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“Difficult Breathing”: to the Problem of Overcoming the Natural in the Cultural

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The problem of transforming everyday concepts of a child into scientific concepts and their interaction posed by L.S. Vygotskii is still relevant. This article analyzes the transformation of the everyday concept of breathing and respiration to the scientific concept, starting with the ideas of a preschooler and up to the end of school age. The material of the experimental teaching within the framework of a five-year biology course for middle school is presented in comparison with the traditional introduction of the scientific concept. Teaching-learning processes are investigated as a series of mediation acts. Analysis of the students learning activity and their learning difficulties demonstrates the dynamics of conceptual changes. It is possible to see the relationship between the initial (‘everyday’) and the emerging scientific concept. Observations are analyzed from the point of view of Lev Vygotskii and his scientific school and other investigators also. The conditions for overcoming the ‘encapsulation’ of scientific concepts in human consciousness are discussed. The way of development and final appropriation of a scientific concept is shown. The nature of the transformation of an everyday concept in interaction with the scientific concept are discussed.

Keywords: everyday concepts, scientific concepts, learning activity, theoretical thinking, conceptual change, meaning.

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«Трудное дыхание»: к вопросу о преодолении натурального в культурном

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Поставленная Л.С. Выготским проблема преобразования житейских понятий в научные и взаимодействия между ними продолжает быть актуальной. В статье анализируется преобразование житейского понятия о дыхании в научное, начиная с представлений дошкольника и до конца школьного возраста. Представлен материал экспериментального формирования этого понятия в рамках курса биологии в основной школе в сравнении с традиционным введением понятия. Обучение рассматривается как серия актов опосредствования. Формирующий эксперимент позволяет наблюдать динамику понятийных изменений и рассматривать взаимосвязи исходного и становящегося понятия с точки зрения идей Л.С. Выготского, его учеников и последователей. Обсуждаются перипетии ста-

новления и окончательного присвоения научного понятия, взаимодействие житейского и научного понятий, условия преодоления «инкапсулированности» научных понятий в сознании человека

Ключевые слова: житейские понятия, научные понятия, учебная деятельность, теоретическое мышление, изменение понятий, значение.

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Introduction

Overcoming the natural in the cultural is a cross-cutting theme of human mental development. Making the subject of the analysis the transition from spontaneous everyday concepts to non-spontaneous, scientific, i.e. concepts in the proper sense of the word, L.S. Vygotskii focuses on the mechanism of changes in thought processes during ontogenesis, on the one hand, and on the possibilities of the educational process as determining the course of development, on the other [2].

Today the transition from everyday concepts to scientific ones still stays an unfinished and urgent problem [6; 10; 16; 18]. This is due both to the tasks of studying the development of thinking and understanding, and to the increasing pedagogical difficulties in the formation of scientific concepts and the search for effective educational technologies.

The purpose of this study is to describe the path of formation of one of the nuclear biological concepts. We want to follow the transformation of worldly understanding in learning, to identify obstacles in the development of a scientific concept, to understand how and to what extent the worldly view is overcome, that is, to describe, in the words of Vygotskii, "...the path from the child's first encounter with a new concept to the moment when the word and concept are made the child's own" [2, p. 191], as well as to show the role of educational technology in this process. Describing the process of concept formation, we will correlate our observations with the ideas of L.S. Vygotskii and his followers.

Everyday and Scientific Concept of Respiration

The concept of respiration is a key concept in interaction with the basics of biology, since it connects the processes of obtaining and spending energy of the body, and can cause an appeal to the appearance, the mechanism for meaningful reading of texts.

According to the biological dictionary definition, respiration is "one of the main vital functions, a sum of processes providing the organism with oxygen, its use in oxidation-reduction processes, as well as the removal of carbon dioxide and some other compounds from the organism, which are the end products of metabolism" [1]. This scientific definition captures the multi-stage process and hides the true essence of respiration as the transformation of energy behind the incomprehension of the majority of schoolchildren and the consequence of the phrase "its use in oxidation-reduction processes".

The everyday meaning of the word "respiration"/"breathing" is vague and bears traces of the study of a scientific concept influence. The dictionaries give the following definitions: this is the name of the air itself that comes out during exhalation and series of continuously alternating movements of inhalation and exhalation, also drawing in and out of air by the lungs, as well as absorption of oxygen and release of carbon dioxide by living organisms. These definitions are not only extremely diverse, but sometimes also erroneous. For instance, the lungs cannot "draw in" air since they are not equipped with muscle tissue providing movement.

The Evolution of the Concept '"Respiration" in Traditional School Education

Students know the words "breathing", "breathe" since childhood, however, as L.S. Vigotskii mentions "the formation of scientific concepts is not completed but only begins at the moment when the child learns the first meanings and terms" [2, p. 188]. According to some reports, important changes in the system of children's ideas about their body occur at primary school age. The processes of nutrition and respiration preschoolers consider at the level of their external manifestations. At primary school age these ideas change towards mechanistic explanations of the processes. A spontaneous "container" theory of the body is being formed: for each "substance" in the body a special container is needed: for example, air requires lungs [10].

However, the idea of the lungs cannot arise without examining the drawings of the human body internal structure, without adults calling this part of the body a certain word. In other words, the emergence of "container" representations is undoubtedly influenced by the content of children's encyclopedias or textbooks, which preschoolers already like to examine.

In elementary school the word "breathing" continues to be used in its everyday sense. Sometimes a teacher or textbook informs students about oxygen and carbon dioxide, but this knowledge is quite formal. "Spontaneous concept and its first inception are still connected with the

direct confrontation of the child with one or another ... real things ..." [4, p. 6], and air gases turn out to be much less real for the child than, for example, virtual heroes of games, because they are invisible, and the means of detecting their presence in the air (a burning torch and lime water) are not offered to elementary school students.

Probably, if education in elementary school was based on educational dialogues with the use of symbolic metaphors [18], this would contribute to the development of everyday concepts about respiration and create the basis for introducing the theoretical concept of respiration in secondary school. However, in the reality of modern mass education in Russia, the persistence of an elementary school teacher often leads to the formation of stable concepts, many of which are obvious delusions, for example: "a person inhales oxygen, but exhales carbon dioxide", "plants breathe on the contrary — they inhale carbon dioxide, and they breathe out oxygen". Elementary school teachers' mission becomes much more difficult than it would be if a) there was no word "breathing" in the everyday language, b) the elementary school did not have to face the problem of talking about the nutrition and respiration of plants.

A.N. Leontiev wrote that "in order to establish higher generalization, a concept, in a child's judgment, it is necessary to construct a system of psychological operations corresponding to this higher generalization; i.e., a change in the child's consciousness occurs as a result of a change in his intellectual activity as a system of psychological operations, determined by the underlying real attitude to reality, and not vice versa" [11, p. 348]. The research and project work of D.B. Elkonin, V.V. Davydov and their colleagues proved the effectiveness of organizing educational activities for the development of the theoretical thinking basis of schoolchildren [5; 7]. Despite this, the way of studying respiration in Russian mass school has not changed much since the time of Vygotskii: "the development *(development of concepts — Ed.)* of scientific concepts begins with the verbal definition..." [2, p. 186].

In traditional teaching the scientific concept of respiration is introduced in the botany course. Today in one of the most common botany textbooks for 6th grade, respiration is defined as "a complex process that occurs in the cells of a living organism. During this process, organic substances decompose into carbon dioxide and water. At the same time energy is released, which is used by the plant for vital processes..." [15, p. 107]. Further, the same way as Vygotskii describes, "this circle of knowledge is developed with the student, this knowledge is compared with other knowledge, various formulations of this knowledge are given..." [4, p. 5]. The process of respiration is compared with the process of photosynthesis that is already learned by the students, which is considered as its opposite.

This way of teaching fundamentally cannot lead to the formation of a scientific concept for the following reasons: 1) by this moment students have NO idea about chemical reactions (especially about oxidation-reduction reactions) 2) the process of photosynthesis is much more complicated than the process of respiration. The logic should be exactly the opposite.

Difficulties in the assimilation of biological key concepts occur in many studies not only in Russia, but also in other countries abroad [26; 27; 28; 29; 30]. It is noted that educational problems are associated with the difficulties of restructuring knowledge, determined by the context, activities, situations in which these concepts were assigned [6; 28; etc.]. It has been shown particularly that the concepts related to functioning and evolution (respiration, gene, mitosis, etc.) are mastered worse than "structural" concepts, such as, for instance, "cell", "organelle" [27; 30]. In our opinion, functional concepts are theoretical scientific concepts, the initial cell of which is a relation inaccessible to direct observation. Therefore, the ways of solving the problem proposed by researchers, such as enhanced visualization of the studied material, imitation games, including practical tasks cannot seriously increase the efficiency of their assimilation.

The starting point of our study was the development of the way to introduce key biological concepts in the basic school as theoretical and comparison of the effectiveness of this way with traditional teaching [9; 21; 22; 23].

In traditional education, the concept of respiration is not assimilated: at the first and second levels, according to the SAM method [13], not a single student out of 55 people in the control group could complete the task correctly. The experimental program training gave a more positive result: 41% of the students out of 160 people managed to solve the tasks of the 1st and 2nd levels.

These data allow us not to consider traditional education as a source of development of the scientific concept of respiration, and to focus on the description of the formation of this concept in the course "New Biology", developed in accordance with the theory of educational activity by D.B. Elkonin-V.V. Davydov. For the purposes of our study, it is also important that in such courses the process of assimilation of scientific concepts becomes observable, suggesting modeling and discussion forms of interaction.

These data allow us not to consider traditional teaching as a source of the development of the scientific concept of respiration any further and focus on the description of the process of this concept formation in the "New Biology" course, developed in accordance with the theory of educational activity by D.B. Elkonin and V.V. Davydov. For the purposes of our study, it is also important that the learning process in such courses becomes more observable and involves educational modeling and discussion forms of interaction.

The Logic of the Respiration Concept Formation in the Experimental Course

In the course "New Biology" the concept of respiration is constructed as one of the central developing concepts. It is possible to consider the subject line of this concept formation, sometimes coming to the fore in education

program, sometimes disappearing into the shadows, intertwining with the lines of development of other concepts. This is described in detail in other sources [22; 23], here we only highlight the main stages and key turns in learning.

1. The transition from the observable to the hidden (insight into the observed process)

At the first stage students discover the meaning of the respiration process as the only process in the body during which energy is released, which is then spent on other processes. (fig. 1). Most experiments on the study of life processes are carried out on themselves, also virtual experiments are used, i.e. there are no deficits in the figurative-semantic basis for the development of concepts, the danger of which V.V. Rubtsov warns about [17].

This period lasts three months. Students reformulate the definition of respiration several times, clarifying it. At the same time, they do not seem to notice that their understanding has changed — the actual use of the word and the way "generalization appears for consciousness" do not coincide[1]. Apparently, in order for this conflict to be exposed, a special turn of events is needed, which becomes the content of the second stage. The result of the first stage is only the construction of supports for this radical conceptual change.

2. Modeling: linking functions and finding the place of respiration in this bunch

The turning point becomes a scheme created by the class that fixes the connectivity of the processes of respiration, nutrition, gas exchange and excretion (fig. 2). An essential feature of this scheme is the placement of the respiration process inside the body of a living being taken in an extremely abstract way. It is this step that makes the students see the need for oxygen and organic matter of food to be carried inside through the abstractly defined boundary of the body, "to where respiration takes place".

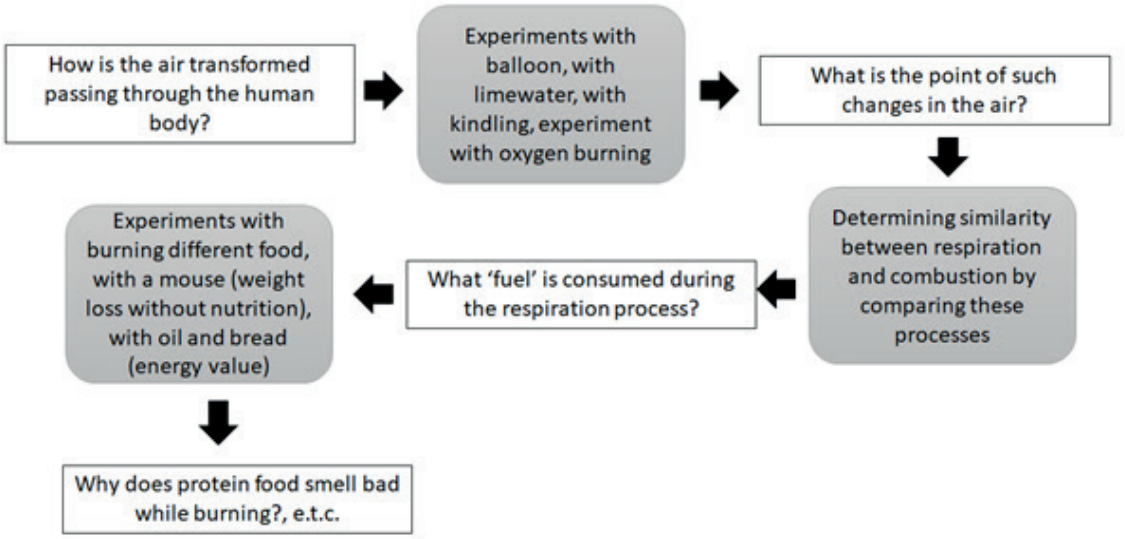

Fig. 1. The first stage in the development of the concept of "respiration" in experimental learning

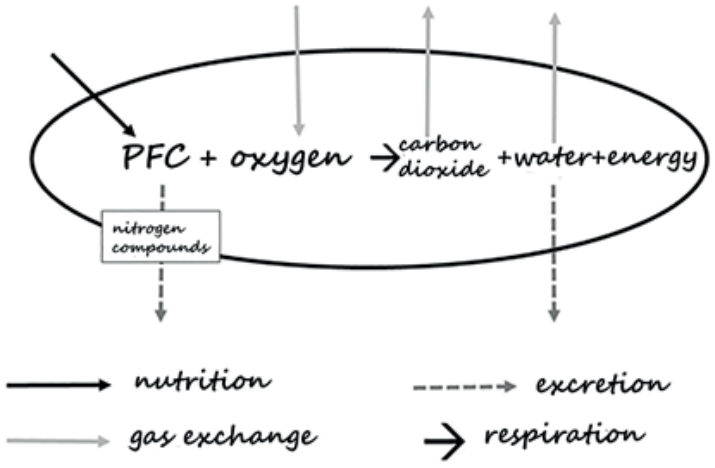

Fig. 2. A diagram showing the connection between the processes taking place in the body of a living being. Different types of arrows indicate different processes

[1] A similar observation is described in the work of A.N. Leontiev (experiments of L.I. Bozhovich).

While creating a diagram, a schoolchild for the first time gets an opportunity to distinguish between the processes of respiration and gas exchange. The scientific term "respiration" means either the process of oxidation of organic substances (narrow sense) or combines all stages of respiration, including the transition of oxygen and carbon dioxide into the internal environment and back, as well as the process of air movement along the respiratory tract. However, there is a special term to designate the transition of gases across the body boundaries in the scientific language: gas exchange. This term is offered to children by the teacher when they independently formulate the definition of this process according to the diagram, describing the gray arrows on the diagram. The teacher helps the students to search for a schematic form and the necessary words thereby emphasizing their statements and actions in a certain way. Thus, for the students initially a contradiction between the original meaning of the word 'respiration' and the new understanding of this process arises.

Children perform tasks on translating statements such as "the dog breathed frequently, sticking out its tongue" from the everyday language into scientific a one, and this work is carried out not only verbally, but also in written forms, which should increase the level of mastery of concepts [20]. The words used by the teacher, everyday one and scientific one, indicate the relationship between "correct" (in this exact situation) and "wrong" [24]. In further discussions after each erroneous statement the teacher asks: "What does Masha confuse?" and children shout in unison: "Respiration with gas exchange!" After a while, the students, without waiting for the teacher's question, say: "Vova, do not confuse gas exchange and respiration!", which marks the "statement of the model" [24].

L.S. Vygotskii writes: "A child who knows water as he knows it in life and who learns its scientific concept at school may not combine both at once" [4, p. 12]. Is the word "unite" suitable for the phenomenon of interaction of two meanings of the word — the old "everyday" one and the new "scientific" one? P. Tul'viste, relying on the ideas of L.S. Vygotskii and V.V. Ivanov, shows that the thinking of an adult is heterogeneous. The reason for this heterogeneity is the variety of activities in which a person is included [19]. Thus, it is clear that everyday word usage should not be completely replaced by scientific one during the course of study. A botanist will not ask at the market to weigh the false fruits of garden strawberries, meaning to ask for a half a kilogram of strawberries. And at the same time, he will think about "strawberries", and not about "false fruits of garden strawberries". However, apparently, in the process of education a person has the opportunity to switch from one word usage to another, becoming (depending on current tasks) either rather primitively thinking, trusting and prone to apothenia [14], or critical, thinking in strict scientific terms.

The result of this stage is a clear distinction and opposition of the everyday and narrow scientific meaning of the word "respiration". The majority of students voluntarily and consciously move from one to another, depending on the task/situation. The condition for the formation of this action, i.e. "the condition for the presence of consciousness" in this transition [24], becomes the opposition and re-meaning of the processes identified by the students and presented schematically by the teacher.

3. Specification of the respiration concept

The next step in the development of the concept is the point of surprise when students discover where respiration takes place — the mitochondria of every living cell. Before that, students knew that the respiration process occurs "somewhere inside, in the internal environment". Whereas in parallel with the development children's everyday ideas about what is "internal" and "external" are being hacked, and it becomes clear that the contents of the lungs are the external environment, although it is a SORT OF THE AREA INSIDE the body. The transformation of everyday ideas is proceeding on a broad front, like an ice motion. This is the very systemic nature of scientific concepts, which L.S. Vygotskii emphasized so often.

Studying multicellular animals, students concretize their understanding: they should detect the energy consumption of a particular process, thereby putting this process in connection with the process of respiration. The function connection diagram is enriched with the ventilation function etc.

4. Understanding respiration as a basis for subsequent action. Formation of a system of concepts

The next milestone in the development of the concept is studying plants. The external immobility of plants is deceptively simple, functionally they are more complex than animals. Therefore, in our course they are studied later. The function connection diagram of the animal organism, created by students, becomes a support in the discovery of the plants functioning principles [9; 22; 23]. The connection between the processes of respiration and photosynthesis, discovered by students, transforms the understanding of respiration, inscribing it into a more powerful system of concepts of plastic and energy metabolism, which develops further in 10—11 grades programs. This leads, in Vygotskii's words, "to its localization within a definite system of relationships of generality..." [2, p. 222]. Thus, the element of learning activity sets a certain rhythm for the development of concepts and connects individual acts of mediation [24].

The Interaction of Scientific and Everyday (Initial) Concepts

The way of learning in Vygotskii's time led him to believe that scientific concepts introduced verbally in learning differ from spontaneous ones in a different relation to the child's experience. We see that the verbal introduction of a scientific concept does not lead to the required result,

and the organization of children's own actions contributes to the development of concepts to a greater extent, which indicates the need to restructure traditional education.

The way of a scientific concept differs from the way of everyday one not only in greater awareness, but in the fact that the subject of awareness (focusing, joint work) is not the content of the scientific concept, but the RELATIONSHIP between it and the content of the original children's ideas. Only a few students are able to do this work on their own, and this fact, apparently, is the basis of Vygotskii's idea that the level of development of scientific concepts "acts as a zone of proximal possibilities in relation to everyday concepts, paving the way for them, being a kind of propaedeutics of their development" [2, p. 187].

The deliberate opposition of the everyday and scientific definitions is a necessary moment in the formation of a scientific concept. Translation from the everyday language to a scientific one is not a technical moment in training, but a repetitive situation of changing positions, transition to a new vision in the simultaneous existence of the old and new views.

The retention of the distinction works not only for the formation of a scientific concept, but also for the development of the original everyday concept, enriching the latter with new meanings and images and making it more "built-in" into the general picture of the universe. The original understanding of respiration is now seen by students as limited. The processes of inhalation and exhalation become more physically felt and sensually differentiated, student's repeated observation of how they occur in his/her own body draws attention to different aspects. These processes are associated with other previously hidden or unknown to the student internal processes, which now, without becoming observable, nevertheless acquire some kind of reality in terms of representations. In the words of B.D. Elkonin: "...cultural is what sets the rhythm and perceptibility to the natural..." [26].

L.S. Vygotskii writes that everyday and scientific concepts "are not encapsulated or isolated in the child's consciousness. They are not separated from one another by an impenetrable wall, nor do they flow in two isolated channels. They interact continually." [2, p. 199]. Our observations show that it does not happen all the time. Often scientific concepts introduced in teaching traditionally verbally remain "encapsulated". The impact of emerging scientific concepts on everyday ones does not occur spontaneously but requires certain conditions: either a specially organized training with returns and rethinking or a person's independent voluntary work to clarify his own concepts (directed reflexive thinking).

Further Development of the Scientific Concept

Speaking about what happens to scientific concepts further, L.S. Vygotskii writes that a clear thought becomes a personal thought "and the task of the psychologist is precisely to trace this process..." [3, p. 72]. Developing these ideas, the followers of Vygotskii discuss the construction of a person's own field of action and their own intentions, as the effects of the mediation act [8; 12].

Tracking the further transformations of the concept of respiration, we offered the students a three-level task (SAM) for this concept (pic. 3). It is difficult to observe the development of a scientific concept at the individual level in the classroom, but it is impossible to study these processes "in their simplest and most expressive form" [11] in laboratory conditions since interaction in the classroom is an essential condition for the formation. It is also difficult to track the dynamics of the formation of concepts in learning due to the "non-classical" nature of the cultural-historical approach: we understand that any intervention changes the course of the process. We have to be content with a comparative analysis of sections made in different classes at different stages of training. For these data statistical analysis seems inadequate: solvability is affected by the depth of understanding by teachers of learning tasks, exactingness towards students, etc. Based on these data, one can only build hypotheses about development trends.

Without analyzing the data in detail, we note one extremely interesting fact: after the growth of understanding, lagging by months and even years, there follows a gradual increase in the solvability of the third level task. The time delay, the lag between understanding and the ability to freely use the concept to solve a variety of "unclassified" tasks, is also indicated by other data [13; 22]. This means that the assimilated scientific concept becomes its own resource and is not finally appropriated immediately.

This is related to the need to reconstitute knowledge obtained not "in life" but in specially created educational

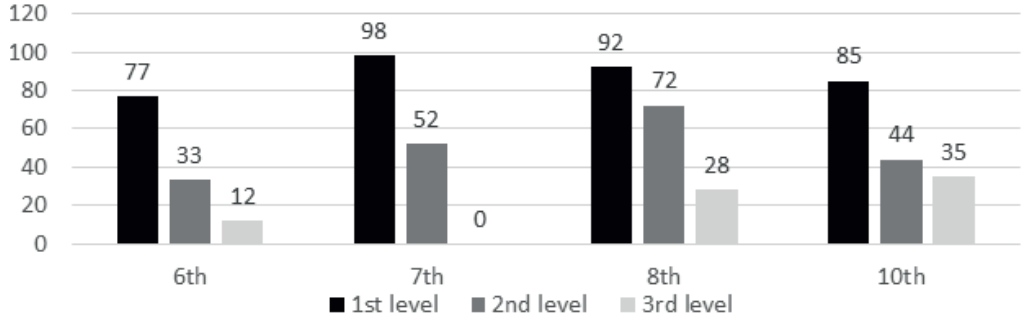

Fig. 3. Solvability of the same three-level problem on the concept of respiration by students of 6th—10th grades (114 people) of the same school, studying with different teachers

situations [6]. But more important is the need to "re-functionalize" the concept — from the object of construction it becomes a tool [8; 25; 26]. Further development relates to its understanding of the concept as a certain operational unit, inscribing it into the contexts of his own actions, individualization of the sign form. The final appropriation occurs in spontaneously emerging everyday situations, but to amplify the effect it is necessary to organize training trials within the framework of directed learning [23].

L.S. Vygotskii notes that "logical thinking is not made up of concepts... it is the concepts themselves in their action..." [3, p. 78]. Fixing the fact of the final appropriation of the concept of respiration, we basically mark a major step in the formation of conceptual biological thinking.

Summary

Assimilation of the scientific concept of respiration does not occur at an easy pace. Even in the conditions of organized learning, the transformation of everyday concepts does not always occur: the learned and understood definitions of terms can remain encapsulated, separated from the original concepts.

The transformation of an initial/everyday concept into a scientific one takes place in a series of mediation acts: this is a set of turns — points of meeting of the developing objective activity with the sign forms that mediate it. It is in them that the meaning of the word "respiration" develops. The paths of the scientific and everyday concepts differ in that the subject of the joint work of the teacher and the student, and, therefore, what the student realizes is not the content of the scientific concept, but the **relation** between it and the content of the original everyday concepts. The condition for the completion of these transformations is the conscious opposition of the old and the new understanding and the retention of the opposition with the help of specially constructed sign forms.

The understanding that has arisen does not yet mean the possibility of using the concept as one's own resource, that is, in pedagogical terms, the possibility of applying a scientific concept. The final appropriation of the concept is associated with its refunctionalization and individualization of sign forms that keep it in the mind.

The formed scientific concept does not replace the everyday one "including it in itself". As a metaphor for understanding the essence of the interaction of scientific and everyday concepts in the human mind, the well-known mathematical problem of six matches from which four triangles are required is suitable. To solve it you need to go out of the plane into space and fold the tetrahedron. The formation of a scientific concept based on everyday ones is the way out of the plane. It is possible to return to the plane, it does not cease to exist. Everyday difficulty instantly returns a person to the plane: "Breathe! Deeper!" — and the person instantly takes a deep breath. However, a three-dimensional structure once erected allows it to be reconstructed again and again, each time making less and less effort. Therefore, in a situation where a deeper/higher scientific view is required, it turns out to be possible not only to rebuild the tetrahedron, but also to look at what is around from the top of this tower.

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