

# Reflexive monitoring of parameters of the development of logical operations as the basis for the individualization of learning

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**Abstract.** The prerequisite for the present study is the lack of instruments ensuring timely identification and development of school students' giftedness in natural science disciplines in the arsenal of a modern teacher. A system of creative tasks integrated into the process of studying chemistry and biology can largely contribute to the development of subject-related knowledge and creative thinking. However, the integration of creative tasks in the educational process should be preceded by purposeful formation and monitoring of the development of a set of reproductive intellectual skills. The main goal of the study is to develop a method for the identification and development of students' abilities including giftedness in chemistry and biology, as well as to study the opportunities for creating individual learning trajectories in natural science disciplines. The study is based on the hypothesis that the development of an individual trajectory in studying chemistry and biology will contribute to the development of individuality and the creative abilities of students. The main method used in the study is determining the speed of completion of logical operations in the process of solving cognitive tasks. Assessment of the speed of completion of logical operations allows determining, among other things, the ability for mastering natural science disciplines and a child's giftedness in this educational sphere. A system of tasks and exercises in chemistry and biology providing for the study of the speed of development of reproductive and creative thinking and allowing real-time monitoring of the effectiveness of the educational process for its timely correction is developed for the first time. The results of the study of the speed of completion of logical operations by a student in the process of solving cognitive tasks presented graphically form the basis for the development of an individual program of development of intellectual and creative abilities of a child.

**Keywords:** creative abilities, individualization of learning, intellectual development; reflection, monitoring.

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## 1 Introduction

The problem of the development of giftedness in the scientific sphere and the creative abilities of students is particularly acute today. For this reason, the PISA 2022 study [1] predominantly focuses on the assessment of students' abilities to solve creative tasks. However, many scientists describing creativity as a multifaceted phenomenon believe [2–6] that it has to be based on subject-related skills. Only a person possessing a sufficient amount of knowledge and understanding of interrelations between the blocks of information and demonstrating a high level of intellectual skills is able to generate creative ideas. This points to the need for the development of creative abilities based on conscious subject-oriented knowledge and skills [7, 8] and for purposeful development of intellectual and logical skills in the process of studying all school subjects.

The focus of Federal State Educational Standards of the Russian Federation on personal results of education implies the corresponding reorganization of the educational process and its organization with consideration of the individual characteristics, abilities, and giftedness of students in the relevant subject area [9].

Methods and technologies of individualized learning ensuring comprehensive development of personal abilities and creative thinking have been developed since the end of the last century (I. Unt, A.S. Granitskaia, V.V. Guzev, etc.) [10]. Individualization of learning involves both the study of mental functions and learning ability and monitoring of the dynamics of students' intellectual and creative development. For this purpose, a teacher needs an appropriate toolkit. Widely used test and measurement materials in chemistry and biology [11] only allow identifying the educational result but not the development process.

This paper presents a study of some dynamic parameters of logical thinking that ensure success in solving creative problems.

The basis for the study is formed by the idea of reflexive diagnostics [12] that involve the analysis of monitoring results simultaneously serving as the basis for determining “the zone of the nearest development”, a criterion for selecting developing tasks for the formation of students' individual learning trajectories, and a way of identifying the reached educational level.

## 2 Methods

The primary factors providing for the development of school students' intellectual abilities and creative thinking are *abilities, motivation for learning, and cognitive activity*. What we consider intellectual abilities relevant for the formation of knowledge in natural sciences are short-term and long-term memory, the volume of information stored in it, and the performance of the logical operations of analysis, synthesis, classification, and the attribution of a corresponding concept based on this information. Of interest to us is also the visual-motor speed of the performed logical operations which is also individual and is determined, in particular, by temperament.

In developing the method for the formation and monitoring of the development of logical operations we accounted for the fact that memory is primarily the result of an in-depth analysis of the perceived information [13] that can serve as a systemic foundation for the mastery of knowledge and the development of logical operations. It is established that the more complex the intellectual processing of the studied material, the more firmly it is stored in memory and the faster its actualization for the solution of a cognitive task. Let us demonstrate it with an example. To perform the task: “Rank the carbonates in order of increasing molar masses: 1) calcium; 2) strontium; 3) barium; 4) magnesium,” one needs to calculate the molar masses and place them accordingly. However, analysis of the content of the task allows establishing that: 1) all compounds contain the same group of atoms

(carbonate ion), therefore, the differences in the molar masses of substances are determined by the difference in masses of metals in salts; 2) there is one metal atom in each salt; 3) all metals belong to the same group of the Periodic System. Consequently, it is necessary to arrange the salts by the increase in the atomic weight of the chemical elements in this group. Thus, the analysis of information and inferences based on it allow completing the task as quickly as possible (the variation in the time required to complete this task ranges from 20 to 96 seconds in the experimental group). The analysis of the time spent on the task allows a teacher to adjust the skills together with the student.

The ability to operate with biological terms and concepts is demonstrated when students analyze graphic images. For example, after studying an image of one of the stages of fruit development, it is proposed to answer the question: knowledge in the field of which botanical science will allow you to study this process? The speed of completion of this task is determined by the development of such important skills as the ability to interpret the presented information in different ways [14].

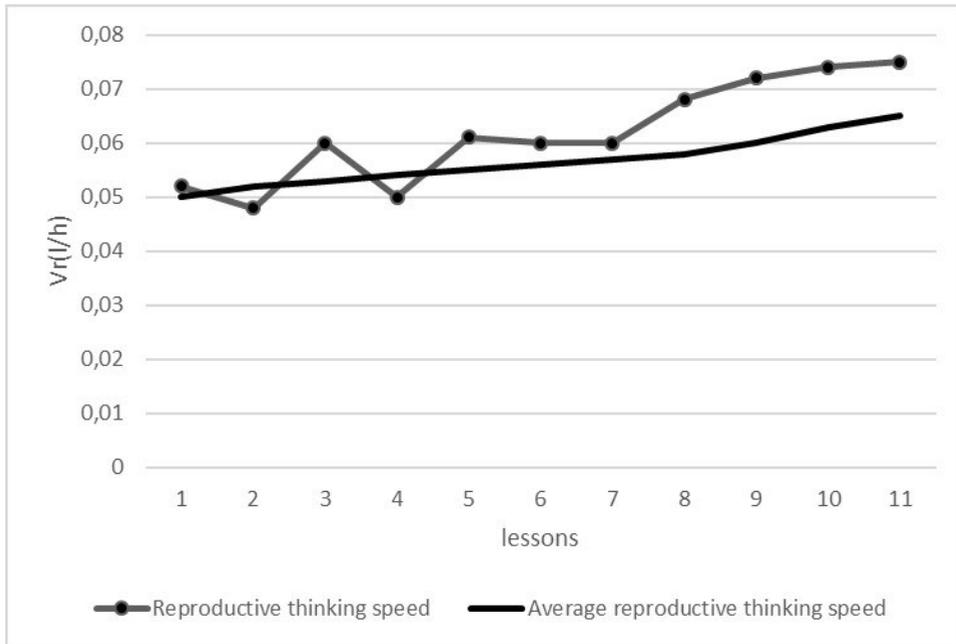
Analysis of the speed and completeness of logical operations serves as a basis for the organization of students' individual cognitive and learning activities.

The method for studying the speed of performing reproductive logical operations involves measuring the time it takes to complete them. Quantitative evaluation is performed using the value:  $Vr = Nr/t$  where  $Vr$  – is the speed of completion of logical operations;  $Nr$  – the number of reproductive operations completed in time  $t$ . The unit of measurement of this value is the **log hour (l/h)** [15]. The process of development of skills is assessed using the average speed:  $\bar{V}_{(n)} = \sum Vr_{(n)} / n$  where  $n$  is the number of lessons.

The development of the skill is described by the value:  $(n) = Vr(n) - \sum Vr_{(n)} / (n-1)$ . Its change can have both positive and negative dynamics. In aggregate, these values can help to assess the effectiveness of learning as they identify the dynamics of the development of logical skills that allow predicting the possible success of a student.

### 3 Results

To quantitatively assess the speed of development of the ability to solve chemical equation problems, we selected a set of tasks each of which is suitable for a certain algorithm consisting of a set of reproductive logical operations. The experiment was conducted in secondary schools in Moscow. The experiment sample included eighth-grade students. During lessons, each student used a stopwatch to determine the time it took them to complete each operation included in the algorithm. According to the results of each participant of the pedagogical experiment, curves describing the speed of their completion of the task were constructed (Fig. 1).



**Fig. 1.** Dynamics of the development of mental operation completion speed when solving chemical reaction equation problems in Student 1

## 4 Discussion

Analysis of the results of the pedagogical experiment allows determining the exact moment in the learning process when the time spent by a student on performing logical operations does not change anymore (“reaches a plateau”). This characteristic makes it possible to conclude that the skill has developed.

The speed of development and the strength of the skill are highly individual and require an individual development program to ensure the development of the skill through the optimal number of repetitions of logical operations in the course of the exercises, as well as the adequate form of realization of students’ educational and cognitive activity (work in groups or pairs of variable composition, individual consultations, etc.).

Thus, the monitoring of the dynamic parameters of reproductive thinking allows planning individual work on the development of students’ intellectual abilities, and the analysis of several parameters at once allows organizing timely and targeted pedagogical influence on its structure to prevent “gaps” in knowledge and skills.

## 5 Conclusion

The development of students’ creative thinking in the study of natural science disciplines is impossible in isolation from the subject of study and without relying on reproductive intellectual skills. The study of changes in the indicators of reproductive thinking is a more important procedure than simply determining the educational results. It allows a teacher to predict the final educational result, to develop individual learning trajectories of students, and to provide reflexive support for the further development of students. It is also apparent that the “manual” monitoring procedure is extremely labor-intensive for teachers. This points to the need to develop a computer-network program that would integrate a database of standard

tasks on the subject content of the school course of chemistry/biology and could be used both for the development of students' reproductive thinking and for its diagnostics. This task will be addressed at the next stage of our work.

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