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Encouraging the Development of Cognitive Operations in Early School Age Children by Applying the System of Didactic Games

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Abstract

The aim of this research was to examine whether the development of cognitive abilities of students can be encouraged under the influence of didactic games. The research was conducted on a sample of 163 first grade primary school pupils and an experiment with parallel groups was applied. The results obtained have shown that there is a statistically significant difference ($r=0.000 < 0.05$) between the achievements of the experimental and control groups in recognizing, naming, abstracting, forming and defining geometric shapes. Hence, this proved that the possibility of applying this approach at the beginning of schooling should be considered.

Keywords: *cognitive development, game, geometric concepts, teaching*

Introduction

Examination of the possibility to influence the development of cognitive abilities is the topic of numerous pedagogical and psychological studies. It has been determined that these possibilities are great, especially if the manner in which the mentioned abilities are influenced is adapted to the needs and interests of children, which change with age and types of activities that appeal to children (Thomas, Warren & de Vries, 2011; Cutter-Mackenzie, Edwards, Moore & Boyd, 2014).

One of the favourite activities of children, especially at a younger school age, is certainly play (Wood, 2010), which leads to the question of how it can be systematically used for didactic purposes, while maintaining its features that are especially attractive to children: its spontaneity, motivation, intellectual effort that it stimulates and self-discipline that characterizes children's behaviour during play (Johnson & Patte, 2013). Play is essential for the education of young children and it should not be abruptly discontinued or separated from learning (Smith &Pellegrini, 2013). Many authors believe that it is necessary to implement play into formal curricula and train teachers to use play as a powerful learning tool (Pramling, Samuelsson & Pramling, 2013).

When discussing play, Piaget interprets the entire development of the child through two complementary processes: the process of accommodation and the process of assimilation, which, in its purest form, is play" (Ebbeck & Waniganayake, 2010; Lillard, 2014). When he talks about play at a school age, he points out that play, unlike in the pre-school period, is now being transferred onto internal processes, internal speech, logical memory and abstract thinking. Piaget mentions three types of play, which correspond to the three stages, i.e. to the three successive forms of intelligence (sensorimotor, representational and reflexive). These are: practical play, symbolic play and play with rules (Kamenov, 2010).

Vygotsky is another great theorist cited in contemporary studies on play. He focused only on one type – symbolic play. Also, unlike Piaget, Vygotsky (1978) believed that symbolic representation plays a crucial role in development: symbolic play is an activity in which children, for the first time, understand that actions (and objects on which they are carried out) can be separated from reality (Lillard, 2014; Lillard & Voollei, 2014; Skoljnika & Bloom, 2006; Taylor, 2013). In this way play contributes to the development of higher mental functions and promotes intentional behaviour. This becomes possible because of the relationship that exists between play and the rules that have to accompany it (Bodrova & Leong, 2015).

Studies of the phenomenon of play indicate its significance in terms of stimulating intrinsic motivation in the child, strengthening self-control, redirecting its attention and behaviour (Cutter-Mackenzie et al., 2014; Platz & Arellano 2011; Wood, 2013). In addition to this, play processes lead to the creation of new mental structures, through solving problem situations cognitive abilities are developed and perfected.

The relationship between play and cognitive development has been the subject of many studies. For instance, there are studies that have linked children's play with mathematical education (Yawkey, 1981), cognitive functions (Saltz, Dixon & Johnson, 1977; Kamarulzaman, 2015), representation ability (Pederson, Rook-Green &

Elder, 1981), problem solving (Smith & Dutton, 1979; Wirawani, 2015), etc. Other authors have examined the influence of play on the development of creativity, thinking and the conversation ability (Bateson & Martin 2013; Howard-Jones, Taylor & Sutton, 2002; Kellock, 2015). The mentioned studies suggest that play is not just a single aspect of life that brings joy, fun and meaning. It is an element in and of itself, but it is also the foundation for learning and the development of children throughout life (Konklin, 2014; Mishra, Koehler & Henriksen, 2011; Henriksen, Keenan, Richardson, Mishra & the Deep-Play Research Group, 2015). The studies conducted by contemporary authors confirm that learning through play at a younger school age represents an efficient manner of acquiring knowledge and its transfer to new situations (Kopas-Vukašinović, 2006; Kamenov, 2010; Vulović, 2011).

Starting from the importance of play and its formative possibilities, it is found to be justifiable to conduct research that aims to determine whether and to what extent it is possible to influence the development of cognitive operations: recognition, naming, abstraction, formation and definition, in first grade pupils, by applying a system of didactic games.

Method

Respondents – During the research, first grade primary school pupils aged 6.5 to 7.5 were questioned. A total of 163 students were questioned: four classes of the "17. Oktobar" primary school and two classes of the "Rada Miljković" primary school from Jagodina, Serbia. We opted for first grade pupils because the main changes in the thinking of a child occur around the beginning of primary school when its thinking approaches that of adults by its characteristics. The sample was convenient. The sample is presented in Table 1.

Table 1. Experimental and control groups with respect to the school they attend

Group to which respondents belong	School attended by students		Total
	"17. Oktobar" Primary school	"Rada Miljković" Primary school	
Experimental	54	28	82
Control	53	28	81
Total	107	56	163

Measuring instrument – The *Instrument for examining the level of the development of concepts about geometric shapes* (sphere, cube, cylinder, circle, ellipse, triangle, square and rectangle) was used in the research. The research included 5 stages: *Stage 1 – Recognition of geometric shapes*;*Stage 2 – Naming*; *Stage 3 – Abstraction– Identifying shapes in objects from the immediate environment; Stage 4 – Formation* (Material: modelling clay); *Stage 5 – Definition* (*How would you describe it to someone who does not know what a sphere looks like?).*

Scoring. Each correct answer is awarded one point. The respondents' mistakes are described and recorded. During the examination the pupils are not to be corrected or instructed, and an impression is made that every answer is accepted[1].

Research procedure. The research was conducted during the 2014/2015 school year, in the period from October 2014 to June 2015.The initial measurement was conducted in the control and experimental groups with the help of the *Instrument for examining the level of the development of concepts about geometric shapes*. The groups of pupils were matched based on the initial evaluation by calculating the arithmetic mean (average measure) and standard deviation (variability measure E-SD=3.61; K-SD=3.30) for each group of respondents.

An experimental program – the system of didactic games for the development of cognitive abilities, specially designed for the purposes of this research, was introduced in the experimental group. The system of didactic games included the following groups of games: *Games that include inductive activities, Operations with geometric shapes, Games that include generalization and classification, Games that include understanding and making concepts and Games and activities that involve reasoning*. The realization of the curriculum by using the system of didactic games lasted 6 months for the pupils of the E group. Teachers were applying the system of didactic games 3–4 times a week in lessons in all subjects with an aim to process, determine and recapitulate the material. In the control group, the curriculum was realized according to the regular activity plan. The retest of the pupils was conducted six months after the completion of the experimental program, by using the same instrument as in the initial evaluation, thus determining the final state, i.e. the difference between the initial state (state before the introduction of the experimental factor) and final state (state after the impact of this factor).

[1] *Instrument for examining the level of the development of concepts about geometric shapes* (series of objective type tasks) was taken from E. Kamenov (1974), who used this instrument in the research on the influence of play on the develoment of intelligence.

Results

The research results are presented in relation to the aim that was set: *to examine whether the development of cognitive abilities of pupils: recognition, naming, abstraction, formation and definition of geometric shapes can be encouraged under the influence of didactic games*.

The initial evaluation that preceded the introduction of the experimental factor, i.e. the dependent variable, which, in our case, is the system of didactic games, was aimed at examining the level of the development of concepts about geometric shapes and determining whether there is a statistically significant difference between the pupils from the control and experimental groups. The significance, calculated by the *Mann-Whitney test* r=*0.828 > 0.05* indicates that *there is no statistically significant difference* between the results of the pupils from the experimental and control groups obtained in the initial evaluation, i.e. that the groups of pupils are matched with respect to their knowledge about geometric shapes.

The research results for the initial and final evaluation, for all the geometric shapes that were examined and for all the cognitive operations, are presented in Table 2.

Table 2. Results obtained by the pupils in the initial and final evaluation

Geom. shapes	Recognition		Naming		Abstraction		Formation		Definition	
	I (%)	F (%)	I (%)	F (%)	I (%)	F(%)	I (%)	F (%)	I (%)	F(%)
Sphere	98.8	99.4	84.7	98.2	92.6	99.4	98.2	100	78.5	92.0
Cube	98.8	99.4	78.5	93.9	38.0	70.6	54.6	69.3	54.6	73.0
Cylinder	98.2	98.8	64.4	81.0	96.3	98.8	86.5	90.8	47.2	62.6
Circle	100	100	93.3	96.9	59.5	76.1	68.7	74.2	47.2	62.6
Ellipse	97.5	97.5	31.9	50.3	90.2	93.3	68.1	76.1	49.1	59.5
Triangle	98.8	99.4	81.6	88.3	90.8	92.6	67.5	73.6	56.4	65.0
Square	100	100	60.1	69.9	87.1	90.8	68.1	77.9	52.1	64.4
Rectangle	100	98.0	75.5	81.0	76.1	84.7	68.1	71.8	51.5	56.4

Based on the obtained value of the *Kolmogorov-Smirnov* test of normality (Table 4) that was applied, it can be seen that the significance is lower than 0.05, which means that there is no normal distribution of data and that the statistical significance of the difference between the results obtained by the pupils from the E and C groups in the initial evaluation needs to be determined by applying the non-parametric *Mann-Whitney* test. The significance calculated by the *Mann-Whitney* test $r = 0.000 < 0.05$ (Table 5), points to the existence of *a statistically significant difference* between the results obtained by the pupils from the experimental and control groups in the examination of the level of the development of concepts about geometric shapes.

Table 3. Examining the level of the development of concepts about geometric shapes (Final evaluation – average number of correct responses per groups – experimental and control)

Respondent's group		Statistic
Experimental	Mean	34.96
	Std. Deviation	4.65
	Minimum	19.00
	Maximum	40.00
Control	Mean	31.57
	Std. Deviation	5.00
	Minimum	21.00
	Maximum	40.00

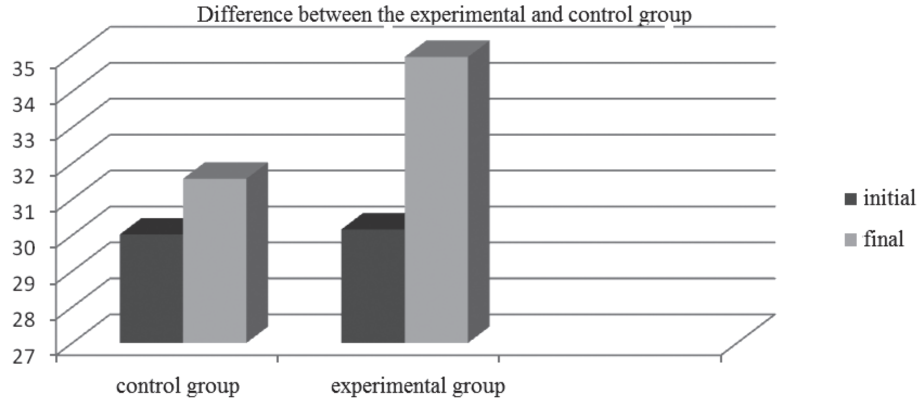
Table 4. Testing normality by groups (final evaluation)

Group	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Experimental	0.161	82	0.000
Control	0.127	81	0.002

Table 5. Mann-Whitney: Final evaluation

	Number of correct responses on the test of knowledge about geometric shapes
Mann-Whitney U	1885.50
Asymp. Sig. (2-tailed)	0.000

As the results show, the similarity between the groups has disappeared in the final evaluation. While the E group obtained high scores regarding every aspect, the scores of the C group revolve around the average. The difference between the groups has become very significant, which is interpreted primarily through the influence of different methods of educational work. This is presented in Histogram 1.



Histogram 1. Differences in the achievements of the experimental and control groups in the examination of the level of the development of concepts about geometric shapes

Discussion

The examination was started by recognizing objects as an initial phase in the development of concepts of geometric shapes, relying on Galjperin's method, in which cognitive actions are built through several characteristic stages, among which the first step towards building cognitive operations is the *material performance of an action*. The next phase is *the verbal performance of an action and, in the end, the transfer of an action to the cognitive area – internalisation* (Galjperin, as cited by: Markovac, 2001). Bruner (1986) also speaks about a similar process through which cognitive actions are built, in the framework of three levels, based on which man draws conclusions about the world surrounding him (enactive, iconic and symbolic representation). Although the pupils obtained very good results during naming, it should be emphasized that success does not testify to the development of appropriate concepts reliably, due to the fact that, in order to achieve it, it was enough to get familiarized with shapes as special kinds of objects by comparing them with objects and judging about them in that manner.

As the next stage in the process of the development of thinking, the ability of the pupils to name geometric shapes was examined. During the naming of geometric shapes the pupils obtained, in the initial evaluation, the best results when it came to naming the circle and the worst results when they were supposed to name the ellipse. When it came to naming the square, a large number of the pupils named this geometric shape the cube. Verbal performance provides relief from manipulating with concrete objects and directs towards cognitive actions. The value of verbal performance is in the cognitive reconstruction of a material action, and in addition to this, explaining the material action by speech allows for the correct understanding of words that gain their real meaning and become the basis of cognitive operations. During the application of the system of didactic games with the experimental group it was evident that the pupils cooperated and communicated with each other as well as with the teacher during the games. Cooperation included frequent naming of geometric shapes.

The operation of abstraction means that, in the process of acquiring knowledge and making concepts, the pupils, on an intellectual level, discard and remove irrelevant, less significant properties, and retain the core, essential, characteristic properties of objects or phenomena. After discarding irrelevant properties, through generalization, they "transfer" the retained prominent property on all objects that possess it and all objects with this property (Sutherland & Friedman, 2013; Cutter-Mackenzie et al., 2014). In the initial evaluation, the pupils mostly recognized, among the offered objects, those in the shape of a cylinder. The worst result, the least correct answers, was obtained during the abstraction of cube shaped objects. In the final evaluation the pupils were most successful in the abstraction of the sphere shape. The worst results, as was the case in the initial evaluation, were obtained for the shape of a cube.

For the evaluation of the pupils' ability to form geometric shapes, in the examination it was planned that they should form a sphere, cube, cylinder and other shapes, using modelling clay. What was noticed in the pupils during the formation of shapes is that some of them formed two-dimensional shapes out of modelling clay more frequently, even though the instruction was to form a three-dimensional geometric shape (e.g., a cube). In several cases the pupils made the opposite mistake, e.g., instead of forming a circle they formed a sphere. Most of the games, applied in working with the pupils from the experimental group, aimed at developing the abilities discussed by Piaget. He defines operation as an action that can be reversed to its starting point and that can be integrated with other actions that also possess the quality of reversibility (Korać, 1997).

In defining geometric shapes, the pupils were most successful in representing the shape of a sphere in the initial and final evaluation, while the success in defining other geometric shapes was around half in the initial evaluation and this percentage had increased considerably in the final evaluation.

This paper particularly focuses on the manner in which the pupils explain geometric shapes, since defining reflects the stage of the development of their thinking. To this end, some characteristic answers of the pupils will be presented, applying the criteria for the procedure of defining used in the Binet-Simon scale (Ivić, Milinković, Rosandić and Smiljanić, 1981). In their research, while determining the rules for assessing children's answers in tests of concept definition, they used: "*definitions of use* at lower ages (if the child indicates the use of what needs to be defined); then, for an older child, if it provides a *descriptive definition* (i.e., indicates the material something is made of, its appearance); for even older children it is required that they provide some form of *logical definition* (but in these cases it was not possible to ask for a complete logical definition and sometimes a positive evaluation was given if the child indicated only the immediately higher class, but not the specific difference)" (Ivić et al., 1981:99). Since the sample in this research consisted of first grade pupils, it was also not possible to ask for complete definitions of geometric shapes, as they were not planned by the program, so in the case of logical definitions it was decided to categorize those pupil responses which, during the defining of geometric shapes, included at least two criteria that were singled out and verbally defined. In addition to this, there were many responses containing a combination of descriptions and definitions of use, so, for reasons already mentioned, one more category of the children's responses was introduced, and this was the *combined form of definition*. Our respondents frequently provided **definitions of use** when defining geometric shapes and this was the case in 23.7% of the cases. In this group we classified the responses of the pupils that indicated the possible uses of a certain shape (an object of a certain shape): Sphere: *"It rolls"* (Ana, 7.6); "*We play with it*" (Luka, 6.7); Cube: *"The cube moves when it is steep (referring to the surface)"* (Maša, 6.11); *"We throw it when we play Ludo"* (Milica, 7.4).

This way of thinking was explained by Vygotsky as a stage in the development of concepts, and this is the *stage of potential concepts*. "It is characteristic of potential concepts that the property, based on which an object is included in a certain group, is a privileged property" (Vygotsky, 1983, p. 133). What defines potential concepts is the fact that this abstraction still refers to the separation of the concrete and real, rather than the essential property. Vygotsky makes it clear that the potential concept is created in the field of practical, action thinking (Bodrova & Leong, 2015). Piaget (1978) would describe this stage in such a way that a child groups objects applying one criterion to all of them, in the case of this research the criterion of use, i.e. whether they can move and what can be done with them. Bruner (1986) would call this stage the enactive stage.

Among the definitions of geometric shapes there was the highest number of **descriptive** ones. In 60.6% of the cases, the pupils defined geometric shapes through the description of their appearance and a comparison with objects of similar or identical shape: The sphere: "*The sphere is like a circle, but it's round on all sides*" (Bogdan, 7.2). Cube: "*The cube is like a house*" (Pavle, 7.3); Cylinder: "*The cylinder is like a candle, it is round*" (Đorđe, 7.1).

In the group of **logical responses** we classified those responses in which the pupils had included at least two properties of shapes or geometric figures. This also confirms that the child has the ability to operate with hypothetical situations, and not just with what is directly in front of its eyes (Bruner, 1986). In addition to this, it was made sure that the properties that the pupils mention in their responses reflect the essence of a particular geometric shape: Sphere: "*The sphere is a curved surface, it is round and thick*" (Aleksandar, 7.5); Cube: "*The cube has 6 faces and pointy edges*" (Anđela, 7.0); Cylinder: "*The cylinder has one curvy surface and two straight ones*" (Nina, 7.0).

Piaget explained this stage by the principle of classification. He states: "Now the child understands that the whole can be compared to one of its parts, and each part is understood as a function of the whole" (Piaget & Inhelder, 1978, p. 55).

In addition to this, the results of this research are consistent with results obtained by other authors. The procedure of defining applied in the Binet-Simon scale (1908 and 1911) shows that the definition tasks are tasks for the age of six (definitions of use) and nine (definitions of a higher order). In the NBS (New Belgrade revision of the Binet-Simon scale, 1976) the definition subtests are found in subtests for ages five and nine. Milinković (as cited by: Ivić, 1981) found that at the first mentioned age children usually provide definitions of use and at the second mentioned age – descriptive and logical definitions. At a pre-school age the authors find several forms of defining. Even Vygotsky pointed out that, at the age of three, the child's word is in the function of pointing to a certain object, and that is why he considers these concepts as the child's "verbal gesture of showing" (Bodrova & Leong, 2015). By applying the procedure of defining, Lj. Miočinović (as cited by: Ivić, 1981) finds, at the primary school second grade age (8–9 years): definitions of use (15.2%), descriptive definitions (3.5%), incomplete logical definitions (7.7%) and logical definitions (4.4%). Vygotsky (1983) points to studies whose findings show that defining concepts with the help of the aim and function declines with age, and defining by using logical definitions increases.

As the results show, the pupils from the experimental group obtained, after the applied method of play, very high scores in all the series of tasks and for all the shapes, when it came to those that they had previously learnt through the traditional method as well as when it came those shapes with which they had no previous experience.

Conclusion

The system of didactic games was very efficient in promoting the development of concepts about geometric shapes: recognition, naming, abstraction, formation and definition. Based on these findings, it is important to select activities that engage both the individual senses as well as more senses simultaneously, in teaching. The games that we proposed and realized with the pupils from the E group made it possible for them to synchronize sensory impressions, which provide a complete image of objects, processes, phenomena and allow for their integration into a complex view of the world. A good integration of sensory impressions is a prerequisite for proper experiential knowledge and an open road for the transformation of representations and the perceptual-practical thinking into conceptual thinking.

In addition to this, a number of questions and tasks to be addressed by further research have been opened. In this regard it would be necessary to: further investigate the possibilities of influencing the adoption of program contents and realization of the tasks of educational work by using the method of play; analyse the rich teaching experience resulting from the use of traditional methods and select the procedures which could be further applied in order to obtain good results in pedagogical work.

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