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Comparative Analysis of Mathematics Teaching Programs in Primary School from the Standpoint of the Cultural-Historical Activity Approach

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In the Russian Federation, 11 mathematics training programs were recommended for implementation in the 2020—2021 elementary school curriculum. The large number of programs raises the question of how they differ, a question which is relevant for both school administrators and primary school teachers, and parents. This article applies the criteria developed in the mainstream of the Cultural-Historical Activity approach to learning, to analyze the most significant differences in the mathematics programs from a psychological point of view. We have analyzed the methodological materials in mathematics and textbooks in the following programs for grades one through five: "School of Russia", "The system of D.B. Elkonin — V.V. Davydov" (the programs of both E.I. Alexandrova, and V.V. Davydov and V.F. Gorbov), "Learning to learn", and "Perspective". Our study showed that the most significant differences between the programs concerned the type of concepts proposed for assimilation; the type of actions by which these concepts were to be assimilated and practiced; and how the means of these actions were provided. The selected criteria corresponded most closely to the program of E.I. Alexandrova, which was created within the framework of the educational complex "The system of D.B. Elkonin — V.V. Davydov".

Keywords: teaching mathematics; activity approach; action; indicative basis of action.

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Сопоставительный анализ программ обучения математике в начальной школе с позиций культурно-исторического и деятельностного подходов

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В РФ на 2020—2021 годы рекомендовано к реализации в учебном процессе начальной школы 11 программ обучения математики. Такое количество программ вызывает вопрос об их действительных различиях, актуальный как для администрации школ и учителей начальных классов, так и для родителей. В данной статье на основе критериев, разработанных в русле культурно-исторического и деятельностного подходов к учению, анализируются наиболее существенные с психологической точки зрения различия программ по начальной математике. Нами были проанализированы методические материалы по математике для 1—4-х классов и учебники для 1-х классов по шести программам: «Школа России», «Система развивающего обучения Л.В. Занкова», «Система Д.Б. Эльконина—В.В. Давыдова» (две программы — Э.И. Александровой; В.В.Давыдова и В.Ф. Горбова), «Учусь учиться» и «Перспектива». Было показано, что наиболее существенные различия между анализируемыми программами касаются типа предлагаемых для усвоения понятий, типа действий, в которых данные понятия усваиваются и отрабатываются, и особенностей предоставления средств этих действий. В наибольшей степени выбранным критерием соответствует программа Э.И. Александровой, созданная в рамках УМК «Система Д.Б. Эльконина—В.В. Давыдова».

Ключевые слова: обучение математике, деятельностный подход, действие, понятие, ориентировочная основа действия.

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Introduction

In 1972, in his classic work [16], V.V. Davydov criticized the type of concepts underlying the prevailing primary school curriculum at the time. He also described the principles for teaching based on the ideas of the Cultural-Historical and Activity approach (hereinafter referred to as CHAT). With the enactment of the current Federal State Educational Standard of Primary Education [29], Russian primary schools have moved from the objective of instilling knowledge, skills, and abilities to the task of student development and the formation of universal learning actions [4]. Reliance on the Federal State Educational Standard is mandatory for every school curriculum; however, the content of the instruction, which was V.V. Davydov's main concern, — i.e., the structure of concepts and methods of actions — is not explicitly specified in the Standard. Therefore, it is relevant to analyze to what extent the principles of CHAT are actually implemented in modern programs.

Many studies have been conducted on elementary school mathematics curricula conducted in the CHAT paradigm [10; 26]; therefore, the analysis of mathematical programs is the most interesting to us. The practical significance of such an analysis is obvious: how can a school or parents choose between programs if they all declare they are implementing the principles laid down in the Federal State Educational Standard? In addition, such a study is important for the development of the instrumentation and control systems themselves, since the programs' general principles often act as normative principles, which are understood as the foundations for developing the program but not for ongoing evaluation [27; 30].

The literature on the methodology for teaching mathematics traditionally deals with one or another version of the comparison of programs [6; 28]. Most often, the main objectives of the programs and the sequence of introduction of concepts are analyzed. Thus, the work of A.V. Beloshistaya [6] discusses how the methods differ in purpose — the development of computing skills and their application to problem solving (textbook by M.M. Moro) versus the child's intellectual development (textbooks by L.V. Zankov, & N.B. Istomina). The programs differ according to their method of introducing concepts: in whether they go from a number to magnitude (M.M. Moreau); from magnitude to a number (D.B. Elkonin and V.V. Davydov); from set to relation, then to a number and magnitude (K.I. Neshkov and V.N. Rudnishkaya); or from magnitude and set to relation, and then to a number (L.G. Peterson).

Such an analysis is useful, but it is carried out from the standpoint of didactics, not the psychology of learning.

A variant of the analysis of textbooks and programs from the CHAT standpoint was presented in the work of V.V. Pavlova [22]. In her paper, the criteria for analysis were the preconditions for the formulating actions, as highlighted in the works of P.Ya. Galperin: whether the actions proposed by the teacher/textbook are adequate to the acquired knowledge; whether and how exactly the guidelines for such actions are given; how generalized and complete the proposed basis for orientation, etc. [*ibid.*, pp. 33—34]. Pavlova's analysis showed that the system of D.B. Elkonin — V.V. Davydov (hereinafter — ED) met these criteria to the greatest extent. However, this work by V.V. Pavlova was published in 2008, before the adoption of the new Federal State Educational Standards, and it analyzed a limited set of programs., and many of the textbooks she analyzed are no longer included in the Federal List. In addition, her work only presented the ED system as expressed in the program of

E.I. Alexandrova; the program of V.V. Davydov and V.F. Gorbov was not considered. Thus, we believe it is relevant to conduct such an analysis for mathematics textbooks included in the Federal List right now. In the comparison, we will rely on what we consider the most essential principles for understanding the learning process, which have been developed in several studies that rely on the CHAT paradigm.

Principle 1. The content of instruction, focusing on the essential relationships among objects. According to L.S. Vygotsky [8, p. 345], primary school teaching should be fundamentally different from teaching a preschooler precisely because of its content. V.V. Davydov showed that in most modern mathematics educational programs, there is a complete "continuity" with the child's preschool experience, and concepts are proposed for assimilation that are not based on the relations essential for this subject area [16, p. 40]. Thus, the understanding of a number as a result of counting individual objects, which develops in preschool practice, is far from the scientific understanding of a number, that is, understanding it as a result of measuring a quantity by an adequate measure. If we rely on the continuity with preschool experience, we thereby introduce children only to a special case of a number, which naturally leads to errors. Reasonableness in the orientation to the essential relations among objects described by mathematical concepts was also emphasized by P.Ya. Galperin [10; 12; 13].

Principle 2. Assimilation of concepts through adequate actions. The second important aspect is the actions by which concepts should be acquired and assimilated by the students. L.S. Vygotsky directly pointed out that scientific concepts are not the result of generalizing about objects according to their observable everyday signs; they are set "from above" [7]. Another important difference in the actions for the assimilation of scientific concepts was explained in the works of A.N. Leontiev and his colleagues [11; 18; 19]: the concept of being set "from above" will be assimilated qualitatively only if the child understands that it is necessary to use it in a certain way, that is, if it becomes the subject of activity [18].

In fact, the actions organized for the introduction of concepts should convey to the child the need for a new concept: that is, allow him to see the task which led it to arise. According to V.V. Davydov, the actions used for the introduction of concepts should be practical tasks, but performed for educational purposes (in order to discover a common way of action) [10; 11; 16]. The actions organized for the elaboration of concepts should be based on the general method not so much for the purpose of its "application," as for the purpose of its concretization, or definition of boundaries [9]. At the same time, such actions should "work" for the formation of a) consciousness (the ability to explain what and why I am doing), for which naming (the speech form of action) and modeling are important; b) generality (for which variations of task types are important); and c) execution in mind, involving gradual reduction and integration into other forms of activity.

Let's analyze to what extent these conditions are supported in the cited mathematical programs.

"School of Russia" (M.I. Moro et al.). The basis of this course's curriculum, which is the most classical one, is the fullest use of the specifics of the subject area for the intellectual development of the student [5]. The authors note the full compliance of the updated program after the introduction of the new Federal Standard with the provisions of the CHAT [ibid., p. 21].

The curriculum indicates that the key content in the first grade textbook is arithmetic material, which involves first studying the numbering of numbers, then arithmetic operations [p. 6]. However, the concept of number is presented as the number of individual objects; numbers (and enumeration) are studied sequentially. Interestingly, the number 10 is studied in the same way as single-digit numbers; the children are simply shown that it is written "like this" [20, p. 60]. In the pre-number period, students learn to identify the relationships "more or less," "as much," and "how much more or less" between individual specific objects.

Comparisons of other characteristics (shape, color, etc.) are presented here as separate tasks in the process of studying numbers (length [20, p. 17, 19, 25, 35], mass [21, p. 36], and volume (capacity) [21, p. 38]). At the same time, comparisons, as well as measurements with the help of measuring units (for example, measurements that are already "embedded" in the length of the segment), are proposed to be done "by eye". Thus, the number is first "tied" to the measurement of the number of specific items, and then the idea of the number is extended to other quantities. From a psychological point of view, this means that from the very beginning, the students do not form a concept that allows them to intelligently solve all problems that require using numbers.

As for the actions used to introduce concepts, the authors note that each lesson should begin with setting a goal (which concepts or actions children need to master), and then "in the form of specially selected tasks, whose performance leads the students to independently obtain new results" [20, p. 22]. In fact, all actions by which concepts are to be assimilated are presented as something "given," which you only need to learn about, or which you need to "master."

Training actions are organized through solving tasks "for the primary consolidation of new material," involving "first speaking out loud and at the same time writing mathematically, and then speaking to oneself, materials for repetition and consolidation and self-control and self-assessment" [20, p. 22]. Interestingly, there are "elements" of CHAT in the form of models (work is undertaken on the relationship between the text and the task-drawing-diagram) and speaking out loud.

In general, we can conclude that in the program of M.I. Moro, there are attempts to implement CHAT principles, but they are in no way related to changing the content of training, so that it really allows you to act rationally.

"Perspektiva" (G.V. Dorofeev et al.). In this program, as the authors note, a set-theoretical approach to the introduction of basic concepts ("number," "magnitude," "figure") is applied consistently [17]. So, at the beginning of the first grade, the concepts of "set" and "element of a set" are introduced; the relationship of equality between sets is established; and tasks for comparing the numbers of sets are considered. The authors write that this "naturally allows children to understand the concept of a natural number, to understand the order of numbers in a natural series, to understand the meaning of the actions of addition and subtraction" [17, p. 3]. However, sets are given only as sets of separate objects, and all the comparisons are made between separate objects. Other values (length, mass, volume) are presented under separate topics during the first year.

The introduction of concepts takes place through the students performing actions that they are familiar with (for example, you need to divide objects into a group of vegetables and a group of mushrooms). After that, the teacher asks exactly how the children acted and either identifies a new term ("these groups are called sets in mathematics") or discusses the method (you need to put sticks here and here). In either case, these actions are not adequate to the content of the concepts being assimilated. Interestingly, when this program introduces new ways of addition/subtraction, modeling is used by presenting a "numerical segment" — an analogue of a numerical straight line: "By 'walking' along a numerical segment and moving chips according to a given route, the child understands which method of calculation is more convenient (adding 1 five times, or adding 3, and then 2) [*ibid*., p. 3]."

As for training actions, the authors of this textbook strive to develop consciousness and transfer it to the children's inner plane through the so-called "three-stage methodology for the formation of computational skills:" a) calculations using subject sets and a numerical segment (perception level); b) abstract calculations (representation level); and c) formulation of the calculation rule (explanation level). At the same time, it turns out that the rules and explanations are given after the actions are performed, which raises the question of on what basis the previous action was carried out.

In general, we can say that this program, although it has specifics and uses some important CHAT principles, does not fundamentally differ from the program of M.I. Moro.

The "Elkonin-Davydov system" (E.I. Alexandrova version). This program is based on Davydov's ideas for a radical change in the content of teaching mathematics in elementary school, *i.e*., basing it on the concept of a rational number [16, p. 311]. The concept of number is introduced here through the concept of magnitude and its measurement — the "postponement" of the unit of measurement (measure) on the measured value and the account of such postponements [1]. The number in this case is a characteristic of the quantity. By changing the conditions for solving measurement problems and their inverse (reproducing the magnitude through postponing measurements), students "grow" various types of numbers and ways to designate them. The program fully complies with the first criterion we have chosen: the proposed concept of a number allows us to act rationally when solving problems.

The activity aspect of the program is represented by a set of educational and practical tasks [1; 2]. The basic task of the first grade is the task of restoring/selecting an object with specified properties (for example, a thread is presented; it is necessary to choose the same length to build a basket for a balloon). In this case, the student doesn't just have to compare objects and highlight their common features but choose an object suitable for solving a practical problem. In the process of solving it, he identifies the attribute according to which his selection is made; that is, knowledge of the attribute here is a means of solving a problem, not a goal in itself. Later, the selection task is supplemented with a replication of the comparison results (modeling). The need for this replication is justified as a recording "for another person," so that the desired value can be reproduced in another place and at another time. This again makes the task meaningful, and not just a task of guessing the correct answer. Indirect comparison of quantities is organized when direct comparison by property is impossible and it is necessary to use an intermediary — a measure equal to one of the compared quantities, and then a number. From the question, what are the measurements, the following question arises: what are numbers and how (what?) are they being recorded (now and before)? A number line and a method of adding and subtracting numbers using a number line are constructed.

In the training tasks, the general method is specified. For example, a situation is introduced where the value is much larger than the measuring unit and you must use a group of measurements (and the measurement result will be expressed as a set of numbers). The relationship between the measurements for their use in another place and at another time leads to an understanding of the need to record digits and the introduction of a multi-digit number. Thus, the concept of number is not just "worked out, " but unfolds into an integral system of individual educational tasks, working on the formation of consciousness and the generalization of the method discovered. The transition to mental form is provided by materialization in the form of modeling and speech form (as in the ability to read this record and those of others).

Thus, in the program of E.I. Alexandrova, a concept of a number is presented which allows you to act with it rationally. It should also be noted that in this program, there are practically no actions that are not built into the logic of the program.

"Elkonin-Davydov' system" (V.V. Davydov, S.F. Gorbov, et al.). The program of V.V. Davydov, et al. in its foundations is based on the same principles as the program of E.I. Alexandrova. It is based on the concept of a real number as a special relationship of one quantity to another (measure) [15]. An important place in the study of the concept of magnitude is occupied by the numerical time frame. However, unlike in the program of E.I. Alexandrova, where this period lasts 120 hours, in that of V.V. Davydov et al. it takes only 30 hours before a number is introduced. It is notable that the central point of the first few sections of the program is not in itself the ability to describe a subject by signs, but the task of applying signs to find (select) a subject suitable for some purposes [14].

Despite its similarity to the main idea of the prenumber period, the implementation of Davydov's program differs from that in the textbook of E.I. Alexandrova. This is due not only to a reduction in time, but also to the actions that students are invited to perform. So, a typical action performed for the introduction of a new feature in Davydov's textbook is a lesson requiring the students to guess the nature of a figure drawn by the teacher (see [14]), for which it is necessary to ask "smart questions" (those by which you can immediately find out what kind of figure was made). The tasks found in the textbook differ in that they are not always related to practical tasks, but are mainly tasks for working with signs (often in mental form immediately), such as to specify the same figures, on which signs are the same, compare in length / height, etc.

The initial forms of actions are radically different in the two curricula. In her textbook, E.I. Alexandrova always calls for a practical action first (for example, for tasks involving selection of a column for a building, the children should cut out variants of columns and apply them to the building, check whether they fit or not); but the Davydov-Gorbov's program calls for them to determine the solution in their mind. Similarly, modeling (by segments) is introduced simply as a way to record the results of comparison [14]. In her textbook, E.I. Alexandrova suggests figuring out how to denote equality if a child or someone else does not yet know how to write these words, before having them consider the equal sign and guessing how the one who invented such an icon reasoned and why it is exactly like that [2].

After introducing the concept of a number, it also unfolds into an integrated system of tasks, which solution is based on using the number line. The difference is that the topic "Addition and subtraction of quantities" and the topic "Whole and parts" are considered here *after* the introduction of the concept of numbers, and primarily on the material of numbers and the number line, rather than on the quantities themselves. At some point the numbers on the number line begin to be indicated by letters.

In general, the program of V.V. Davydov and V.F. Gorbov, et al. gives a full-fledged scientific concept of a number that allows you to act intelligently with it. Adequate work with the signs of objects and the allocation of quantities unfolds from a conceptual point of view, although the actions by which these signs are allocated raise questions. The introduction of concepts often occurs in logical actions, which makes naming and differentiating features from each other and from subjects the main goal of children's educational work. This raises the question of the children's motivation and assumes separate and special work by the teacher to create specific motivation.

"Learning to learn program" (L.G. Peterson). L.G. Peterson notes that her course was created in full compliance with the requirements of the system-activity approach [24, p. 4]. She relies on the ideas of N.Ya. Vilenkin about the continuous development of the main lines of the school mathematics course (numerical, algebraic, etc.). She emphasizes that each of these lines is developed on the basis of those real conditions that led to their emergence in culture [*ibid.*, p. 11]. Thus, if we talk about the number line, then it is built on the basis of both counting objects (elements of the set) and measuring quantities; it is believed that these two lines "bring students from different sides to the concept of number" (p. 12).

The first-grade textbook begins with tasks for comparing sets of objects that have a common property (such as shape, color); equal and non-equal signs are introduced, and comparisons are made by making pairs, joining into one whole (addition), and removing part of the set (subtraction). However, most often such aggregates are aggregates of individual items. Already in the ninth lesson, letter designations for aggregates are introduced. When introducing addition and subtraction operations, it is not emphasized that, in principle, it is possible to add/subtract not only those quantities that are separate. Therefore, this kind of introduction can give the child the erroneous idea that everything can be added/subtracted with everything. Although the author notes that the number is also introduced as a result of measuring quantities, the task of comparing and measuring quantities is not presented until lesson 76, after the introduction of numbers in lessons one to nine, the numerical line and operations on it. So, the children will be able to form only a specific idea of the number, which does not allow them to act rationally.

Actions for the introduction of concepts are organized through a system of "activity-based teaching," the essence of which is that students do not receive knowledge in a prepared form, but extract it themselves in the process of their own educational activities [24, p. 5—7]. In this program, the actions by which concepts are introduced most often coincide with the actions for their application [22, p. 58]. Guidelines for such actions are found through the implementation of "old" actions by students using new material. The guidelines for the new methods are either not set at all, or are presented in the form of step-by-step support for the execution of actions, or they are given priory-made, but with the preliminary organization of their independent search when trying to perform an action [22, p. 59]. Usually, the search actions are to be performed by the students in their minds.

As for the training actions, there is little support for the actions of transferring to the mental plane. Working out a problem begins with speech, not with material, materialized forms of performing an action, which are used only to depict the result. There are no logical variations of the material in the tasks proposed for practicing the action. Situations for assimilating the orientation for various conditions of action are replaced by the performance of a huge number of tasks for which these guidelines are not needed [22, p. 63]. This reduces the likelihood of a full-fledged transition of the action into a mental level.

Thus, despite the declared reliance on the CHAT principles, L.G. Peterson's real program uses only its elements. This may be due to a different understanding of the essence of CHAT.

The program "System of developing instruction of L.V. Zankov" (I.I. Arginskaya et al.) is also of interest. We will not dwell on it in detail, since this analysis has been carried out by V.V. Pavlova [22]. We will only note that despite statements about the importance of organizing children's activities and the presence of two approaches to the introduction of the concept of number at the same time (set-theoretic and through the measurement of quantities) [3; 25], the concept of a number proposed in the first grade does not call for reasonable action to solve problems. The actions by which the concepts are introduced are not psychologically adequate to their content and basically represent actions for which students do not have ready-made ways to perform them, and thus need to be "discovered" [22].

Conclusion

Our analysis of the programs shows that in each of them, there are indeed attempts to rely on the basic CHAT principles in the different ways the authors understand their content. The most frequently used provisions of CHAT are organizing the actions of the children themselves, setting educational tasks, presenting guideposts in a material/materialized form (including in the form of models), supporting the speech form of actions, etc. However, at the same time, it seems that the authors of the programs do not always understand what issues these provisions of CHAT were introduced to resolve: namely, that the content of instruction and the sequence of studying topics should ensure the rationality of action; eliminate formalism from mathematical concepts; that materialization and modeling are necessary to fix generalized methods for the purpose of further work with these models as means of solving problems, that the speech form is mandatory for the formation of consciousness of action, etc. The most consistently specified principles are implemented in only one program, that of E.I. Alexandrova ("Elkonin-Davydov System"). This means that the task of devising a more reflexive and less formal use of CHAT to create educational programs is still relevant.

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