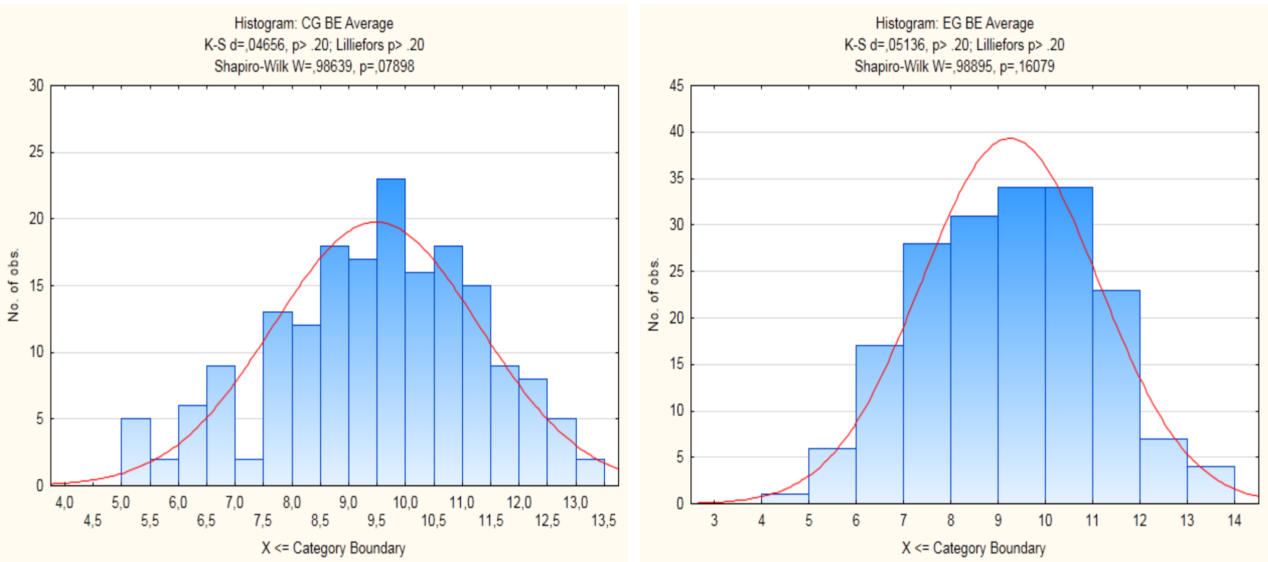

Fig. 1. Graph of the density of the standard normal distribution of data from the control and experimental groups before the experiment

Table 1. Descriptive statistics of preliminary testing of the control (CG) and experimental (EG) groups

		N obs.	Average	Minimum	Maximum	Stand. deviation	Stand. error
REO	CG	179	9.397	5.100	13.900	2.572	0.192
	EG	184	9.173	5.000	13.800	2.435	0.179
WS	CG	179	9.508	4.100	14.400	3.078	0.230
	EG	184	9.249	4.000	14.600	3.004	0.221
MR	CG	179	9.542	4.000	14.900	3.152	0.236
	EG	184	9.313	5.000	13.800	2.459	0.181

Average	CG	179	9.482	5.200	13.500	1.821	0.136
	EG	184	9.245	4.800	13.200	1.882	0.139

Note:
REO – The relationship of external objects
WS – Work with symbols
MR – Mental rotation

Table 2. Criterion of paired samples before the experiment

		Paired differences						
					95 % confidence interval for the difference			
		Average	Average. deviation	Average. error of the average	Lower	upper	t	Degree of freedom
REO	CGBE - EGBE	.2045	3.3848	.2530	-.2948	.7037	.808	178
WS	CGBE - EGBE	.2877	3.9997	.2990	-.3022	.8777	.962	178
MR	CGBE - EGBE	.2061	3.9615	.2961	-.3782	.7905	.696	178
AV	CGBE - EGBE	.2328	2.4806	.1854	-.1331	.5987	1.255	178

Tables 1 and 2 show the average values and standard deviations of both groups.

The overall average test results showed $t_{0.05} = 1.255$, $p > 0.05$. Tables 1 and 2 show the mean values and standard deviations of both groups. M ± SD of control group (CG) is 9.482 ± 0.136, M ± SD of experimental group (EG) is 9.245 ± 0.139.

With a detailed distribution of preliminary testing tasks into groups, the following results were obtained: an assessment of the spatial representation of the relationship between external objects and the body (BBO) t (178) = .808, p >.05; control group (CG) N (179) (M = 9.397, SD = .192, experimental group (EG) N (184) (M = 9.173, SD = .179). Work with symbols, t (178) = .962, p >.05 ; CG N (179) (M = 9.508, SD = .230), EG N (184) (M = 9.249, SD = .221). Mental rotation t (178) = .696, p >.05; CG N (179) (M = 9.542, SD = .236), EG N (184) (M = 9.313, SD = .181).

Comparing the overall average results of preliminary testing, the test showed $t_{0.05} = 1.255$ and when comparing the obtained value of the student's t-test with the table value ($t_{0.05} = 1.990$) with the number of degrees of freedom 178 and the significance level $p > 0.05$ ($t < t_{0.05}$; $1.255 < 1.990$) shows the statistical insignificance of differences between the compared values and the forecast H0 is accepted, that is, the degree of knowledge in the experimental and control classes at the initial stage is the same. Therefore, the difference in the level of knowledge of students in the experimental and control groups is insignificant.

Only those children who participated in both pre- and post-tests for each group of tasks were included in the data for the calculation.

When summarizing the test results, no significant differences were found between the experimental and control groups. Thus, at the initial stage of our study, both groups were not randomly selected, but had the same levels of spatial representation. Thus, we exclude any systematic differences between the groups at the beginning of the study, which could affect the results of the study.

At the next formative stage of the study, our task was to increase the level of spatial representations by applying the selected methods to the learning process. With this approach, children gain knowledge about geometric shapes and they develop spatial thinking.

For the development of spatial representation in children, the main condition is the use of special exercises and techniques in the learning process.

To achieve this goal, teachers of mathematics of the experimental groups for half a year used the technique of planar and spatial modeling of geometric figures (visualization and description of geometric transformations using volumetric and virtual geometric figures in didactic games and exercises). This methodology was supposed to provide flexible education, preservation and ability to manipulate visual-spatial information in younger schoolchildren.

As a result of studying the course of mathematics, schoolchildren must learn to recognize, name, depict geometric figures and bodies, be able to build geometric figures, be able to use geometric figures to solve mathematical problems, navigate the locations of objects on the plane and in the surrounding space, the children's ability to independently solve the set educational and practical tasks, instilling independence and initiative.

The game is aimed at developing spatial representations, elements of geometric imagination in children, developing practical skills in drawing up new figures by attaching one of them to another, teaching children to analyze the sample and verbal expression of how to connect the spatial arrangement of the parts.

When playing, children remember the names of geometric shapes, their properties, distinguishing features, examine forms visually and tactile motor, freely move them to get a new shape. Children develop the ability to analyze simple images, to distinguish geometric shapes in them and in surrounding objects, to practically modify the figures by cutting and making them out of parts.

Various exercises with geometric material, exercises for constructing 2D and 3D figures were selected. These exercises were used in lessons on various topics at the stage of summarizing the material studied. The purpose of these tasks is not only to generalize the knowledge gained in the lesson, to get acquainted with new geometric figures, but also to develop spatial representations, logical thinking, the ability to construct, and form the integrity of perception on their basis.

At the end of the formative stage of the experiment, we once again tested the levels of development of spatial representations using previously performed methods.

The results of the obtained data from the control and experimental groups showed a standard normal distribution (Figure 2).

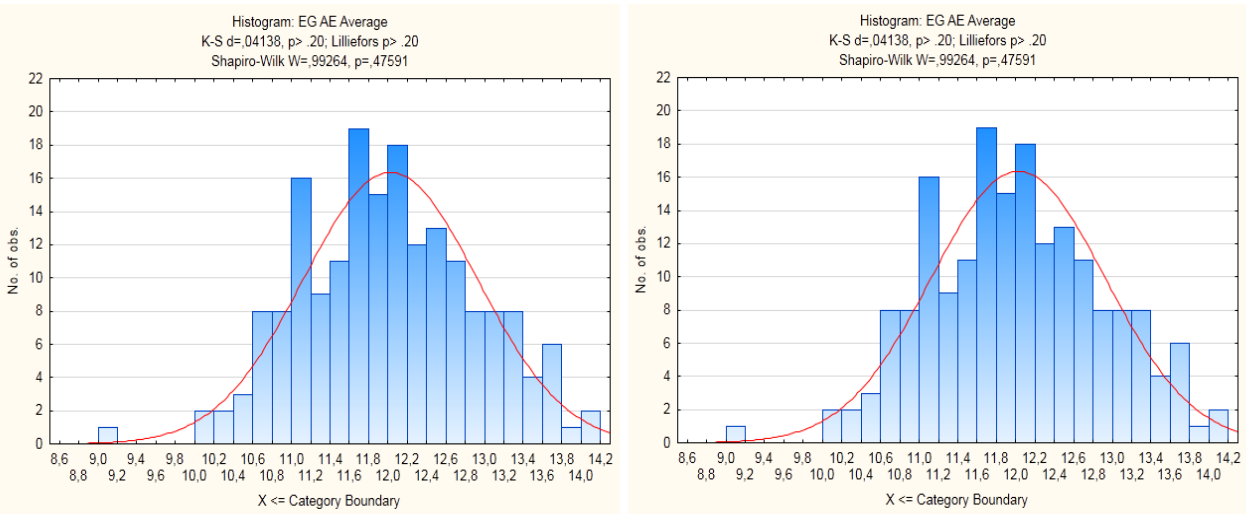

Fig. 2. Graph of the density of the standard normal distribution of data from the control and experimental groups after the experiment

Table 3. Descriptive statistics of post-testing of the control (CG) and experimental (EG) groups

		N obs.	Average	Minimum	Maximum	Stand. deviation	Stand. error
REO	CG	179	9.806	5.100	14.800	2.885	0.216
	EG	184	11.534	8.000	14.900	1.956	0.144
WS	CG	179	9.542	4.200	15.000	3.071	0.230
	EG	184	12.007	8.900	14.000	1.189	0.088
MR	CG	179	9.684	5.000	13.900	2.511	0.188

	EG	184	12.534	8.900	15.000	1.393	0.103
Average	CG	179	9.677	5.933	13.900	1.674	0.125
	EG	184	12.025	9.133	14.100	0.905	0.067

Note:
REO – The relationship of external objects
WS – Work with symbols
MR – Mental rotation

Table 4. Criterion for paired samples after the experiment with data obtained before the experiment

		Paired differences						
					95 % confidence interval for the difference			
		Average	Average. deviation	Average. error of the average	Lower	upper	t	Degree of freedom
REO	CGBE-CGAE	-.4089	3.5348	.2642	-.9303	.1124	-1.548	178
	EGBE-EGAE	-2.3607	3.0992	.2285	-2.8114	-1.9099	-10.332	183
WS	CGBE-CGAE	-.0341	4.3344	.3240	-.6734	.6052	-.105	178
	EGBE-EGAE	-2.7574	3.2503	.2396	-3.2301	-2.2846	-11.508	183
MR	CGBE-CGAE	-.1425	4.0314	.3013	-.7371	.4522	-.473	178
	EGBE-EGAE	-3.2213	2.7303	.2013	-3.6184	-2.8242	-16.004	183
Av	CGBE-CGAE	-.1952	2.3363	.1746	-.5398	.1494	-1.118	178
	EGBE-EGAE	-2.7798	2.0249	.1493	-3.0743	-2.4853	-18.622	183

When analyzing the dependent samples obtained during repeated measurements, the parameters of the pre- and post-T tests were shown in the experimental group $t_{0.05}$= 18.622, p > 0.05, N (184) (M = 12.025, SD = 0.067), while in the control group $t_{0.05}$ = 1.118, p >0.05, N (179) (M = 9.677, SD = 0.125) (Tables 1, 2).

When analyzing the spatial representation level by task groups, the results of pre- and post-testing of the relationship between external objects and the body (BBO) in the experimental group (EG) t (183) = 10.332, p >.05; N (184) (M = 11.534, SD = .144), Work with characters t (183) = 11.508, p >.05; N (184) (M = 12.007, SD = .088), Mental rotation t (183) = 16.004, p >.05; N (184) (M = 12.534, SD = .103).

For the same groups of tasks, the results of pre- and post-testing testing in the control group are as follows: estimates of the level of spatial representation of the relationship between external objects and the body (REO) at CG t (178) = 1.548, p >.05; N (179) (M = 9.806, SD = .216), Work with symbols t (178) = .105, p >.05; N (179) (M = 9.542, SD = .229), Mental rotation t (178) = .473, p >.05; N (184) (M = 9.684, SD = .187).

When comparing the obtained total average result obtained in repeated measurements of the conducted pre - and post T-tests showed in the experimental group $t_{0.05}$ = 18.622, p > 0.05 and when comparing the obtained values of student's t-test with the table value ($t_{0.05}$ = 1.973) in the number of degrees of freedom of 183 and the significance level of p > 0.05 (t > $t_{0.05}$; 18.622 > 1.973). Whereas in the control group $t_{0.05}$ = 1.118, p > 0.05 and when comparing the obtained value of the student's t-test with the table value ($t_{0.05}$ = 1.990) with the number of degrees of freedom 178 and the significance level p > 0.05 (t < $t_{0.05}$; 1.118 < 1.990).

This circumstance shows the statistical significance of the differences between the compared values and an alternative forecast H1 is accepted, i.e. it is established that the level of knowledge prevails in the experimental groups in relation to the control group, and the conclusion is made about the effectiveness of the experimental influence.

By difficulty levels

At this stage of the experiment, we found that the level of development of spatial representations of students in the control and experimental groups is insufficient and there is a need for focused work on the development of spatial representations by means of various tasks in the educational process.

The preparation of assignments according to the classification of educational goals according t Bloom's taxonomy were planned at 3 levels.

The 1st level (low level of development of spatial representations) was based on the memorization and reproduction of the studied material from specific geometric materials to a holistic representation. The ability to reproduce terms, names of geometric shapes, the basic concepts of the location of one's own body relative to space, the principles of their construction.

The 2nd level (the average level of spatial representation formation) consists of the transformation of materials from one form to another, interpretation of the material, an assumption about the further course of phenomena, events. Presumably describes future transformations of geometric shapes from existing data. Ability to apply the studied material in specific conditions and new situations.

Level 3 (a high level of spatial representation development) of tasks is designed to develop the skills to break down material into components so that it can distinguish the relationships between geometric objects, combine elements to get new ones. To develop the ability to evaluate the value of a particular geometric material, the logic of building objects. Estimates the significance of a particular geometric object.

Analysis of the results of the answers by the difficulty levels of the tasks at the end of the formative stage of the experiment, we obtained the following results:

The share of the development of spatial representations at the first level of the total in both groups decreased. In the control group from 38.55 % to 21.79 %, in the experimental group from 37.43 % to 6.15 %. The number of students with an average level of spatial representation development indicators in the control and experimental groups increased from 50.84 % to 63.13 % and from 45.25 % to 49.72 %, respectively. The number of owners of the third level of spatial representations in the control group changed from 13.41 % to 17.88 %, and in the experimental group 17.32 % to 44.13 %.

The results of the study show that spatial representations in the control groups are formed more slowly than in students of the experimental group who were trained according to a specially developed program. The indices of the development of spatial representations of the third level in the control group remained at the same level as at the beginning of the experiment, and the same level among the students of the experimental group showed a significantly increased result, which suggests that the development of spatial representations increased to a high level, i.e. e. Developed the ability to break down the material into components so that they can distinguish the relationship between geometric objects, combine elements to get new geometric objects and the ability to evaluate their location in the surrounding space relative to a specific geometric object.

Indicators of the development of spatial representations in students of the control and experimental groups are presented in the form of a diagram (Figure 3).

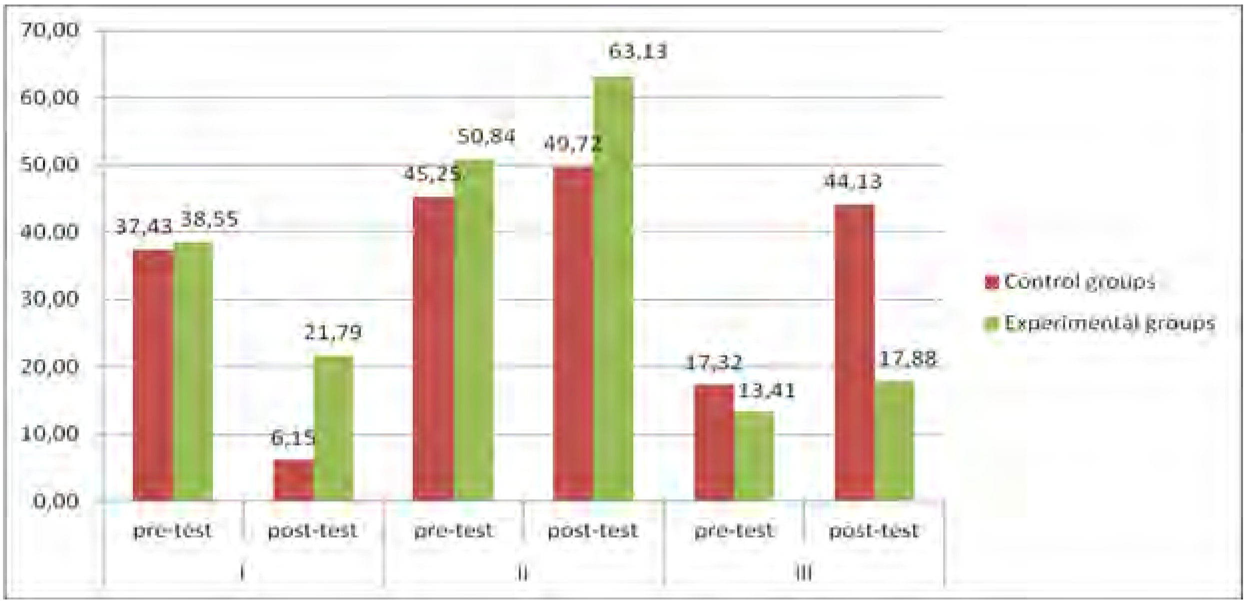

Fig. 3. Indicators of the level of development of spatial representations of students in control and experimental groups according to the level of difficulty of tasks (%).

This stage of the experiment allows us to conclude that the level of spatial representations of students in experimental groups increased compared with the initial level before the start of the study. When comparing the results of the control group in which the level of development has not changed.

Analysis of the given indicators shows that a significant increase in the share of the level of spatial indicators among representatives of the experimental group gives reason to judge the effectiveness of the use of didactic games of plane and spatial modeling of geometric figures in mathematics. There is reason to believe that the ability to distinguish a given object of geometric materials from other objects has changed, the ability to freely recognize and imagine a given object from the drawing, but the percentage of correct answers that allow errors in assigning connections between the expressed characteristic and the image of a spatial object, the ability to reproduce terms , names of geometric shapes, basic concepts of the location of one's own body relative to space, the principles of their construction. The second indicator is the percentage of students who are able to transform materials from one form to another, the interpretation of the material. Presumably describes future transformations of geometric shapes from existing data. The ability to independently compose the studied material in specific conditions and new spatial objects. The third indicator is the result of the level of development of skills to break down the material into components so that it can distinguish the relationships between geometric objects, combine elements to get new kinds of objects. The ability to evaluate the value of a particular geometric material, the logic of building objects. Assessment of the significance of a particular geometric object.

Of course, not all students of the experimental classes have spatial concepts of the second and third levels, but the relative proportion of participants in the experiment has the opportunity to form a spatial representation. This explains the high rates of spatial representation development in the experimental groups. Thus, one can affirm the positive impact of the proposed methodology.

Let us turn to the consideration of the results of the study. To identify the relationship between the level of development of spatial representations of students and the success of mastering knowledge in mathematics, we used the Spearman correlation coefficient (nonparametric criterion), since the distribution of the results in the sample under study only tends to normal.

A positive statistically significant correlation was found between the development of spatial representations and the success of mastering knowledge in mathematics ($R = 0.734$) in the experimental group and a positive significant correlation ($R = 0.342$) in the control group.

We see that the correlation indicators in the experimental group are quite high than in the control group, which allows us to argue that the development of spatial representations of students has a significant impact on the success of mastering knowledge in mathematics. Moreover, the connection between the development of spatial representations and the success of mastering knowledge is strong.

Consequently, the development of spatial representations in the students examined by us was formed at a fairly high level.

A qualitative analysis of the tasks performed by the subjects leads us to the conclusion that students are easier to cope with tasks that reveal the development of ideas about the shape of objects, changing the spatial position of the image. And much more difficult for them is the task of transforming the structure of the image, changing the position and structure of the image at the same time, that is, to identify the development of spatial thinking.

3. Conclusion

Thus, the results of the study gave us reason to believe that the success of mastering knowledge by younger students is, in fact, determined by the development of their spatial representations. The analysis of typical difficulties experienced by students in the implementation of the methods and the peculiarities of the development of their spatial representations became the basis for the development of a more focused training program.

The experiment provides additional evidence that spatial visualization skills can be improved by introducing didactic games using planar and spatial modeling.

The results obtained emphasize the importance of the choice of tasks for the development of cognitive mechanisms in the development of spatial representation, which are closely related both conceptually and cognitively with the design of spatial visualization.

Thus, we came to the conclusion that in order to effectively improve the performance of children in these fields of geometry, the development of spatial thinking skills will be required; it is necessary to use didactic games of plane and volume modeling of geometric figures in mathematics lessons. This method, unlike other programs of spatial learning, contributes to the development of medium and high levels of spatial representation, characterized by the development of the neurophysiological ability of the child's mental activity. The method contributes to the development of skills to distinguish the relationship between geometric objects, combine elements to get new ones. To develop the ability to evaluate the value of a particular geometric material, the logic of constructing objects, operate with a large number of signs, abstract and mentally rotate volumetric figures.

4. Limitations

This study has the following limitation: These are restrictions related to the number of experimented students in both the control and experimental groups, which do not allow us to extend the research data to other students of secondary schools in the region, applying it only to primary school students of our chosen schools.

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