Psychological and Pedagogical Approach to Designing Developmental Computer Programs for Senior Preschool Children

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This article decribes the specifics of using computers and computer programs in developmental work with children of preschool age. The concept of a computer game and the activity mediated by the computer is discussed. We present analysis of modern computer programs for preschool children, including shortcomings and risks of the usage of entertainment programs. Design stages of the computer program from the point of view of activity approach are introduced. Two types of developmental computer programs are appointed: closed and open type. Advantages of programs of open (creative) type are shown. The contents of a uniquely designed computer program of open (creative) type are described, with indication of the principles that methodology of the lessons is based upon. Finally, we present the results of a formative experiment, which showed that the developmental computer program and the suggested methodology of lessons promote development of certain components of systemic thinking, general integral indicator of systematic, as well as flexibility of thinking and imagination of senior preschool children.

1. Special features of using computer technologies in education

Nowadays modern preschool education faces the tasks related to active and effective use of new technologies in education and developmental work with children. Preschool education in this context demands a special approach to the contents, methods and forms of work with children. New computer technologies cannot be mechanically transferred to the educational environment of a kindergarten. Special research is necessary to provide scientific ground for introduction of the computer technologies into this primary and in many respects key stage of education.

Already at preschool age, modern children become a part of a new kind of activity – a computer game. The term “computer game“ is used for designation of children’s interactive computer programs. However, is it possible to call such kind of activity a “play“ in the true sense of the word? Play of preschool children is a creative activity; in this activity they create a special play situation, in which they replace some objects with others, and real actions with symbolic ones, reproduce the main meanings and relations between people. In the real play, the child assumes functions of the adult, thus reproducing in generalized and symbolic way the activity of an adult and subordinating his/ her actions to the rules of this role (Vygotsky 1966, Elkonin 1999, Obukhova 1998)

Therefore, in a role-playing game “playing computer“ a suitable replacement object, which is externally similar to the computer should be enough for the child. But, as practice shows, it is more interesting for modern children to interact with the computer, instead of playing it. At that, cognitive activity that the child will carry out at the computer and the impact of this activity on the child’s development depend on the tasks set for the child by the computer, or rather, by the program which was put in it by adults.

In this article we will consider interaction of the preschool child with the computer not as a play, but as an activity in which the computer and contents of computer programs offered by it act as one of didactic developmental educational tools.

The first acquaintance of the child with the computer often begins with computer interactive software bought by adults. At present, the market offers an abundance of computer programs for children from the age of 3. Among them, there are arcades, quests, strategies, simulators. Such programs should be classified as entertaining. Many of them are developed with purely commercial purposes and do not meet the psychological and pedagogical requirements. Moreover, they bear potential harm for the child: they do not set intellectual tasks, prematurely actualize competitive motives, advocate aggression and most importantly – form computer dependence.

It is better to engage a preschooler in computing by means of the programs, which haven’t been constructed on a suspenseful, venturesome, emotionally charged plot. Game programs with long suspenseful plots do not allow stopping computer game over a short period of time – 10-15 minutes, which are dictated by age norms and sanitary requirements. Compulsory attempts of adults to do it often

lead to negative affective reactions of children as they are interrupted in the most interesting moment, cannot finish a level, receive a bonus, etc.

Computer programs created by the principle of play-like developmental mini-tasks, each of which represents logically complete plot, are the most preferable for children of preschool age. Such programs make it possible to stop computing without stress, meet timing standards of this age (10-15 minutes), and let the child a chance to finish a task, to get and see the result of his/her activity and an assessment (or encouragement) from the computer program. We would call such programs the developmental computer programs (DCP).

Quality requirements for DCP in many respects are defined by characteristics and capabilities of age, therefore, it is important to note that we can acquaint the child with the computer not earlier than at 5 years of age. The reason for this is the complexity of actions and operations, which the child should carry out in activity mediated by the computer:

- First, in order to use the computer as a means of activity in full, the child needs an ability to use symbols (signs) and generalized images (and, therefore, a rather well developed thinking and creative imagination). Images on the screen are always images and symbols of real or play objects and in order to successfully operate them, a substitutionary (symbolical) function of thinking has to be developed.
- Second, work with the computer program can be considered as twice-mediated activity: the preschooler has to act with hands, pressing fingers on keyboard or mouse buttons and at the same time to observe the changes of objects and backgrounds represented on the screen.
- Third, the child needs to have developed a certain level of voluntary actions (attention, perception, memory), and volitional self-regulation (Novoselova/ Petku 1997, Gorovits et al. 1998).
- Finally, and that is the most important thing, if DCP is introduced to a child too early it can inhibit and reduce normal development of real play in which personality and mental development of preschool child is carried out.

The analysis of the results of theoretical and experimental research leads to conclusion that computer can become an effective means of personality and cognitive development of a child at the senior preschool age. The main factor here is a quality of computer programs and pedagogical conditions of their utilization. In this

regard, it is extremely important to reveal basic provisions of psychological and pedagogical approach to design of computer programs for children of preschool age and on this basis to develop adequate programs for preschool children. This article is devoted to the solution of these tasks.

2. Design stages of the developmental computer program for children of senior preschool age

A fundamental thing in designing any tools for the educational environment (including computer programs) is the *analysis of activity*, which defines the ways of utilizing these tools which, in turn, are aimed at receiving a certain developing result (Davydov et al. 1996, Rubtsov et al. 1991). According to this requirement, we can postulate the main design stages of developmental computer programs (CDP).

At the *first stage* it is necessary to carry out the analysis of the educational developmental situation and to define types of activity which influence the possibility of developmental effect. In relation to work with senior preschool children it is important to combine activity with objects, productive activity, and play activity (both individual and cooperative).

Let us look at types of activity and actions of children with DCP, which we had divided for the purposes of our discussion into programs of the closed and open type.

The main feature of computer tasks of the *closed type* is a complete external control on the side the computer program. In such tasks the instruction defines and directs specific actions of the child in accord with the computer program: to choose the correct answer to a question, to connect corresponding figures, to choose only demanded pictures, to point out a certain letter, etc. These are mainly the tasks aimed at training the skills and exercising some cognitive processes.

When performing such tasks the child becomes an executer, the “doer”. The computer sets a task, controls its execution and evaluates results. The child has no opportunity to show any initiative in such a work.

In tasks of the *open type* there is no external control from the computer, and the tasks the child solves and actions he/ she carries out can be diverse and varying.

Such tasks allow the child to show maximum of initiative and self-control of his own actions.

Computer tasks of the open type correspond more to requirements of the age and provide a bigger developmental potential.

At the *second design* stage it is necessary to carry out the analysis of the subject content which children face when performing activity. DCP has to be guided by the educational content for preschool children. Since the activity mediated by the computer has a sign and symbolical basis, we believe constructive-modeling activity with objects representing signs (models) of some things familiar to children can be an effective design option.

At the *third stage* it is necessary to create a system of tasks, actions and operations which implement the allocated type of activity. DCP designed as an open (creative) program gives children a possibility to carry out varying constructive modeling actions in all their completeness. It creates a basis for the substantive analysis and comparison of properties of objects with pronounced search activity, a basis for generalization of concepts and actions, helps children to solve problems through their own productive and creative activity, to include play elements in the activity mediated by the computer, to organize children in collaboration. The solution of such tasks creates a basis for formation of systematic thinking.

3. Characteristics of the experimental developmental computer program for senior preschool children

The purpose of our experimental study was the development of DCP accounting for the mentioned provisions, and further examination of its efficiency in development of cognitive abilities of preschoolers, namely systematic of thinking and its prerequisites as leading indicator of intellectual maturity of children of senior preschool age.

At the *first stage* of this study, we developed a DCP of open (creative) type based on requirements from a psychological and pedagogical point of view.

The developed program represents an open type environment, in which specific tasks are not given to the child, instead, the tools for performance of varying actions are provided. Various elements, objects, forms and figures act as these kinds of tools (squares, circles, triangles, leaves, petals, cones, cockleshells, etc.). These elements can be picked out and transferred into a working field of the screen

where there are opportunities to perform different actions with them by means of special functional keys (movement, turn, change of an arrangement, size and/ or color, deleting) (see Fig. 1). Thus, any activity of the child in this program has a constructive character. Performing any tasks on creating something whole from several elements, the child carries out constructive modeling actions with the elements presented in the program, thus analyzing, comparing and generalizing their properties.

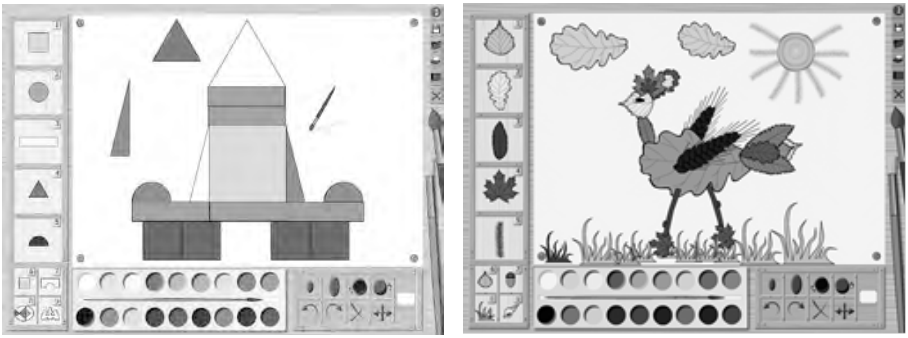

Fig. 1: Fragments of DCP design

This program allows operating in imaginative mode the visual objects and develops substitutionary function of thinking. All elements and objects to work with are presented on the screen (as drawings) and are symbols, signs of real objects. Each time creating a product, the child selects elements, which have the properties necessary to create what was intended, which promotes the development of generalizing function of thinking (for example, the sun is round, but the circle among elements isn't present, however there is a berry which is in shape similar to the sun, so the berry can be used to make the sun). Such activity has also a productive nature, meaning that it actively involves creative imagination.

The contents of this DCP take into account the contents of educational and developmental programs for children of senior preschool age. When working with the computer program children operate familiar objects (natural, construction materials, artistic and decorative elements, etc.), which they learn about at other lessons and use in other types of activity.

The program helps to enrich computer lessons with organizational forms of work with elements of joint activity of children with the teacher and joint-distributed activity between children. Also the program allows combining activity by means of which it mediates with children's own productive, object-related and play activity.

4. Research of influence of experimental DCP on cognitive development of preschool children

In total 87 children of senior preschool age took part in the study: 26 children participated in the pilot run, 61 children – in the main formative experiment. During the main experiment, we gave 24 developmental lessons with the computer. Lessons were given during 3 months, two times per week; they took place in a computer class of a preschool institution with the use of DCP we developed. Each lesson lasted not more than 30-35 minutes and included the following stages:

1 stage – preparatory (5-10 minutes). It took place in a play area of a computer class. Children were introduced to the content of the forthcoming activity by means of visual didactic materials; the motivation to work was formed.

2 stage – the main stage (15 minutes). It was carried out at the computers. At first children were given general explanations and short instruction, then, they took their places and got down to work. Observation over their work was carried out, if necessary additional explanations were given, the task was clarified. At the end of the lesson all children's creative works were saved in the computer, if necessary, they were also printed out.

3 stage – final stage (5-7 minutes). Children went back to the play area of a computer class, where they had discussion on the results of their work, comparison and discussion of all works and summing up the impressions from their activity. Using the results of their work, children were involved in a play, productive and object-related activities (drawing, construction, composing fairy tales, etc.).

At some lessons, children were paired up and worked over one project together at the same time (using different computer mice) or in turns (using one computer mouse). Occasionally we divided some tasks between the children, so that everyone carried out some part of the project at the computer to be further integrated into a final product.

It is very important that at the final stage of the lesson (control and evaluation stage) the works of children were looked at, compared, discussed, used to compose stories or create games to play together, etc. In this way the result of their work becomes a part of new kinds of activity – productive, practice-related: drawing, scissoring, gluing, using their computer projects as an example for further work, etc.

The main diagnostic method was the set of tests designed by N.I. Polivanova and I.V. Rivina (1996), which help measure the levels of formation of imaginative component of systemic thinking (”Turns of figures“), analytical components (”Choice by analogy“, ”Classification“, ”Add to a set“), and also an integrated indicator of development of systematic of thinking as a whole (”Row of rings“). As an additional measurement in the second diagnostic session, which followed the main formative experiment, we used V.V. Holmovskaya’s test, which measures the levels of development of child ability to freely mentally operate with objects and to see the object as a whole when it is deliberately divided into several parts. For diagnostics of the levels of creative thinking development (fluency, flexibility, originality) we used the „Circles“ test. Statistical significance of differences was evaluated with φ – Fisher LSD criterion and U Mann–Whitney criterion.

Results of the diagnostics, which has been carried out prior to the beginning of formative experiment showed no significant differences between experimental and control groups in all tests.

Comparative data analysis of control and experimental groups after formative experiment (see Table 1) testifies that children from experimental group surpass children from control group in terms of levels of development of imaginative thinking: they have better developed ability of mental operating the visual objects („Turns of figures“) ($p \leq 0{,}01$ U – Mann-Whitney). Children from experimental group also have significantly higher rates in level of development of ability to point out and correlate essential characteristics of objects, to establish the principle by which a system is structured and how its essential characteristics are interrelated („Add to a set“) ($p \leq 0{,}01$ U – Mann-Whitney). If we look at the levels of development of ability to abstract from insignificant characteristics in the process of classification („Classification“) we can see that in experimental group the number of children with the highest level (1 level) of this ability significantly prevails ($p \leq 0{,}05$ ϕ–Fisher) (see Table 1).

Above we compared the results obtained in each group, according to indicators of development of the main components of systemic thinking (imaginative and analytical). Diagnostic methods applied in this research also show the level of development of systematic of thinking, which manifests itself in the development of child analytical and constructive ability. We can detect it when the child demonstrates an ability not only to point out the principle of a system's structure, but also to create a new system on the basis of the revealed regularity („Row of rings"). Results show (see Table 1) that in larger number of children from experimental group we can observe that systematic of thinking is formed (1 level) (p≤0,05 ϕ–Fisher).

Table 1: Results of the experiment in control group (CG) and experimental group (EG) after formative experiment according to subtests of a system thinking diagnostic procedure

Methods		**CG**	**EG**	**Criterion value and significance of difference**
«Turns of figures»		69,5	84,2	U_{emp}=110,5 (U– Mann-Whitney), p≤0,01
«Choice by analogy»		69,9	72,4	–
«Add to a set»		59,1	74,7	U_{emp}=113 (U– Mann-Whitney), p≤0,01
Classification (%)	level 1	24	50	Φ_{emp}=1,75 (ϕ–Fisher), p≤0,05
	level 2	71	50	–
	level 3	5	0	–
Row of rings (%)	level 1	10	35	Φ_{emp}=1,99 (ϕ–Fisher), p≤0,05
	level 2	33	20	–
	level 3	57	45	–
V.V. Holmovskaya test		9,6	12,3	U_{emp}=95,5 (U– Mann-Whitney), p≤0,01

Note: Only values of criteria having significant difference are presented in the table.

The diagnostic set also included a method of diagnostics of creative thinking "Circles" which measures such characteristics of creative thinking as fluency, flexibility, originality.

The analysis of the results helped define that only the indicator of flexibility of thinking was significantly higher in children from experimental group ($p \leq 0,05$ U – Mann-Whitney) (see Table 2). Flexibility of thinking in this experiment characterizes ability to generate different creative images belonging to different classes of objects, overcome rigidity of thinking, ability to give varying answers.

Table 2: Comparison of results of "Circles" test in control (CG) and experimental (EG) groups after formative experiment (GPAs)

Indicators of the test	CG	EG	Criterion value and significance of difference
fluency	12,2	13,4	–
flexibility	20,4	26,1	U_{emp}=131,5 (U– Mann-Whitney), $p \leq 0,05$
originality	4	5,3	–

Note: Only the values of criteria having significant difference are presented in the table.

5. Discussion of results

The obtained data show that use of DCP we developed substantially promoted development of imaginative component of systemic thinking. It can be explained by the features of DCP, which is the program of the open type and presupposes that children implement productive activity with elements of designing, modeling, performance of mental transformations of objects, and also, in planning and predicting actions.

The contents of tasks solved by children, the nature of their actions with DCP (modeling, project creation using sample model, classification, connection to practice-related experience, creative projects, performance of creative tasks with rules) had an impact on development of separate analytical components of systemic thinking. It promotes the development of ability to carry out operations of analysis, synthesis, comparison, abstraction, which are the basis of implementation of generalized actions, and skills of finding essential characteristics of objects and characteristics of system structures.

The fact that the methods applied in computer lessons took into account the interrelation of computer activity with other key activities for development of preschool children also influenced the development of components of thinking.

Children's activity at computer lessons had essential impact on development of flexibility of creative thinking. We can see that an ability to generate different images, to give varying answers; to overcome stereotypes of thinking in task performance were much higher in children from the experimental group. Development of this quality was promoted by creative nature of activity of children with the DCP, which presupposes solution of varying productive tasks with the use of construction material.

Using computer as a means of activity creates a basis for development of the highest forms of thinking, which are determined by sign-symbolic essence of this activity. It appeared that DCP of the open (creative) type helps the child carry out productive activity, design, experiment with a set of objects. It also creates a basis for active analysis and comparison of their properties and thus can be taken as a more effective one.

When activity with DCP is included in joint activity with the adult and with other children, children's' own productive activity, and a play as well, it provides favorable pedagogical conditions corresponding to special aspects of age and creating a basis for effective development and formation of systematic of thinking as a whole.

Thus, results of our research confirm efficiency of DCP utilization in education of preschool children, as long as such program corresponds to special properties of preschool age.

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