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DIDACTIC POSSIBILITIES OF USING THE 5E MODEL IN DEVELOPING LOGICAL THINKING IN STUDENTS

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ABCTRACT

This article examines the role of the 5E instructional model in developing students' logical thinking skills. The impact of each stage of the model on cognitive processes—such as analysis, synthesis, comparison, and reasoning—is explained. Practical mechanisms for applying the model in classroom settings are also discussed. Research findings indicate that the 5E model effectively enhances students' logical operations and supports deeper cognitive engagement.

Keywords: 5E model, logical thinking, educational technologies, inquiry-based learning, problem-based learning, logical operations.

In the context of modern education, one of the most important tasks is to teach students to think independently, creatively and logically. Especially in mathematics, natural sciences and technology, the gradual development of student thinking is a key indicator of the quality of education. In recent years, the 5E model, based on a constructive approach, has become significant in that it allows students to become the center of the active learning process. This model serves not only to impart knowledge, but also to form logical processes such as searching for knowledge, analyzing it, and drawing conclusions.

Theoretical foundations of the 5E model The 5E model is based on the principles of constructive pedagogy and ensures that the student learns the knowledge he or she has sought. The five stages of the model reflect the natural sequence of learning activities:

1. Engage – arouse interest in the student, activate existing knowledge.

2. Explore – attempt to understand the problem through independent research.

3. Explain – logically formulate the ideas found and enrich them with theoretical knowledge.

4. Elaborate – apply new knowledge in different situations.

5. Evaluate – analyze the acquired knowledge and logical processes. These stages work in harmony with the main components of logical thinking — comparison, analysis, generalization, cause-and-effect determination[7].

The role of the 5E model in the formation of logical thinking

• Engage stage: activating thinking through a problem situation At the beginning of the lesson, the student is presented with a real-life example, an unusual question, or a short experience. This process helps to focus the student's attention and raise logical questions. For example, a question like "If two sides of a triangle are known, can the third side be found?" encourages the reader to think.

Sensation and perception provide us with knowledge of the individual—of individual objects and phenomena in the real world. However, such information cannot be considered sufficient. In order to live and work normally, a person must anticipate the consequences of certain phenomena, events, or their own actions. Knowledge of the individual is not a sufficient basis for foresight. The multi-stage transition—from the individual to the general and from the general back to the individual—is accomplished through a special mental process: thinking. The essence of this process lies in the generation of new knowledge based on a person's creative reflection and transformation of reality.

Human thinking is the subject of study by various sciences. It is studied by dialectical logic, psychology, formal logic, the physiology of higher nervous activity,

and cybernetics. Each of these sciences examines specific aspects and properties of thinking, using different methods. Dialectical logic studies the patterns of formation and development of our cognition, which is realized through thinking. Dialectical logic studies the methods of formation and the patterns of development of concepts. Dialectical logic reveals the general patterns of development of our cognition, which are used to align theory with practice[8].

• Explore stage: finding cause and effect through independent research Students conduct experiments, observations, and practical exercises in small groups or pairs. The process of independent research is the first stage of coming to a logical conclusion. Here, the student: hypothesizes, tests, compares, and looks for ways to solve the problem.

• Explain stage: expressing logical thought Students explain their discoveries in words or through mathematical expressions. The teacher corrects this process in scientific language. This stage develops the skills of justifying logical thought, reasoning, and analyzing

• Elaborate stage: improving and expanding New knowledge is applied in various practical situations. Solving more complex problems further strengthens logical operations. For example: the student analyzes real-life shapes based on a geometric rule.

• Evaluate stage: evaluating the thinking process This stage serves to evaluate not only the final knowledge, but also the logical thinking process. The student: analyzes his/her own mistakes, justifies his/her reasoning, explains the reasons for choosing a solution, and self-evaluates. This approach develops the ability to independently control logical thinking[9].

Let’s consider the essence of the concept of thinking.

S. L. Rubinstein, examining the nature of thinking, says: "Thinking is the movement of thought, revealing the connection that leads from the particular to the general and from the general to the particular. Thinking is a mediated—based on the

revelation of connections, relationships, and mediations—and generalized cognition of objective reality"[1].

A. N. Leontiev defines thinking as "the process of cognitive reflection of reality in its objective properties, connections, and relationships that include objects inaccessible to direct sensory perception."

According to A. V. Petrovsky, thinking is "a socially conditioned mental process of searching for and discovering something essentially new, inextricably linked with speech, a process of mediated and generalized reflection of reality through its analysis and synthesis."

Thinking, as a cognitive, theoretical activity, is closely linked to action. A person cognizes reality by influencing it, and understands the world by changing it.

Logic often employs the method of formalization, i.e., the method of identifying the structure of our thoughts, and from this identification of the structure of thoughts, rules and laws are formed. The fact is that the process of formalization is applicable only to ready-made, formed thoughts and logical techniques applied to them[2]. Logical techniques of action can be logical operations or actions establishing relationships between thoughts. Thus, a logical operation is a logical action of forming new objects from existing objects. Establishing relationships between thoughts is a logical action through which we obtain a thought that characterizes it in terms of truth or falsehood.

The process of thinking in which conclusions are strictly based on correct judgments is called logical thinking, and the science of the laws of correct thinking is called logic.

The hallmarks of logical thinking are the logicality of conclusions and their rigorous argumentation (from the Latin argumentatio)—a set of arguments (logical reasons that serve as the basis for proof in favor of something). With logical thinking, the phenomena under consideration receive a convincing explanation, and cause and effect are unmistakably established. Through logical thinking, connections and relationships between concepts are revealed. These connections and relationships are

expressed in judgments whose validity cannot be refuted[5].A striking example of rigorous logical thinking can be found in the proofs of theorems in geometry and other mathematical deductions, where everything that follows is based on previous propositions, one inevitably following from the other.

Thinking is a socially conditioned mental process, inextricably linked with speech, of searching for and discovering something essentially new, a process of mediated and generalized reflection of reality through its analysis and synthesis. Thinking arises from practical activity, from sensory cognition, and extends far beyond it[6].

Logical thinking, as a distinct mental process, has a number of specific characteristics and attributes. The first such attribute is a generalized reflection of reality, since thinking is a reflection of the general in objects and phenomena of the real world and the application of generalizations to individual objects and phenomena.

The process of logical thinking begins to manifest itself most clearly only when a problematic situation arises that needs to be solved. Thinking always begins with a question, the answer to which is the goal of logical thinking. Moreover, the answer to this question is not found immediately, but through specific mental operations that modify and transform existing information. Thinking is the search for and discovery of something new. According to A.V. Brushlinsky, in cases where old, familiar modes of action, prior knowledge, and skills can be used, problems do not arise, and therefore thinking is simply not required. At the same time, notes L.D. Stolyarenko, automated action patterns can be considered thinking skills. The role of thinking skills is particularly significant in areas where a highly generalized system of knowledge exists, for example, in solving mathematical problems[4].

Human thinking is realized at various levels and in various forms, which together allows us to speak of the existence of different types of thinking. Several approaches to the classification of types of thinking have developed in psychology.

The most common classification of types of thinking in psychology is based on the content of the problem being solved. It distinguishes between objective-active, visual-figurative, and verbal-logical thinking. The characteristics of objective-active

thinking are manifested in the fact that problems are solved through the actual physical transformation of the situation, participation, and internal mental processes. In adults, objective-active thinking always "works" in combination with other types.

Visual-figurative thinking includes attempts aimed at finding a solution to the problem, but these attempts are performed mentally, using images. It is the images that serve as the means for solving the problem, while internal attempts serve as the methods.

Verbal-logical thinking is thinking through reasoning. Reasoning is a conclusion that allows one to connect different pieces of knowledge to obtain an answer to a question or solve a mental problem. Clear reasoning typically occurs when solving mathematical or physical problems.

Thinking develops through two stages: pre-conceptual and conceptual. Pre-conceptual thinking is the initial stage of a child's thinking development, when their thinking is organized differently than that of adults; children's judgments are isolated, about a given, specific object[14]. When explaining something, they reduce everything to the particular, the familiar. The central characteristic of pre-conceptual thinking is egocentrism (not to be confused with selfishness). As a result of egocentrism, a child under five is unable to see themselves from the outside and cannot correctly understand situations that require some detachment from their own point of view and acceptance of another's perspective (M.I. Dzhumaev). Egocentrism determines the following characteristics of children's logic:

1) insensitivity to contradictions;

2) syncretism (the tendency to connect everything with everything);

3) transduction (the transition from the particular to the particular, bypassing the general);

4) lack of understanding of the conservation of quantity.

A logical form, or form of thinking, is a way of connecting the parts of thought content, its continuity, thanks to which the content exists and reflects reality. Three basic forms of thinking are distinguished: concept, judgment, and inference.

A concept is a form of thinking that reflects the essential properties, connections, and relationships of objects and phenomena. A concept contains properties that are common and essential to a wide range of similar objects[11].

A concept exists as the meaning of a word, designated by a word. Every word generalizes (except for words denoting proper names). In concepts, our knowledge of objects and phenomena of reality is crystallized in a generalized and abstract form. In this respect, a concept differs significantly from perception and memory representation; a concept has a generalized, abstract, and non-visual character.

A representation is an image of a specific object. A concept is an abstract thought about a class of objects. A concept is a more developed and comprehensive form of cognition; it reflects reality much more broadly and fully than a representation.

Judgements reflect the connections and relationships between objects and phenomena of the surrounding world and their properties and attributes. A judgment is a form of thinking that contains the affirmation or denial of a proposition regarding objects, phenomena, or their properties. Judgments can be general, partial, or singular.

Logic studies various types of judgments from the perspective of their structure. Psychology primarily studies the content, or form of thought, of judgment.

Inference is a form of thinking in which a person, by comparing and analyzing various judgments, derives a new judgment from them. Humans primarily use two types of inference: inductive and deductive. Inductive inference (induction) is a method of reasoning from particular judgments to a general judgment, establishing general laws and rules based on the study of individual facts and phenomena. Deductive inference (deduction) is a method of reasoning from a general judgment to a particular judgment, understanding individual facts and phenomena based on knowledge of general laws and rules[4].

Both types of reasoning (inductive and deductive) help people expand their knowledge of the world around them. In the real process of thinking, the content and forms of thought exist in an inseparable unity. There is no pure, formless content, nor are there pure, contentless forms. However, for the purposes of a specific analysis, we

may abstract from the specific content of thought, focusing on its form. The study of logical forms, regardless of their specific content, constitutes the most important task of the science of logic.

A law of thought is an internal, necessary, and essential connection between thoughts in the process of reasoning. A distinction should be made between formal logical and dialectical laws of thought.

Violating the requirements of these laws makes thinking confused, incoherent, and contradictory, leading to logical errors.

However, thinking is not only subject to formal logical laws. It is also subject to the laws of dialectics (the unity and struggle of opposites, the transformation of quantitative changes into qualitative ones). As laws of thought, they represent a reflection of the dialectic of the objective world.

While cognizing the complex dialectical processes of the objective world, thinking is also subject to formal logical laws, without which it is impossible to reflect the dialectic of things.

Thus, the laws and forms of thought represent a reflection in human consciousness of the properties, connections, and relationships of objects of objective reality. The recurring connections and relationships of objects and phenomena of the external world are constantly reflected in human thought and become entrenched in it in the form of logical figures: the laws and forms of thought.

P. Ya. Galperin introduced new ideas to this field of research. He developed a theory of thinking formation, known as the concept of the planned formation of mental actions. Galperin identified the stages of internalization of external actions and defined the conditions that ensure their most complete and effective translation into internal actions with predetermined properties. A special place in research devoted to the development of thinking belongs to the study of the process of concept formation. This represents a high level of development of verbal thinking. P. Ya. Galperin’s theory was based on the concept of a genetic relationship between internal intellectual operations and external practical actions. He believed that the development of a child’s thinking

in the early stages of development is directly linked to object-oriented activity, manipulation of objects, etc. However, the translation of external actions into internal ones, transforming them into specific mental operations, does not occur immediately, but rather in stages. At each stage, the transformation of a given action occurs only along a number of parameters[13]. According to P. Ya. Galperin, higher intellectual actions and operations cannot develop without relying on previous methods of performing the same action, which in turn rely on previous methods of performing the same action. Ultimately, all actions are fundamentally based on visual-effective methods.

According to P. Ya. Galperin, there are four parameters by which an action is transformed. These include: level of execution; degree of generalization; completeness of the operations actually performed; and degree of mastery. The first parameter of an action can be found at three sublevels: actions with material objects; actions in the plane of external speech; and actions in the mind. The three remaining parameters characterize the quality of the action formed at a particular sublevel: generalization, abbreviation, and mastery.

The action being developed and mastered by the learner does not acquire mental form immediately, but gradually, passing through several stages, or phases, each of which is qualitatively different from the preceding ones. Mastering an activity, and consequently, acquiring the knowledge that underpins it, can only be successful if the learner sequentially goes through all stages. This was first discovered by P. Ya. Galperin and was reflected in his theory of the stage-by-stage development of mental actions:

1)The first stage is called the introductory-motivational stage. At this stage, the action is not yet performed; it is only being prepared. The learner becomes familiar with the action and the conditions for its implementation. They comprehend the purpose of the action, its object, the system of reference points, and the knowledge that must be relied upon when performing the action. At this stage, a diagram of the orienting basis for the action is developed. The teacher reveals the content of the

orienting basis for the action by analyzing the conditions for its implementation, and the learner, using previously formed actions, develops the orienting basis for the new action. First, a general orientation is provided, followed by an orientation toward execution[12].

The learner develops an action plan (problem solving), determines the order of its implementation, composition, and sequence of operations. The learner must understand the logic of the action being mastered and assess the feasibility of its implementation. At this stage, the task of motivating the action is also addressed. This is preceded by motivation for the activity as a whole, and, as a rule, the motivational sphere of learners is already formed (those who do not want to learn cannot be taught). However, it can (and if possible, then it must) be strengthened by motivating a specific action. This can be done through dialogue, involving learners in the orientation process, using various activation methods, introducing elements of professional orientation into the content of the action, etc. Trainers often set understanding as the operational goal of learning activities, believing that if the learner understands, then they have learned. However, the goal of learning is action, and it cannot be learned simply by understanding what it consists of. Even observing the actions of others (both teachers and fellow students) is not enough, although useful. To master an activity, it is necessary to perform it yourself. This is what the other four stages imply: the stage of material (materialized) action, the stage of speech action, the stage of speech action to oneself, the stage of mental action;

2) At the second stage—the stage of forming actions in materialized form—the action is performed in material form, with all its constituent operations expanded. At this stage, there should not be a large number of similar tasks. Otherwise, the result of their solution will be a "premature" reduction and automation of the action. This will complicate the mastery of the action in speech form. To facilitate the translation of the action into speech form, it is useful to verbalize the operations performed, formulating in speech everything that is being performed practically;

3)The speech action stage—aimed at developing the action as a speech action. At this stage, all elements of the action are presented in the form of socialized speech; the action undergoes further generalization, but remains neither automated nor abbreviated. Speech action, like material action, must be mastered in an expanded form. All operations included in it must not only acquire speech form but also be mastered in it. Here, too, one should not strive for automatism;

4) The stage of performing a speech act silently. A distinctive feature of this stage is that the learner, as in the previous stage, verbalizes the entire process of solving the problem, but does so silently, without any external manifestation. Essentially, this is the same speech as before, but it is no longer socialized; it occurs internally, inaccessible to an external observer. Initially, the action is essentially no different from speech in its basic characteristics, but then begins to rapidly shorten and become automated. This shortening and automation of the action indicates that its development is moving on to the fifth, final stage.

5) The stage of mental action. The action quickly shortens and becomes automated, becoming inaccessible to introspection. It becomes a habit[9].

It should be emphasized that only mental actions developed in the order described above can possess high values for both primary and secondary properties. However, practice shows that the theory of the step-by-step development of mental actions has not been adopted in either secondary or higher education. Nevertheless, people study, then work (and often quite well), and the traditional education system has demonstrated undeniable success. This is partly due to the fact that human learning has come a long way and has accumulated a vast empirical foundation.

Teaching methods based on this theory enable higher-quality results to be achieved in a shorter timeframe, with less effort, material, and financial resources.

- These methods dramatically accelerate (at least twofold, and sometimes even an order of magnitude) the development of high-quality intellectual and practical skills and abilities;

- These methods individualize the learning process, bringing literally every student to the desired level of professionalism;

- These methods make learning virtually error-free for students (there is no "trial and error" inherent in conventional methods);

- These methods provide the opportunity for self-study for anyone who wants to master a new skill;

- These methods eliminate the need for specialized memorization, making it unnecessary to memorize knowledge before applying it;

- These methods do not require any additional expensive technical training aids beyond those typically used;

- Methods produce long-term economic benefits, as each method lasts as long as a given specialty or professional activity exists;

- Methods ensure such high-quality training in the acquired activity that, as a rule, 95 to 100% of trainees perform it error-free, enabling them to work as professionals immediately after completing their training.

The accelerated learning methodology is based on the psychological law of knowledge acquisition, according to which knowledge is formed in the human mind not before, but during, its practical application, as well as specially developed frameworks for the orienting basis of actions[10].

The theory of the stage-by-stage formation of mental actions, developed by P. Ya. Galperin, describes the externally controlled process of forming ideas and concepts about objects based on external actions. This concept is based on a number of assumptions:

1. Before performing a new action, the subject must actively orient themselves to the conditions of the action.

2. The construction of an action is carried out primarily based on the tools of mental activity, which include standards, signs, and measures.

3. Perception and thinking are internalized external objective actions.

This theory describes a set of conditions required for mastering a new mental action: the presence of motivation, the execution of the action externally without errors, the acquisition of the properties of generality and rationality by the action, and the transfer of the action to the mental plane. When implementing the requirements of this theory in the educational process, the following steps are regulated: first, the student is explained the guiding principle of the action, which is presented as a diagram on a card. Based on this diagram, the student begins solving problems, the full set of which corresponds to a complete action. In this case, the action is first carried out and practiced in external speech, which transitions to internal speech and, finally, to hidden speech, which is a purely internal action.

At approximately 6-7 years of age (upon entering school), the child begins to develop two new types of thinking: verbal-logical and abstract. Success in school depends on the level of development of these types of thinking[6].

Insufficient development of verbal-logical thinking leads to difficulties in performing any logical actions (analysis, generalization, identifying key points when drawing conclusions) and verbal operations. Exercises to develop this type of thinking are aimed at developing the child’s ability to systematize words according to specific features, the ability to distinguish generic and specific concepts, the development of inductive verbal thinking, the function of generalization, and the ability to abstract. It should be noted that the higher the level of generalization, the better developed the child’s ability to abstract[7].

Here we also provide a description of logical problems—a special section on the development of verbal-logical thinking, including a wide range of diverse exercises. Logical problems involve a thought process associated with the use of concepts and logical constructs based on linguistic resources.

During this type of thinking, a transition occurs from one judgment to another, their relationship is mediated through the content of some judgments by the content of others, and, as a result, a conclusion is formulated. As the Russian psychologist S.L.

Rubinstein noted, "in inference... knowledge is obtained indirectly through knowledge, without any borrowing in each individual case from direct experience."

When developing verbal-logical thinking through solving logical problems, it is necessary to select problems that require inductive (from the individual to the general), deductive (from the general to the individual), and transductive (from the individual to the individual or from the general to the general, when the premises and conclusions are judgments of equal generality) inference.

Transductive inference can be used as the first step in learning to solve logical problems. These are problems in which the presence or absence of one of two possible attributes in one of two objects under discussion leads to a conclusion about the presence or absence of that attribute in the other object. For example, "Natasha has a small and fluffy dog, while Ira has a large and fluffy dog. What is the same about these dogs? What is different?" [8].

True logic develops primarily during school age. Systematic school instruction plays a very important role in this. By introducing children to the logic of performing actions (particularly when solving arithmetic problems), we develop their own abilities for logical thinking.

Human thinking develops, and their intellectual abilities improve. Psychologists have long since reached this conclusion through observation and the practical application of thinking development techniques. In practical terms, the development of intelligence is traditionally considered in three ways: phylogenetic, ontogenetic, and experimental. The phylogenetic approach involves studying how human thinking has developed and improved throughout human history. The ontogenetic approach involves studying the process and identifying stages of thinking development throughout a person’s life, from birth to old age. The experimental approach to solving this same problem focuses on analyzing the development of thinking in specific, artificially created (experimental) conditions designed to enhance it.

• The effectiveness of the 5E model Research and pedagogical observations show that in lessons organized on the basis of the 5E model: students think independently;

• the ability to ask questions and find answers develops; the ability to see logical connections increases; knowledge is retained for a longer time; the lesson process becomes interesting and active. This model also encourages students to clearly express their thoughts, reason clearly and consistently.

To conclude from the above points, the 5E educational model is an effective tool for developing logical thinking in students. Each stage of the model serves the consistent development of student thinking, the formation of the ability to express their own opinions based on reason, and the ability to draw independent conclusions. Therefore, the regular use of this model in mathematics and other natural science lessons plays an important role in developing students' functional literacy and logical thinking

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