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Symbolic representation in early years learning: The acquisition of complex notions

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This article defines the concepts related to symbolic and sign representations, cognition and learning in the early years. The first study experiment of teaching 33 preschool children (19 boys and 14 girls; $M = 68$, 5 months) the notion of rainbow phenomenon proved the equal effectiveness of the use of both sign and symbolic tools. The second study experiment of teaching 49 schoolchildren (23 boys and 26 girls; $M = 102$ months) the complex notion of a mathematical function furthered our understanding of the impact of sign and symbolic tools and showed that the use of symbolic tools (metaphors and imagery) as mediators for successful transference to sign representation is effective for children who otherwise experience difficulties mastering new and complex content. The authors discuss the importance of children's play in the early years as a space where children experience and acquire operations with symbols, and the role of symbolic tools in transference to sign representation. The article furthermore provides considerations regarding the challenges and potential policy directions suggested by these research findings.

Keywords: symbol; sign; symbolic tools; children's play; representation

Theoretical framework

Beginning from the nineteenth century, philosophical tradition has divided tools of mental representation into two major categories – signs and symbols (Schelling 1936; Hegel 1969; Losev 1976; Mamardashvili and Pyatigorsky 1997). Signs directly correspond to the things they signify and refer to; they imply a connection between themselves and their objects. For example, a scale model of a room signifies the actual room it represents and refers one directly to it. Signs are inexpressive in their nature because their sole purpose is to direct orientation of a subject immediately to the signified. On the other hand, symbols are expressive and lack direct correspondence between themselves and the content they are supposed to refer to in a current situation. They are figurative in their nature and engage the subject in orientation within their sum of meanings to get to the symbolized content. A metaphor is an example of a symbol.

Starting from the works of Davydov (1972), Elkonin (1989) and their followers, learning to understand notions has been the cornerstone of the Russian educational process for children of senior preschool age and older. Following Vygotsky (1982) we understand notion as a generalization where established properties categorize objects into certain classes. Since a notion, according to Vygotsky (1983), is a high

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form of cognitive process reflection, it is considered that mastering notions allows children to perfect the thinking process. It is the reason why preschool and school education in Russia relies heavily on symbolic tools that fall into the sign group (predominantly schemes or models). However, many children face difficulties when learning new and complex notions through the use of signs, and instead of comprehension they often resort to mere memorization.

The purpose of this article is to show that the use of different symbolic tools, including the ones with vivid emotional components that convey notions in a symbolic form (for instance, a metaphor) can also be efficient for content mastering in early years learning.

The concept of symbolic representation

Ever since Jean Piaget (1945, 1969) wrote his seminal works, the phenomenon of symbolic representation has been viewed as children's inherent form of reality representation, dependent on their individual activity. Symbolic representation is understood as a special form of mental representation of a learned object or a phenomenon in the mind where the latter are represented through their external (as opposed to their content) traits that can be substituted by some other object or a phenomenon. Hence, symbolic are children's play, mathematical transformations and many other types of child activity in early years.

Being an integral part of child psychology, symbolic representation was found to most vividly manifest itself in children's play, especially pretend play – a traditional subject of developmental psychology. The studies of children's play pointed out its similarity to modelling, which occurs when children try to reconstruct the realm of social interrelations (Zaporozhets 1966). However, in contrast to a model, symbols of children's play are essentially affective (possessing vivid external traits) and are employed when children face difficulties coping with externally imposed problems. But according to Piaget, a symbol is not a tool for solving problems (Piaget 1945, 1962). The question of what essentially underlies children's play – modelling or play symbolization – was approached by Salmina (1994), who experimentally showed that the children initially employ symbolization, which prevails in children's play, rather than representation through a scheme or model. This allows us to conclude that whenever children are introduced to models and other symbolic tools they initially perceive them as symbols, and become emotionally engaged in using them as orientation tools.

In educational practice the use of symbols is most effective in situations where 'traditional assistance from a grown-up doesn't bring a child to steady self-guidance' (Bugrimenko 1994, 60), or in situations of uncertainty. In our opinion, the orienting within situations of uncertainty can be attributed largely to the key difference in operations with symbolic tools depending on their properties. Sign tools (schemes, models) are most efficient when the structure of a situation corresponds to the structure of a sign. In this case it channels orientation directly to the meaning. In contrast, symbolic tools (play situation, metaphor) are used when there is no direct correspondence between the structure of a situation and the available tools, carrying orientation out exclusively within the situation's figurative (external, aesthetic), symbolic content, and the meaning is searched for through operations within the properties and interrelations of a symbol's structure. Being encapsulated within the symbolic content, the operation itself remains symbolic until the structural correspondence between constituent parts of a symbol and an actual situation is discovered; this discovery makes the subsequent transference from symbolic to scheme or model mediation possible, and results in the productive resolution of situations of uncertainty.

Symbolic representation in a learning context

As it was noted, symbolic representation most vividly manifests itself in children's play. Many researchers, including Piaget's followers, agree that the emergence of substitutions in children's play signifies the child's advancement to a new level of cognition where they are able not only to simultaneously operate within two situations – the true reality and the one of make-believe play, but also to make a conscious transference from one to another (Leslie 1987; Perner 1993).

Studies reveal that a play situation enables children to solve tasks otherwise insolvable in reality. Thus, in an imagined situation, children aged four- to six-years-old are able to solve syllogisms, which is impossible for them in the plane of reality. For example, if a child is asked what will come from their mother playing football the majority of them will reply that their mother does not play football. However, if a child is asked what will come from a toy dragon playing football, the majority of them will rightfully conclude that the toy dragon will get dirty, tired and so on. Having found no other explanation of children's achievements within play situations, Lillard writes that 'a child play is the child's zone of proximal development in which a grown-up is not an essential partner' (Lillard 1993, 348), because while playing, children explore opportunities for symbolic representations all by themselves.

The importance of considering the unity of the child's cognitive and affective spheres was noted by Vygotsky, and we believe that the symbolization in children's play reflects this unity most vividly (Vygotsky 1983). When playing, a child operates within a symbolic space because the reality to them remains a mystery (Leontiev 2000). In other words, children's play is characterized by uncertainty, and the unknown is what essentially powers it. It is the situation of uncertainty that evokes intense emotions in a child that accompanies their play. The uncertainty of the outside world, and a child's intent to understand it through make-believe play, creates a special form of representation: a child uses emotionally rich pretend reality to understand the structural relations and models of the real world. This is where a child makes the transference from symbolization in a play to a scheme or a model – from symbolic to sign symbolic tools.

As established by Elkonin (1989) and Davydov (1972), schemes and models are in exclusive educational use during the senior preschool years, and continue to be actively used throughout subsequent school years. However, the fact that teachers both in preschool educational establishments and in schools spontaneously introduce symbolic tools (metaphors, for instance) into educational process shows that symbolization does not lose its developmental potential at any educational level (Elkonin 1989). Symbolization occurs in the learning process of children, whose natural notions are far from 'ideal forms' in their content (Ilienkov 1984).

The research questions

The study raises question about whether a symbol that arises in play (a metaphor) is efficient for mastering new content in senior preschool and early school age (from five to nine years of age) during guided learning. We attempted to answer it by conducting a double experimental study aimed at forming complex notions in children of both age groups using two categories of symbolic tools: the traditional educational tools such as schemes and models common for schools, and the symbolic tools such as metaphors during play activity.

To initiate symbolization in the children of both age groups we turned to experimental methods aimed at creating situations of uncertainty for the participants (Veraksa 1981; Phelps and Woolley 1994; Subbotsky 1994, 2007).

The situation of uncertainty for the group of preschool children had to be based upon a phenomenon familiar to them but outside of their understanding. We have decided to choose the rainbow phenomenon, familiar to all the children through multiple visual encounters but obscure to them in terms of the mechanism of its formation. The preliminary talk with children proved that they neither had the knowledge of the cultural norm pertaining to seeing rainbows, nor did they know the physical law that causes it. It should be noted that in the Russian language the word raduga ('rainbow') does not have a word 'rain' in it, or any other hint at its shape or the conditions of its occurrence in the sky.

As for the young schoolchildren from eight to ten years of age, assuming that symbolization can be effectively used in the educational process, we have chosen teaching the mathematical concept of a function, a well-explored subject in various psychological and pedagogical studies (Vinner and Dreyfus 1989; Even 1993), as the educational task. We have chosen mathematics for an experiment because, although mathematics is essentially about operating complex structures, some researchers claim that such operations are carried out within the surface, or external (aesthetic), layers of their content (Sinclair 2004).

Poincare (1989) was one of the first mathematicians to see aesthetic play having a major role in the subconscious operations of a mathematician's mind. He argued that the distinguishing feature of a mathematical mind is not logic but aesthetics. From his point of view, the aesthetic principle of harmony serves the mind as a crucial selective function. In other words, an aesthetic response to a problem evokes the construction of the necessary cognitive structures that contribute to its solution.

Educational situations that children face at school feature two main characteristics: an external condition and the culturally introduced rule pertaining to it, the uncertainties regarding mathematical problems traditionally pose difficulties for elementary school pupils at various levels – from understanding the initial data and the requirements to the selection and application of the proper rule. However, in our belief, all these instances can be mediated by symbolic representation.

Methodology

Study 1: preschoolers

Sample

The research sample included 33 children from one Moscow public kindergarten (19 boys and 14 girls; $M = 68,5$ months). The children were divided into two groups: the experimental group ($n = 18$), and the control group ($n = 15$). The groups were balanced based on the assessment of the level of children's intellectual development by means of Raven's Coloured Progressive Matrices Test (Raven, Raven, and Court 2009).

The research was carried out with accordance to the Code of Ethics of Russian Psychological Society: the permission for the participation of the children were obtained from their parents. Consent was obtained also from staff and local authorities.

Assent was inferred from young children for whom written informed consent was not practical. Children were keen to be involved in the activities and to be included in the study. The study was designed to take the form of group activities because in Russian kindergartens children spend most of their study time in groups and therefore are familiar and comfortable with this setting. Each session began with the experimenter asking children whether they wanted to learn more about the rainbow, and every time children eagerly agreed.

Design

In order to form an understanding of the rainbow phenomenon in children a three-stage intervention program was designed. The first and the third stages were identical in the methods in both groups of participants, with the key difference being the method of introduction of the content in the second stage of the experiment.

Procedure

At the first stage children of both groups were individually shown a video of the rainbow's occurrence in the sky and asked to tell what they knew about rainbows. After that, the experimenter, using two puppets, acted out a story that ended with an appearance of the rainbow. Then a child was asked a question 'Why, in your opinion, did the rainbow occur?' At the end of this stage a child was asked to draw the rainbow and to describe their drawing.

At the second stage children were taught the mechanism behind the rainbow phenomenon using a different method of instruction for each group.

Children of the experimental group were told about the occurrence of the rainbow through symbolization of the interrelations between the key elements of the phenomenon during play that was designed to reveal the interrelations of the rainbow's key elements in a symbolic manner. A grown-up emphasized that in order for the rainbow to occur, the presence of the sun, and the rain, all preceded by a thundercloud is required. Children were divided into small groups of three, where each child played a character ('raindrop', 'ray of light', 'the sun', 'the rainbow') in a theatrical enactment of the rainbow occurrence. They needed to act out three scenarios, in one of which the rainbow occurred, and in the other two it didn't. In the first scenario the children played the roles of the 'sun' and 'rays of light' showing the sunny weather; the roles of big and small 'clouds' and 'raindrops' showing 'heavy rains' and 'small rains'. In the second scenario the children showed a combination of sunny weather and rainy weather and enacted situations when 'rays of light' ran through 'raindrops' and 'rainbow' appeared – which consisted of rays of light that 'took color' from raindrops. In the third scenario the rainbow did not appear as the 'raindrops' were too big and did not let the 'rays' from the sun shine through them. All the children from the experimental group enacted the three scenarios. Overall there were three sessions with each of the groups lasting 20 minutes each.

Children of the control group, also in groups of three, were told the key interrelations between the elements of the rainbow phenomenon using visual schemes and modelling with a construction toy. The experimenter explained, showed and described the same scenarios, in which the rainbow either occurred, or didn't.

At the third stage, carried out seven days later, the children of both groups were once again shown the video about the rainbow occurrence in the sky and asked to draw a picture of it. Then children commented on their drawings and answered pertaining questions.

Evaluation

At the end of the first and the third stages independent expert psychologists with no previous experience of working with the participant children analyzed their drawings and verbal responses for the evidence of children's mastery of the phenomenon. The drawings and verbal responses were classified according to the presence of the two main criteria: *key elements* (the rainbow, sun, rays of light, raindrops, thunderclouds, etc.) and *structure* (the structural interrelations between the key elements).

The obtained data were analyzed using the standard SPSS statistical package version 17.0, including variance analysis, correlation analysis (by calculating the Pearson correlation) and non-parametric Wilcoxon–Mann-Whitney test.

Results

The classification provided us with the quantitative data for the subsequent analysis of the extent to which children mastered the rainbow phenomenon. Variance analysis of the main indexes – elements and structure revealed no substantial differences in classifications of the expert psychologists ($p > 0.05$). In other words, the experts were consistent in their evaluations of the children's progress in mastering the phenomenon in question. The mean values of the results obtained at the first and the third stages of the experimental study are presented in the Table 1.

The results reveal that children of all groups substantially improved their understanding of the rainbow phenomenon, which was further confirmed by non-parametric analysis: Wilcoxon–Mann-Whitney test allowed comparing the level of the rainbow phenomenon mastery at the first and at the third stages of the experimental study and revealed substantial differences in parameters ($p < 0.009$). Furthermore, the results showed that both experimental and control groups are statistically similar to one another at the end of the first and at the third stages of the experimental study. In other words, children of the control group showed statistically similar results in mastering the notion in question as the children of the experimental group.

Discussion

The results of the first stage showed that when asked about the nature of the rainbow, the majority of children referred exclusively to the external traits of the phenomenon – its shape, colors, and expressed their emotional attitude ('It's beautiful!'). The study of

Table 1. The mean values of the phenomenon mastery indexes.

Group		Structure	Elements
Experimental	Stage 1	1.07	1.23
	Stage 3	2.38	2.84
Control	Stage 1	0.8	0.9
	Stage 3	2.8	2.9

Figure 1. Examples of children's drawings at the first stage of the experimental study.

their drawings revealed that children were focused on drawing a rainbow the right way – to draw the right arc shape, and to put its colors in the right order. To get the colors right children either resorted to the rhymes for the colors of the rainbow (Russian equivalents of 'Richard Of York Gave Battle In Vain', for example), or tried to recall their order from the video they had been shown. All of the children ignored the constituent elements of the rainbow, such as the sun, rain and thunder-clouds, from which it was evident that children perceived the rainbow as a standalone object, not intrinsically connected to other natural phenomena (Figure 1).

The analysis of the children's drawings of the third stage showed that almost every one of them in one way or another depicted the conditions necessary for the rainbow to occur (cloud, rain, the sun) (Figure 2). However, when asked what they had depicted in their drawings, children could give no detailed explanation. 'The rain is falling, the rainbow, the sun is shining. … Why I decided to draw all that? To make it look pretty'. 'The sun and two clouds … are just a background'. 'This is an elephant. Something magical happened to him, he is sprinkling water from his trunk and the rainbow occurs'. These commentaries children gave about their own drawings suggest that the content of the phenomenon manifested itself in a non-verbal form, on a symbolic level.

On a verbal level children could not effectively explain their drawings. We believe this illustrates that at the preschool age the child's activity is closely connected with the use of symbolic images that underlies it. In other words, in their drawings, children

Figure 2. Examples of children's drawings at the third stage of the experimental study.

depicted a structure that they intuitively (according to Piaget) grasped through the use of a symbol but failed to explain due to the lack of conceptual (abstract) apparatus. This makes it clear why preschool and primary school teachers intuitively use symbols in introducing problems – because children's inherent symbolic representation of reality allows them to freely interpret new meanings introduced within the traditional educational process and serves as an orienting tool when they are coping with discrepancies between their own system of meanings and the meanings introduced by educational content.

Study 2: young schoolchildren

Sample

The research sample included 49 children (23 boys and 26 girls; $M = 102$ months) from three different third grades of a common Russian public school (in Russia, grades 1–4 correspond to primary school).

The research was carried out with accordance to the Code of Ethics of Russian Psychological Society: permission for the participation of the children was obtained from their parents. Consent was also obtained from staff and local authorities. Assent was inferred from young children for whom written informed consent was not practical. Each session began with experimenter telling children what they were about to do and asking them whether they wanted to take part in the proposed activity. The children's class teacher was not present in the classroom to keep their decision to participate or not free of pressure and external influence. Two children did not attend the second day of study due to their engagement in a sporting competition and their data were excluded from the analysis. All of the children were keen to be involved in the activities and to be included in the study.

Acquisition of symbolic systems, including mathematical operations, is highly dependent on the development of overall intellectual abilities. Therefore Raven's Coloured Progressive Matrices Test was used (Raven et al. 2009). The children were placed into three categories according to their scores on the test: 24 children with 25–50 percentile frequency scores, 11 children with 50–75, and 14 children with 75–95. These children were evenly distributed between two groups: the experimental group ($n = 25$) and the control group ($n = 24$). Therefore each group consisted of three categories of children according to their percentile frequency scores on the test. No statistically significant differences between the test results of girls and boys were found.

Design

The study of the mathematical concept of a function according to the Russian curriculum for secondary schools begins in the sixth grade (when pupils are approximately 12-years-old). The choice to base the experiment on this concept was made after careful research and consultations with math teachers, which indicated that for third graders a graph of a function is completely new knowledge outside their zone of actual development but at this age children have the necessary background knowledge to master it.

Therefore, a three-week program of six classes of 40 minutes each for third graders was developed; the classes covered the mathematical concept of a function and its graphic representation. The classes were designed as standard math classes in a school setting familiar to the children; their math teachers conducted the classes. An assistant who was present in each of the classes supervised conformity of classes with the program.

Rather than focusing on the precise definition of a function, the primary task was to make children comprehend the very concept of a function – the idea of the conversion, or the transformation, of the independent variable (argument) into the dependent variable (value).

The two groups of children were given the same initial math assignment in the first experimental class and were asked to solve it: ‘A cyclist travels from point A to point B traveling at 10 km per hour. The distance between the two points is 50 km. Assuming that a bus is traveling at 40 km per hour, how many hours can a bus wait at point A after the cyclist’s departure to arrive at point B earlier than the cyclist?’

Based on our previous research, we assumed that the introduction of a completely new concept would put children into a situation of uncertainty, where the use of sign tools is hindered. Such uncertainty could trigger the mechanism of symbolic mediation if relevant images, with structures resembling the structure of the concept, were introduced.

The first three classes for the children of the experimental group were aimed at introducing a symbolic image (‘magic wand’) that is not directly connected to the mathematical concept in question but intrinsically resembles its structural interrelations; introducing such an image would allow the further transference of the core idea from a symbolic image to the mathematical concept. The goal was to lead the children to ‘spontaneously’ discover the idea of transformation and to transfer it to the concept of a mathematical function. It was necessary to have a medium representing the concept of transformation that would be easy for a child to operate because of its familiarity.

Since transformation is a core concept of magic, magic as the medium was chosen for the experimental group and an image of Fairyland, where two sorceresses could do magic and turn everything into anything, was introduced. We assumed that children would get emotionally involved in this story, live through it, and imagine being able to turn everything, including themselves, into anything. With help from the teacher the children inevitably acknowledged the problem that if anyone could be anyone and anything, it is very hard, if not impossible, to tell who was who. The key moment in the story’s plot is the initial meeting of the two sorceresses. In this dramatic event, the people of Fairyland could not tell which sorceress was which; the children were asked for help to solve the problem of telling one sorceress from another, knowing that both of them could become anything they liked and could even turn themselves into one another. We assumed that the greatest challenge for the children in this situation would be to reason the grounds on which the two sorceresses could be distinguished from one another. In this situation we expected the play setting to facilitate the search for a solution and to promote critical evaluation of various ideas that might emerge during discussions about who the sorceresses essentially were, what it was that they could transform with their magic, how they could do that, and how was it possible to distinguish one sorceress from another.

Procedure

Children of the experimental group tried, in their first class, to solve the introduced initial math assignment to no effect. They seemed lost and unmotivated. Phrases like 'we didn't study this', 'show us how', 'I don't know', 'not interesting' were predominant. Children behaved badly, spoke loudly, turned and talked to each other. It was obvious that they couldn't stick to the task.

When the experimenter began to talk about Fairyland, the situation changed: The children began to listen attentively, were active in sharing their assumptions about the traits of this magical country and its inhabitants, and named a sorceress as one of them. They discussed the ways in which a sorceress is different from an actual human being ('she can cast spells', 'can make everything beautiful, magical'). The experimenter then started a discussion about the nature and the purpose of sorcery. The children eventually came to the idea that sorcery is the transformation of objects into something else with the help of a magic wand. The children agreed that a magician is simply a person who can change the surrounding world – that is, transform objects.

In the second class the children were introduced to the problem of how to tell the two sorceresses apart. In the beginning, the children's suggestions were to use their clothes, looks, age, beauty, and other external traits as a basis for distinguishing them. After it became clear that clothes, looks, and everything else can vary and can be changed, the idea emerged of distinguishing them by their names. However, this assumption was also rejected because the sorceresses can respond to each other's names. Then the children proposed that one sorceress could rule over weather and the other one could rule over people and pets. Thus, although they started by analyzing external traits, the children eventually came to the idea that sorceresses might differ in their abilities, meaning that their respective magical domains could be different. For example, some sorceresses have powers over weather; others, over animals; and so on. Children came to the idea that the types of objects that sorceresses have powers over could be the criteria for their differentiation.

In the third class the children picked up where they left the last discussion about the sorceresses and about the ways those two could be told from one another. They remembered a Harry Potter movie and noted that the magic wands of its heroes differed in their magic power rather than visually. They concluded that the magic wands of their sorceresses might also be different in their transformational magic power. The children gave examples of the differences between a strong magic wand and a weak one; one example was the maximum scale a wand could change an object: a strong wand could make an object much bigger than a weak one could. Thus the children intuitively came to the idea of the coefficient of proportionality as a power of a magic wand. Then the children were given time to draw pictures of the sorceresses and the transformation events.

At this point three classes, in our opinion, led the children to understand the relationship between the argument (the initial object) and the rule of its transformation (the power of a magic wand). This relationship characterizes functional dependence.

Classes four to six were dedicated to the transference of ideas from the symbolic image to the actual content of the mathematical concept of a function. In classes four and five the children were given simple mathematical functions with positive numbers ($y = x$, $y = 2x$, $y = 3x$) along with their graphs. The experimenter emphasized that, like a sorceress, a function is connected with the transformation of entities. At the class six the children were given problems to solve.

Children of the control group were taught the mathematical notion of a function in accordance with the standard national curriculum for sixth graders.

In the first class children learned about the coordinate system. Teachers explained that this system could be found in real life in various forms, like an address, an airplane or theater seat, email, or games like Battleship and Chess.

In the next class the teacher explained the correspondence of two numbers to one point in the coordinate system. Examples of finding a point by its coordinates and vice versa were given. The children learned to find the coordinates of the intersection point of two narrow lines and to build a linear graph of two points on a coordinate system.

The third class was dedicated to learning about values. Examples of variable and constant values were discussed (height of a person, height of a room, distance traveled, distance between two points). The domains of variables and of function were explained and exemplified.

In the fourth class the children learned table and letter representation of linear dependence and drew linear graphs for natural numbers.

The children solved problems connected with vehicle motion using graphs of the $y = k \times x$ linear function in the fifth and sixth classes.

A week after the last class, children of both groups took a final test consisting of five problems requiring graphical solutions.

Evaluation

In the final phase of the research, in the last classes children in all the groups were given problems of the same complexity. The control problems (see the Appendix) were given to children of both groups in the final test not earlier than a week after the last class. The control problems were analogous to those children solve in the 6th grade of the Russian schools during testing of their mathematical skills. Solving four or more problems out of five was graded ‘good’ and ‘excellent’.

The obtained data were analyzed using the standard SPSS statistical package version 17.0, including variance analysis and non-parametric Wilcoxon–Mann-Whitney test.

Results

In the final test a child was given 1 point for each successfully solved problem. The results are presented in Table 2.

The table shows that the 75–95 percentile children of the control group were the most successful in the experimental task ($M = 4.40$). However, the difference in the performance of the 50–75 and the 75–95 percentile children between the groups is statistically insignificant.

The 25–50 percentile children performed significantly better in the experimental group, as compared with their peers in the control group.

Table 2. Average score on the final test for five control problems.

	Average score (*M*)	
Categories of children	Experimental Group	Control Group
Children in the 25–50 percentile	3.38	1.88
Children in the 50–75 percentile	3.67	3.75
Children in the 75–95 percentile	4.20	4.40

As shown by the results, the use of signs and symbols as tools of mastering different notions in early years is proved to be effective – experimental classes built on such use reached their aims and were beneficial for children of five to six and eight to nine years of age.

Discussion

As shown by the results of this study experiment the use of both signs and symbols is equally efficient in school.

The experiment demonstrated that the type of representation employed in educational practice does not make a significant difference for children with high levels of intellectual development (75–95 percentile children). These children equally effectively operate with symbolic tools of both categories and experience no trouble learning, as is proved by their academic success.

Most important for the hypothesis are the results of the 25–50 percentile children, who were commonly described by their teachers as academic underachievers. These children showed a productive response to the type of representation employed in the educational program. It turned out that an emotional symbol of magic proved to be an effective cognitive instrument. Symbolization was purposely used as a tool for bringing the children to acquire signs, and the 25–50 percentile children did so successfully. This suggests that in educational practice, usage of the symbol is beneficial for children who have trouble solving problems that require sign usage.

The important task in this research was to establish the possibility of transitioning to sign through operations within a symbolic plan. In her work, Sfard (1994, 2000) studied metaphor as a symbolic tool for solving mathematical problems. Sfard (1994) distinguished two types of mathematical thinking: operational and structural. Structural thinking employs metaphors. Sfard emphasizes that the structure of a metaphor is beyond logical description. Unfortunately, her work does not explore the emergence of a symbolic image and regards a metaphor as a defined principle. We believe that a metaphor, being essentially a reduced symbol, is the product of the exploration of a metaphorical plan.

General discussion

A number of works demonstrate the possibility of employing symbolic tools in preschool educational practice (Perner 1993; DeLoache 2000; Poland and van Oers 2007), ascribing it largely to the double-coding principle – an ability to simultaneously hold two realities (the actual one and the one of a game) – which is acquired through play activities (Lillard 1993).

It seems important to distinguish between two principal types of situations in which coding occurs. In the first instance, the sum of meanings of both realities is defined, as, for example, in the DeLoache scale room experiment (DeLoache 2000); in the second the meanings of one of the realities are relatively uncertain. This second type of situation is the one that constitutes play activity and the application of symbols in the frame of play.

Vygotsky (1967) describes the common instance of a boy hopping on a stick while he imagines riding a horse. In this situation the stick's sum of meanings is derived from its utility, whereas the purport of the boy's actions becomes clear only if they are attributed to the sum of the meanings of a horse, which is yet uncertain to him.

Given that the second type of situation is characterized by uncertainty of the sum of the meanings of one of the realities, the motive for the boy's actions (Leontiev 2000) is not that he is using the stick because of the unavailability of a real horse but that he is attempting to understand operations with a horse through operations with a stick. The same phenomenon of reality exploration is noted in the works of Diachenko (1987), which demonstrate that children's activity within play reality brings out possibilities that they can later actualize.

In both our experiments we attempted to create a play situation and use its potential for teaching children new content. The metaphorical setup of a play situation allowed children of five to seven years of age to master the notion of the rainbow phenomenon (evident in their drawings), and children of eight to nine years of age to master the notion of the mathematical concept of a function (evident from the 'good' marks received from teachers for solving control problems typical for the curriculum for 6th graders).

Conclusions

The obtained data show the special role of children's play as a symbolic plan that allows using symbols. Our study demonstrates how symbols allow transference to signs in situations where they are not easily grasped through a special metaphorical, game plan.

Education in general can be viewed as a model of the transition from an ideal form (embodied in concepts and other symbolic forms of reality representation) to its realization in the real world. In the moment of this transition, as Elkonin writes, 'a subject of activity emerges … "at the point" when the action is required and no pertinent automatism is available, i.e., at the point of form transformation' (1994, 32). An ideal form, being a normative product, is internalized by a grown-up that translates it to a child. To a child this ideality, even when it is most vivid, remains obscure and uncertain until, according to Leontiev (2000), the child's psyche accommodates to it. This happens when a child's activity collides with the ideal form. Regarding teaching mathematics, Vygotsky wrote, 'In a child's development almost always important moments occur; the child's own arithmetic always collides with the other form of arithmetic taught by grown-ups. Teachers and psychologists must remember that children's internalization of cultural arithmetic always involves conflict' (1983, 202–203). When encountered by children, an ideal form is instinctively symbolized because they do not yet comprehend its true meaning. Such symbolization can happen with the use of tools that are accessible to a child at the particular stage of their development. That is why we highlight the importance of combining various complementing symbolic tools.

Limitations and implications for further research and practice

The establishment of the causal connections between the cognitive development of children and the use of symbolic tools was not the aim of this study. At the same time we established that symbolic tools of different types, however being structurally different, are consistent with the age of the studied children and can be equally effectively used in solving cognitive tasks. In this regard it would be justifiable to continue this line of research using this kind of a study design on a larger sample controlled for gender.

The research on the use of symbolic representation in educational process has further pedagogical implications. We believe that understanding the use of symbols as cognitive tools may inspire new thinking in people who work with children, not only teachers, but also parents and caregivers. Employing symbolic representation at school and home environments in teaching new concepts and notions that are otherwise difficult for some children to master is ensuring the best possible conditions for their growth, learning and development. Once again, we would like to emphasize that the ability to operate symbolic tools is directly connected to the proficiency in any kind of play activity.

For these reasons we hope to see more of the research on this subject, especially longitudinal studies to provide policymakers, teachers and parents with more evidence on the importance of play and other symbolization activities and experiences in preschool and primary grades for the child's development. Having a substantial body of evidence will help to demonstrate to policymakers and practitioners in the field of education that the development of representational skills is important for academic readiness and later school success.

The article describes two types of cognitive tools – signs and symbols, shows that they can be successfully used in educational process in kindergartens and schools. We believe that children's play is intrinsically symbolic and spontaneous activity and individuality of the child is closely connected to symbolic tools. Therefore children could benefit from educational process that considers and employs the findings of this study. For example:

- Developmental environment designed with symbolic mediation in mind would benefit preschool children
- Educational process that provides children with an opportunity to master symbolic tools as well as sign tools that in their nature are closely related to signs (visual models) would be an effective educational strategy in the period of transition from preschool to school.
- Educational process built predominantly upon the use of visual modelling and other sign forms proves to be effective for children in their school years. And introduction of various forms of symbolic mediation in the educational process would help children with difficulties in mastering sign tools to succeed in learning.

The implications of this study offer tools for future research. It could be valuable for preschool and school education to establish the influence of sign and symbolic forms of mediation on development of children's creativity and initiative, as well as on the voluntariness of their behaviour.

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Appendix: Assignments

Problem 1
Four graphs of linear function with different coefficients of proportionality were introduced, each of them representing the motion of a bus, a train, a car, and a motorcycle. Looking at the graphs, a child was supposed to define the motion of the vehicles represented. The children were expected to make their choice based on a graph, rather than on their common notions of the speed of objects.

Problem 2
Four graphs representing bus motion were introduced. Each graph represented a situation in which a bus was at first in motion, then was still, and after that rode again. The children were required to identify the graph that represented a bus that at first rode rapidly, then made a three-hour stop, and after that rode slowly.

Problem 3
The children were asked to draw a movement graph of a cyclist riding 20 km per hour and to tell how long it took this cyclist to go 35 km.

Problem 4
The children were given the following problem: 'A cyclist left from point A for point B going 10 km per hour. Four hours later a bus left point A for point B going 40 km per hour'. The children were asked to draw movement graphs of both vehicles and to calculate the distance from point A at which the bus would overtake the cyclist.

Problem 5
A caterpillar started crawling up a tree at the speed of 1 m per hour. It crawled for four hours, then stood still for an hour, and then resumed crawling at a speed of 2 m per hour. Two hours after the caterpillar started climbing the tree, a bug began to crawl up the same tree with a speed of 3 m per hour. The children were asked to draw movement graphs of both insects and to find out at what altitude they met.