Activity approach to learning and the problem of creating digital learning aids

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The article touches upon various aspects of using computers and digital technologies in the learning process from the perspective of the activity approach. The challenges of using computers as a means of activity modeling are discussed.

1. The role of machines in human activity

Computerization of learning is one of the forms in which human-machine systems are extensively entering all areas of life. According to theory, the main component of such systems is human activity, while the machine component serves as a means and as a tool for its effective realization. Human activity has many types and forms, all of them derived from work activity. Its evolution in history generated other forms of activity, such as play, learning, research, etc. All forms of activity, though different in specific content, have common structure, which includes the following main elements (see A.A. Leontiev):

1. needs and motives;
2. tasks;
3. actions;
4. operations.

Actions of a human correspond to goals of a certain activity, and operations included into those actions correspond to conditions of accomplishment of those goals. When a machine is involved in the action, the human executes goal-setting and delegates operational realization of the action to the machine. At that, the proportion of actions and operations complies with a certain principle: when an action loses its goal, it turns into an operation, and vice versa – when an operation gains a goal, it turns into an action. Such mutual transitions are embodied in the process of creating human-machine systems.

In human-machine systems, which correspond to a certain type of activity, the human follows specific needs and motives to set forth tasks, and executes the operational part of the action directed at solving that task with the help of the machine. In other words, when human-machine system functions, the goal of the activity is defined by the human, while reaching the goal, i.e. getting some real product, is carried out by the machine.

However any human-machine system is effective only with the concurrency of its components, when the machine is well “inscribed” into the wholeness of human activity where needs, motives, goals and actions ultimately define productive functioning of the whole system.

Conditions for achievement of the goal, to which the operational part of the human action and, consequently, the use of machine tools and means are inextricably connected, can vary greatly – for instance they can be related to properties of the end product, speed of its production, physical or psychical capabilities of the acting person, or alterability of the conditions themselves. Human-machine systems were created when the human for one reason or another was not able to perform the operational part of his actions, and the machine could do it for him. Traditional machines were performing operations predominantly related to relatively constant and stable conditions of achievement of the goal, such as physical capabilities of human, requirements for speed of the product production and product quality etc. However the machines, being oriented at such conditions, were not able to perform operations that suggest, for example, account for rapid change in conditions of execution of the human actions.

This situation changed drastically when development of informational technologies led to emergence of intellectual systems, which intruded into the way a human executes cognitive actions. Such actions usually demand that the human orients himself to a large quantity of rapidly changing non-recurrent conditions, many of which are connected to properties of human psyche and properties of functioning of its products. Intellectual systems (IS) can fixate a certain part of those conditions in their configuration, and in that way perform operations of corresponding cognitive actions of a human. Yet any IS remains a tool and a means for performing operational part of such actions, while the tasks are always set by the human.

2. Human-machine systems for learning activity

Learning activity, in accordance with its specific content, is composed of learning needs and motives, learning tasks, learning actions and learning operations. The content of this activity consists in mastering theoretically generalized knowledge and skills, which allow a person to successfully solve different practical problems. Needs and motives of learning activity are connected to the aspiration of a person to master such knowledge and skills before one actually encounters practical problems, so as to be prepared to resolve them correctly. The learning tasks possess a special quality – when solving these tasks a person discovers the process of the genesis of the content of theoretical knowledge and skills and masters generalized modes of action in specific practical situations (see V.V. Davydov 1986).

The composition of learning actions, which a person performs when solving a learning task, is quite complicated, so they need to be listed. They are:

- transforming conditions of the learning task with an objective to discover a common relation in the basis of system of theoretical knowledge being studied;
- modeling a relation that was found in graphic or sign medium;
- transforming the relation model with an objective to study its general properties;
- singling out and solving specific practical problems using a generalized mode;
- control over aforementioned actions;
- evaluation of mastering the generalized mode of solving this learning task.

When a person performs these learning actions, he\she masters a certain system of theoretical knowledge and a general mode of solving a certain class of practical problems.

Learning operations are related to conditions of execution of learning cognitive actions; they are quite diverse and changeable, because those conditions correspond to the content of the subject, which is studied (mathematics, physics, language, history, etc.). If we consider the interchangeability of learning actions and operations, defining the composition of operations affirmatively to any extent is very difficult.

Due to this circumstance creating human-machine systems in the area of learning activity posed great problems, even though technologies, both elementary and complex, have been used since long ago (for example, calculation devices in learning arithmetic, different audio-visual aids, etc.). In 1920s in USA attempts were made to create real learning machines which would make learning easier for people, and in 1940-1950s programmed learning emerged, which was implemented necessarily with the use of computers, i.e. modern human-machine learning systems.

The experience of programmed learning with the use of computers still has scientific and practical significance. However we need to keep in mind that it was created on the theoretical basis of behaviorism, which tends to regard the learning process in a limited way, does not uncover the true content and structure of learning activity and is unable to define the true place of computer components in this activity. Behaviorist theory of learning made an absolute of exercise in the integral process of mastering knowledge and skills. Exercise may be correlated to some extent with such learning actions as solving specific practical problems and result control; however its connection to other significant learning actions, such as modeling, is negligible.

Based on this theory and with the use of computer systems, exerciser-type learning machines were created, which executed the processes of training and testing of knowledge and skills in different subject areas. However there are grounds to assume that in this way not the operations of the student's learning actions were mechanized, but certain operations of teacher's work (which in itself is surely important). As a result, when introducing students to new areas of knowledge and organization of learning activity such systems do not overcome but aggravate the problems that are typical of traditional machine-free learning. The scheme of knowledge transfer process accepted in this educational technology creates great difficulty for students in mastering the bases of reflective theoretical knowledge, because in the framework of this scheme learning becomes some sort of "programming" of actions and operations of the students.

Use of computers in educational process is not only a prerequisite of improvement of learning, but also a potential source of negative consequences. In particular, using IS can be a reason for breakdown of integrated activity system "teacher –

class" into isolated elements "student – computer" controlled by a teacher. Therefore, when designing computerized educational technologies one faces a special challenge of finding ways to organize communication and cooperation between teacher and students and among students. Development of such ways should involve:

- creating conditions of cooperation between schoolchildren and teacher during their work when such work is mediated by a computer;
- organizing collective "projects" which demand for a group of students to interact with a computer and for groups of students to interact with other groups;
- defining an optimal balance of computerized and non-computerized forms of learning;

The following three main aspects allow an integrated cohesive organization of educational process in conditions of computerized learning:

- management of gnostic activity of individual students
- management of learning activity as a system "teacher – computer – student"
- management of interactions between teacher and students and students among themselves

Being guided by psychological regularities and principles of each of these types of management is a mandatory condition for development of human-machine systems in education.

3. New computerized educational technologies – basis for development of modern education: Integration of the learning subjects in conditions of using computerized learning aids

Analysis of worldwide trends shows that digitalization expectedly led to new demands towards the system of education and towards the very principles of how we organize transmission of cultural-historical experience to younger generation.

The new intellectual learning gnostic tool with unlimited application potential that emerged in our culture uncovered widespread inadequacy of existing traditional forms of education, its objectives, content and ways of organization. Accordingly a

more constructive and essentially humanistic approach to design and prognosis of applicability of computer technologies in education gradually emerged and now dominates; this approach consists in shifting focus from the machine itself onto the subject of learning activity ("teacher – student – students") as the key factor in designing educational technologies.

Dedicated attempts to understand and conceptualize the poly-functional application of computer technologies in learning, to define their true influence on children's learning and upbringing processes and processes of acquisition of knowledge and skills resulted in emergence of interdisciplinary research area on the junction of psychology, pedagogy and technics which deals with a wide range of issues in knowledge engineering, computer science, linguistics, sociology, artificial intelligence and most importantly developmental psychology. In this new socio-ocultural situation the task of reconstructing education and developing new educational technologies (using IS or not) can only be solved with participation of all the aforementioned research areas, most importantly the ones that are human-oriented.

The following are the main characteristics of a computer as an instrument of human activity and principally new learning aid:

1. Computer provides access to virtually unlimited volume of information and its analytical processing. Sharp quantitative increase of potentially available information and speed of its acquisition leads to qualitative leap – a phenomenon of "direct involvement" of a person in the society's informational culture.
2. Computer is a universal tool of human gnostic and research activity.
3. Computer provides new, active form of fixation of psychic activity products. All preceding means of objectivation of psychic activity only created prerequisites for transformations performed by human himself, for example, analysis of selected aspects of knowledge content, verification against preexisting data, adding new information to data, using information to organize practical actions, and so on. Computer allows for the first time to fully execute and partially automatize these transformations.
4. Computer is the second most important (after traditional writing) sign tool enabling efficient exchange of information on the content of activity. Thus we

see an emergence of an essentially new area of application for language and generally for sign-symbol means of activity.

5. Among tools and instruments of human activity a computer has a special communicative characteristic which makes it stand out, a capacity to "enter into a constructive substantial dialogue" with a user and constitute together with a user a unified functional subject-oriented medium. Special character of this activity approach to organizing "the world of objects" is that a computer not just merely enhances a person's intellectual capabilities, affecting his memory, emotions, motives and interests, but changes and reconstructs the very structure of human gnostic and then productive activity.

It is known that active independent construction or reconstruction of activity is available to a person when he is able to purposefully access the basis of his own actions, perform planning and reflection, transform and construct subject content with which he is working. A computer mediating the gnostic activity provides such a possibility, because any action and impact from the user can be indexed, represented as a scheme or a model, saved, returned and fixated for analysis, evaluation and control. Additionally, any action can be scaled down to an operation and contrariwise explicated or reconstructed according to intentions and possibilities of the user and conditions of dynamic time-space representation of objects. In that sense computer is such an effective and sophisticated tool of objectivation for all components of learning activity, that it's hard to find an analogue in educational practice. At the same time computer as bearer of sign-symbol universe of activity is naturally oriented at integral, a priori ideal mode of representation of objects, whose modeling is impossible outside of integral poly-semantic explication that adequately reflects the contents of reality.

Hence we can make at least two conclusions. The first one is related to possibility of an integral representation of the content of the object environment created with the help of a computer, which seamlessly combines specific structures of knowledge (sciences and humanities) that fully represent the content of relevant items of learning. The second conclusion is that by virtue of integral object environment the most effective conditions emerged for children to form generalized modes of action, which determine development of proper forms of reflective theoretical thinking.

This integration itself can be done in two interrelated directions. Firstly, by combining material from different subject areas, which allows to determine and define the generalized principles and regularities of its explication. Secondly, such integration can be done as per modes of action of a student with subject content. In this case a system of generalized strategies for solution searching, information structuring, problem setting, etc. is formed, and at the same time this contributed both for the cognitive development of students and for effective mastering of the learning material. It should be noted that both integration per content of items of learning and integration per modes of transformation of items of learning should be based on logical-psychological analysis of subject or operational structures of knowledge that essentially define the new content of education.

That being said, using computers in the system of activity, which only aims at production of "symbolic material" (i.e. purely quasi-object-related activity) creates the risk of knowledge being broken off from object-related practical basis from which it originated. The solution to this problem lies in the way we use the learning aids. This is an area of complimentary complex application of the whole spectrum of cultural means of organizing learning activity and representation of knowledge content. In this context one can mention complex use of different IT tools in creating poly-functional object environment – joining computer, video, television, film, and interaction of this poly-functional environment with object-related "computerized learning forms".

4. Functions of educational computer as a means of activity modeling

As modern teaching practice shows, using computers in educational process is intended for predominantly the flowing four types of tasks:

First, a computer is used as aid for a more effective solution of existing didactic tasks. The content of an item of learning in a computerized learning program of this type is reference data, instructions, calculation operations, demonstration, etc. An example of such use of computers is IS.

Second, a computer can be a tool of solving individual didactic tasks within the common structure, goals and tasks of machine less learning. In this case the learning content itself is not input into a computer (which performs functions of con-

trol, training, etc.). This function of a computer is widely represented by interactive systems which model the activity of a teacher.

Third, the use of a computer allows setting and solving new didactic tasks, which cannot be solved in traditional way. A good example are computer programs imitating experiments. In these programs the item of learning can be: a) external parameters of some process; b) regularities not accessible to observation in natural circumstances; c) connections of phenomena being imitated with parameters automatically set by the program; d) search for parameters which optimize the process being imitated, etc. Possibilities for conjugation of real and computer experiment in learning are also subject of research.

And finally, fourth, a computer may be used as a means of modeling of the content of learning items by constructing it. In this process we can see realization of principally new educational strategies. A good example of such developments in computerization of education are the so called computer-based learning media, which represent models of knowledge areas that are being learned (see S. Papert, USA). Functionally oriented learning environment creates prerequisites for creating objectives and plans of action, which opens a possibility for a student to be the subject of his own activity. At the same time problems and restrictions of this learning technology based on constructivism principle in psychology (according to the concept of intellectual development of J. Piaget) are determined by the spontaneity of students' activity which in turn is related to the activity being performed through a system of game-like actions of a user with the content of object environment. For that reason the problem of transforming play motivation of children's activity into a full-scale executed and internally motivated learning activity remains an urgent issue in development of such technologies.

We believe that the principle of computerized activity modeling where conditions for search, representation through models and analysis of essential characteristics of an item of learning are recreated should be the basis for designing new developmental computer technologies in education. Computer is a peculiar learning aid and as such it performs several fundamental functions, more precisely, serves as a means for:

a) modeling subject content of items of learning;
b) modeling corresponding generalized modes of action;

c) modeling interactions and joint activity organization (“student” – “group of students”, “student” – “student”, “student” – “teacher”);
d) performing control and evaluation of students' actions adequately to joint activity structure and content of items of learning.

In interaction of the aforementioned functions computerized learning systems constitute an object-focused and communication-focused reflexively administered learning environment, which is organized as an integrated activity system including control as a necessary condition of its full functioning.

Attempts of experimental implementation of the named functions of computers demonstrate a number of important psychological characteristics of computerized technologies application on different stages of learning. For instance, constructing models of content of the items of learning with the help of a computer allows students to set and solve new problems on their own, which in turn allows a teacher to manage their improvement and transitions from one form of learning activity organization to another, so that the students develop in the logic of learning material. Possibility for mediated evaluation of their actions allows students to develop the basis of reflexive theoretical attitude to reality, ability of self-organization, planning and correcting their own learning work. Finally, we need to note the efficiency of using computers in the control and evaluation activity of schoolchildren.

To specify the strategy of activity approach based development and the use of computerized and digital learning aids in education let us lay out some clauses:

1. Computerized learning systems must be created purposefully for inclusion into integrated learning activity while taking into account all its components (with a special emphasis on learning actions and operations). This will ensure that the activity will not be deformed or even destroyed by the use of computers in learning process (which is what goes on more often than not). Computers should be used not only to teach a person certain knowledge and skills, but also to organize and manage his learning activity.
2. Computerized learning systems should be designed on the basis of preparatory analysis of content of the corresponding knowledge and skills as learning items: different content should have accordingly different programs of com-

puterized learning. But one computer can service the demands of different learning subjects.

3. Each program is created for the purposes of mastering some content represented in the language of some specific actions and operations. This allows construction of learning activity in accordance with the principle of movement of the thought from mastering basic actions and operations to mastering their complex ensemble; the latter is a prerequisite of integration of study subjects.
4. Computerized learning systems must combine the qualities of dynamic and semiotic (sign) models; when mastering these models a person performs the corresponding learning actions and thus will master the content of a certain subject matter that these models uncover. When working with such systems a person does not adapt to them, but instead acts with them, performs transformations of some subject material and controls these transformations in relation to the tasks set forth.
5. Computerized systems per se are not the "teacher", they are not the "management apparatus" which regulates the learning process; they are organically included into the process of solving learning tasks by the student. Computers here serve as a means of organizing joint activity of the teacher and students among themselves, providing for the following forms of their interaction:

    - distribution of actions and operations in the process of solving learning tasks between participants as well as cooperation between them;
    - mutual control and evaluation of actions and operations of students in the process of solving learning tasks with a certain sequence
    - joint modeling of schemes of object transformation as per teachers specification
    - reflection and presentation by one student of mode of solving the task applied by another student

6. These forms of student interaction organization allow the teacher to use the computer to organize learning activity in the system of "a collective polyalogue", i.e. to design learning situations as a dynamically modeled communicatively organized environment that provides wide interaction and cooperation possibilities to participants of the activity.
7. Certain types of computerized learning systems should be used for purposes of diagnostics of the level of development of certain learning activity compo-

nents, as well as control and evaluation (including testing) of results of knowledge mastering and skills content.

8. Computerized systems should be based on the age aspects of human development: different age periods correspond to different modes of content representation in learning systems (from quasi-object-related play forms in primary school age to quasi-research and creative research forms in middle school and high school age, etc.).
9. Creation of computerized learning systems should be done through in-depth research of modes of their application in different learning situations; such research and development should be the basis of understanding the possibilities of each system and its application in teaching and learning.
10. Using computerized learning systems should foster development of reflexive theoretical thinking, which uses logical and mathematical means for programming and planning of one's own cognitive actions and analysis of their implementation.

Clauses and conditions set forth above are already being put into practice:

- in development of examples of computerized learning systems based on modeling the content of objects of Russian language, physics, English language, nature study;
- in development of computerized methods of organizing joint activity of teacher and students in the process of setting and solving learning tasks, including ones based on using computer networks;
- in development of computerized methods of diagnostics of learning actions development level in different age groups of schoolchildren, and also computerized methods of reflexive-theoretical thinking development diagnostics.

This being said, there is still the need to deepen the research in this direction and create supportive conditions for it. We need to construct, on the basis of activity approach in learning and the acquired experimental data, a theory of design and application of computers in the system of integrated learning activity, and then we need to fill educational institutions with exactly such computerized learning systems, using which, in our opinion, will create the required learning effect.

References

Davydov, V.V. (1986): Problemy razvivayushego obucheniya [Issues of developmental learning] Moscow.

Leont'ev, A.N. (1975): Deyatel'nost. Soznaniye. Lichnost' [Activity. Consciousness. Personality] Moscow.

Computer v uchebnom processe: psychologo-pedagogicheskiye problemy [Computer in learning process: psychological and pedagogical issues] (round table discussion materials) // Journal Voprosy psychologii, 1986, 5, 65-90.

Rubtsov, V.V. (2008): Social'no-geneticheskaya psychologiya razvivayushego obrazovaniya: deyatel'nostniy podchod [Social-genetic psychology of developmental education: activity approach] Moscow.

Tikhomirov, O.K. (1986): Informatika i noviye problemy psychologicheskoy nauki [Computer science and new issues of psychology]. In: Voprosy filosofii, 7, 39-52.

Children in an information age: Tomorrow's problems today. Varna, 1985, V. 1-2.

Larsen, S. (1986): Influence of the new technology on the school and on its general educational functions. Plowdiv.

Rubtsov, V.V. (1991): Learning in children: organization and development of cooperative actions. NY.

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