The Development of Creative Thinking as an Important Task of Educational Process

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Abstract: Current trends in improving the educational system involve the parallel acquisition of multifaceted knowledge, the maximum expansion of horizons and the preparation of students for the optimal choice of profession. Scientists and methodologists from many countries work in this direction. The solution of these problems is inextricably linked with the task of developing general intelligence and creative thinking. In this work the role of lateral thinking in the creative process is discussed. Lateral thinking is an important component of creative thinking. The article discusses the essence of lateral thinking and possible ways to test it. Here we discuss also the features of the probability distribution function for various psychological parameters characterizing the personality. It was noticed that the more universal the psychological parameter, the closer its probability distribution to the ideal normal distribution. It is shown that the probability distribution of the lateral thinking parameter is similar to the normal distribution of Eysenck's parameter for general intelligence. The latter indicates that lateral thinking is a fairly universal personality trait.

1 INTRODUCTION

Educational process is aimed not so much at the transfer of knowledge, but at the development of thinking (Dickens and Flynn, 2001) and, in particular, creative thinking (Chen et al., 2019; Vlasenko et al., 2020). In the new programs created in connection with the modernization of the education system, this is the central task. This means that the teacher, along with the knowledge of modern approaches to improving the education system, in particular the STEM methodology (Kramarenko et al., 2020; Lovianova et al., 2019; Ponomareva, 2021; Semerikov et al., 2021), should be quite familiar with the psychology of thinking and the nature of creative thinking.

The problem of personality testing has a long history. Since ancient times, the assessment and prediction of human capabilities has been of fundamental and practical interest. And in our time, the creation of psychological tests is an important task, which is a subject of numerous studies and discussions. The skill of a teacher to assess the abilities and creative potential of students determines the level of the educational process.

There are different approaches to testing the intelligence and specific abilities of personality (Jesson, 2012; Kaufman, 2009; Katsko and Moiseienko, 2018). They are widely discussed, criticized, and at the same time are often used to solve practical issues. For example, one of the popular is Eysenck's IQ test (Eysenck et al., 1985; Cahan, 2018) for assessing the general intelligence. Many studies have been carried out using these tests in various countries, and these results are reflected in a lot of publications (Cahan, 2018; Juškevič and Kopelevič, 1994). For this test the distribution of the probability of detecting a particular level of intelligence IQ follows a normal law.

The law of normal distribution means that the parameter values tend to concentrate around the value of the mathematical expectation. The degree of spread of a random variable relative to the mathematical expectation is determined by the variance. Any empirical distribution curve is characterized by two parame-

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ters: the coefficient, which determines the symmetry of the curve with respect to the mathematical expectation (A_s), and the coefficient of kurtosis (E_x), which sets the "sharpness" of the distribution peak. In the case of a normal probability distribution law (Gaussian curve) (Dickens and Flynn, 2001) $A_s = 0$ and $E_x = 0$. Psychological parameters characterizing personality are described by different laws of probability distribution.

The psychological characteristics of a person can be classified according to the degree of their universality. For example, general intelligence is certainly a fairly universal characteristic of a person. All people have a certain level of intelligence. (We do not consider options of pathological psychological characteristics.)

At the same time, general intelligence is formed on the basis of different individual abilities. The formation of general intelligence depends on memory (various types of memory), the peculiarities of thinking, in particular, creative thinking and other personality abilities. It is obvious that the normal law of probability distribution, which is fulfilled for the IQ parameter, is not necessarily the case for other (less universal) psychological characteristics of a person. Therefore, we can judge the degree of universality of the psychological characteristics of a personality based on the proximity of the distribution function of its probability to the normal law.

Let's look at some different examples. What is the probability distribution for those with musical memory? It should be noted that the perception of music and musical memory characterize the emotional and psychological sphere of the personality, to a large extent determining its psychological portrait.

Outstanding scientists saw in music the highest manifestation of human intellectual achievements. Gottfried Wilhelm Leibniz wrote in the letter to Christian Goldbach: "music is a secret arithmetic exercise of the soul, which calculates without knowing it" (Patel and Read, 1996). Helmholtz's research (Cahan, 2018) touched upon various scientific and practical issues related to the problems of perception, creativity, diagnostics of abilities, methods of musical education, which gave a powerful impetus to the development of almost all areas of musical psychology. At the same time, if to compare the distribution of the probability of manifestation of high general intelligence of IQ with the function of the probability of manifestation of musical memory, we can see significant differences (figure 1). They consist in the fact that in the latter case the coefficient of kurtosis EX differs from zero and the variance σ^2 is much less.

Let us turn to such a person's condition as depression. This condition is experienced by a significant proportion of the world's population. The probability distribution for carriers of this state differs from the normal law already in opposite signs: the distribution peak is sharply lowered, and the variance is sharply increased (figure 1).

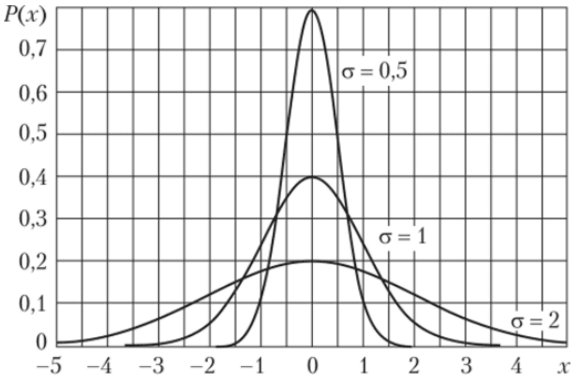

Figure 1: Illustration of the difference between the distribution curves for the parameters: IQ (σ =1), parameter of musical memory (σ = 0.5) (Stough et al., 1994), parameter of depression (σ = 2) (Mozhaleva, 2015).

In our work, we set out to investigate lateral thinking as an important component of creative thinking. Lateral thinking as a thought process was discovered by De Bono (De Bono, 2015). The essence of such a thought process is that we are distracted from the object in question and switch to another object, which at first glance has nothing to do with the first. However, after such a transition, completely new possibilities of considering the first object open up. Albert Einstein said that life is like a bicycle: "as soon as you stop pedaling, you fall" (Einstein, 2016). This is a good example of lateral thinking.

Somebody think that a creative process is better described as a process of logical thinking, trial and error, feedback, and reflection. We do not reject such opportunities. However, there are many people whose experiments and articles show that training and developing lateral thinking leads to an improvement in the emergence of creative solutions in standard or stressful situations (Mellenbergh, 1989). There are guidelines for developing lateral thinking. But in order to track the development of lateral thinking, there is a need to measure it.

It is known that all scientific research tends to use models. Lateral thinking is manifested in this. The scientific result depends on a well-chosen model. The famous models are used in the natural sciences, in particular, in physics: models of atom, atomic nucleus, crystal etc.

In cosmology, models of the Universe are being widely studied and discussed.

Our work is aimed at drawing attention to the problem of the development and use of lateral thinking. A task set to compile a questionnaire to test lateral thinking. An experiment was carried out with groups of students and engineering workers. The probability distribution functions for the studied groups are obtained and analyzed.

2 TESTING LATERAL THINKING

Among the tests designed to assess the parameters of thinking, very little are used to determine the level of lateral thinking. This is due to the fact that some psychologists underestimate the role of lateral thinking in the creative process. However, understanding the essence of lateral thinking and its development in students is necessary to increase the creative potential of the individual. A possible approach for assessing the level of lateral thinking is proposed below.

2.1 Test Questions Formulation Principle

In the case of lateral thinking, unobvious special "associations" take place. These are associations that are not caused by the external similarity of objects. In this case, objects and phenomena are compared on the basis of the subjective view of a person having his vision. A typical example is the creation by physicists of a model for the fission of an atomic nucleus. Frenkel and Weizsaeker "saw" in the atomic nucleus a drop that drains from a drainpipe during rain (Frenkel, 1996). The picture of the separation of a drop from a pipe led to the thought of a drip mechanism of nuclear fission. The drop model of the atomic nucleus is described in all textbooks on nuclear physics (Hawking, 2018). The question of interest is of the extent to which lateral thinking is present in human thinking at various levels. In drawing up a questionnaire for assessing lateral thinking, we chose triads of words in which two words are far from each other in content, and two words are close. It is proposed to determine two words that at first glance are in no way linked associatively and try to find in these words something common. The questionnaire is attached in figure 2. It has been checked in accordance with the requirements to tests (section 2.3).

2.2 Description of Experimental Results

For the study, 3 groups of subjects were selected, of which two groups were students (140 and 70 people) aged 19–22 and a group of engineers and technicians (56 people) aged 30–45 years. A questionnaire was used to assess the level of lateral thinking (figure 2). The content of the questionnaire and the principle of assessing the correctness of the answer are described above.

No suggested choices for matching word pairs were provided. It was suggested to make an appropriate choice of two words and in each case provide a short justification for the choice made, similar to those on the right side of the figure 2. The choices made and their rationale may not be the same as those suggested in figure 2.

The ratio of the number of (n) triads in which the corresponding pairs of words were correctly selected to the total number (N) of triads (in figure 1) was used as a parameter characterizing the level of lateral thinking ($LT = n/N$).

Using the obtained data, in all cases the parameter distribution characteristics were calculated: average values of the measured value ($\bar{x}$), mathematical expectations (μ), standard deviations (σ), third moment of inertia (μ_3) and fourth moment of inertia (μ_4). The results are shown in table 1.

Table 1: Characteristics of parameter LT distribution for studied groups.

Number of group	$\bar{x}$	σ	μ_3	μ_4
1	0.43	0.65	0.05	0.48
2	0.37	0.68	0.10	0.44
3	0.32	0.54	0.02	0.42

Using the data in table 1, we calculate the values for the coefficients of skewness (A_s) and kurtosis (E_s): $A_s = \mu_3 / \sigma_3$ and $E_x = (\mu_4 / \sigma_4) - 3$. The results are presented in table 2.

Table 2: Values A_s and E_x for studied groups.

Number of group	A_s	E_x
3	0.7	-0.53
1	0.18	-0.18
2	0.32	-0.98

Figure 3 shows the experimental distribution of the parameter LT for the first group.

2.3 Checking the Applied Test

2.3.1 Validity of the Test

Validity is checked as the correspondence of the measured parameter to the psychological characteristic that is being studied. In our case, we are talking about the assessment of lateral thinking. Therefore, during the testing process a survey was conducted to find out

River	Sunset	A life	The flow of the river is usually associated with the flow of life, but in the case of lateral thinking, the combination "Sunset of life" is applicable.
Crimes	Hurricanes	Cataclysms	Hurricanes and cataclysms are related concepts, but crimes as cataclysms are a lateral vision of the subject.
Hunger	Loneliness	Insulation	Loneliness and isolation are close concepts, but a person who thinks laterally understands loneliness as a hunger for communication.
Eye	Sadness	Depth	The expression "sad gaze" is often encountered, but the expression "deep gaze" already indicates more lateral vision.
Mountain	Barrier	Patience	Climbing the mountain naturally requires preparation and patience, but overcoming any barrier also requires preparation and patience.
Needle	Spark	Think	Thought flares up like a spark, and sometimes pierces like a needle.
Cloud	Sea	Sky	The sea is usually associated with the sky, but in the case of lateral thinking, a person compares the sea with a field (he sees wheat stalks swaying in the wind).
Wind	Hurricanes	Think	The wind is naturally associated with hurricanes, but it happens that "the wind walks in the head."
Face	Portrait	Decision	The face is naturally associated with the portrait, but you can talk about a decisive facial expression.
Find	Art	Eureka	Eureka is the intuitive finding of a solution, also an unexpected image in art.
Science	Target	Vertex	Science is aimed at achieving a specific goal, but it is also the pinnacle of human intellectual activity.
Song	Soul	Life	Of course, there is the soul in the song, but spirituality is the basis of life.
Thoughts	Mysteries	Horses	There are secret thoughts, but you can imagine "thoughts - horses".
Steps	Tops	Run	Running is quick steps, but steps can be thought of as moving to the top.
Road	Lights	End	The road is usually associated with road lights, but in the case of lateral thinking, the words "lights" and "end" are chosen (light at the end of the tunnel).
Poems	Formulas	Regulations	Formulas describe laws, but poetry obeys its own laws.
Friend	Present	The God	The best gift from God is good friends.
Libra	Character	Sensitivity	It is important to have a sensitive scale, but also a sensitive character.
Neighbor	Character	Enemy	The enemy can be a neighbor, but also your own character.
Rescue	Berry	Horse	Both a horse and a berry can save.
Wood	Family	House	The family is associated with the home, but there is also a family tree.
Chord	Disappointment	Note	A chord is associated with a note, but there is also a "disappointment note".
Bicycle	A life	Snake	Life wriggles like a snake, but "looks more like a bicycle" (A. Einstein).
Bonfire	Fire	Ice	Bonfire is associated with a fire, but "ice and fire" appears in poetry (A. Pushkin)
Autumn	Evening	Sunset	Evening is associated with sunset, and in the case of lateral thinking, autumn is perceived as sunset of the year (or sunset of life).

Figure 2: Questionnaire for testing lateral thinking. The words of the recommended choice are underlined.

what unity of the chosen word pairs a person implied. In order for the correct result to be counted, it was necessary for the test taker to explain his choice in the spirit of the comment in figure 2. It was not necessary that this explanation coincided with the comment in figure 2. The main requirement was that the original vision manifested the subject in the interpretation of the unity of the objects being compared. Situations arose when the subject chose objects that had obvious commonality, but at the same time a "lat-

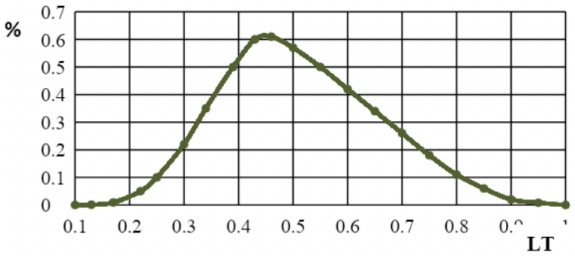

Figure 3: Experimental distribution of the parameter *LT* for the first group.

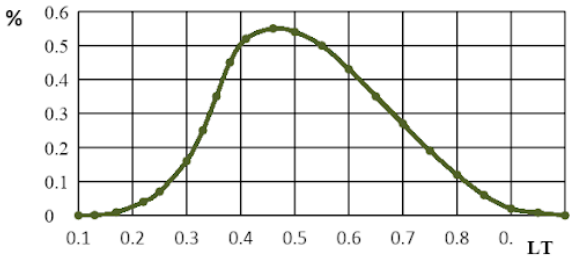

Figure 4: Experimental distribution of the parameter *LT* for the second group.

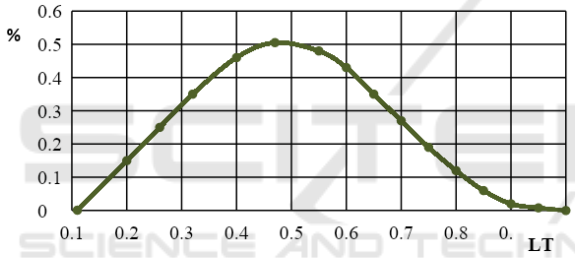

Figure 5: Experimental distribution of the parameter *LT* for the third group.

eral" vision was manifested and the unity of objects was noted that could not be noticed by another person. Thus, for each subject in all three groups, the parameter $LT = n/25$ was determined.

2.3.2 Test Reliability

Reliability of the test involves obtaining close results in repeated measurements as well as for subjects whose parameters differ little. To check the test reliability, we conducted testing of studied groups at different times with an interval of two-three months. We obtained similar test result as a result of multiple measurements of the parameters of the same group. Discrepancies in the parameters of the various groups also persisted.

2.3.3 Representativeness of Test

Representativeness suggests that test results obtained for a specific group of people represent the large part of population. To check the compliance of the test with this characteristic, we have taken two groups with twice as different the number of subjects (70 and 140). In both groups, the contingent is selected with close characteristics (educational level, professional qualifications, etc.). We obtained that in these groups the experimental results for the studied parameter (*LT*) differ slightly (table 1).

2.4 An Example When Studying Vacancies in Crystals

When studying the real structure of crystals, the concept of a vacancy (an empty place from which an atom left) and an interstitial atom (an atom that left its place with the emergence of a vacancy) are introduced. If an atom leaves close to its vacancy, a so-called Frenkel pair is formed. However, an intermediate variant is possible, when the atom does not move far enough from the vacancy, and the vacancy pulls it back in. When this process is repeated, a so-called "blinking vacancy" appears. Such a vacancy either appears or is "healed" by the returned atom. The concept of a "blinking vacancy" appeared relatively recently (Paritckaia et al., 2018). Physicists came up with the idea of a blinking vacancy by observing raindrops falling on the calm surface of a river. Raindrops leave a mark on the water, which disappears with a blink. This is a typical example of lateral thinking, just like in the case of nuclear fission above (Hawking, 2018) (figure 6).

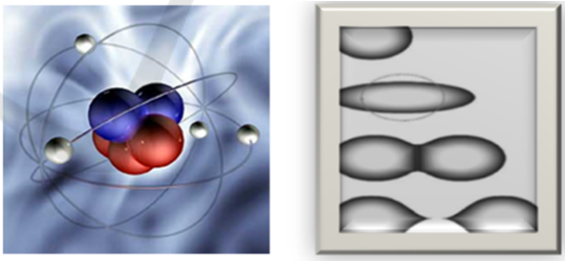

Figure 6: Illustration for the droplet model of the fission of an atomic nucleus. Left – an image of an atomic nucleus, on the right – an image of fission of a liquid drop.

3 DISCUSSION OF RESULTS

The problem of thinking, which is one of the central problems of psychology, is given little attention in addressing issues of improving the system of education, new methodological approaches, and developing new curricula. Despite the ambiguous attitude of psychologists and teachers to existing models and ideas about the mechanisms of thinking, it is useful to take into

account the use of accumulated experience and ideas in the educational process. The concepts of productive thinking introduced by Wertheimer (Wertheimer, 2020), the concepts of lateral thinking introduced by De Bono (De Bono, 2015) and other well-known models of thinking (Young, 2008), must be taken into account in the learning process, when solving specific methodological problems. The teacher's attention should be focused not only on effectively communicating knowledge, but on choosing a teaching method that develops thinking. Therefore, it is important to be able to assess the student's ability to a certain type of thinking.

In this work, we investigated the possibilities of objective assessment of lateral thinking. Testing this type of thinking requires special care, since it is not about solving specific tasks. It is required to trace the course of a person's thinking and to distinguish the degree of originality of various approaches to the assessment of the meaning of concepts.

In many cases of life, a person is faced with the need to apply lateral thinking, in scientific research, in the perception of humour and simply in everyday life. When compiling a questionnaire for assessing the level of lateral thinking, we tried to give the subject the opportunity to find a wide range of associations.

The proposed test has been verified in terms of validity, reliability and representativeness. During the experiment, however, an additional approach was applied to assess the significance of this test. It is known that the probability distribution of detecting a certain value of the measured parameter during testing is typical for a particular test. In the case of measuring the IQ parameter, this probability distribution obeys the normal law. The IQ parameter is a fairly universal characteristic of a person. This parameter characterizes any person (except for pathological cases). It can be assumed that the closer the probability distribution of a given parameter is to the normal law, the more universal psychological characteristic is this parameter.

In the case of testing lateral thinking, an insignificant deviation of the measured empirical distribution of the probability of the *LT* parameter from the normal law was revealed, which indicates a fairly high universality of this personality characteristic.

4 CONCLUSION

The possibility of assessing the level of lateral thinking using the proposed verbal test is shown. The compiled questionnaire is a set of triads, in which each triad includes three words, of which two words are outwardly in no way connected in meaning. The task is to select these two words that have no outwardly any semantic connection and find something in common in these words. It is also required to briefly explain what exactly was found in common in the selected words. An experiment was conducted with the proposed test, in which two groups of students (140 and 70 people) and a group of engineering and technical workers (56 people) took part. As a result of processing the results, the values of the asymmetry and kurtosis coefficients were obtained, which characterize the deviations of the obtained empirical distributions of the probabilities of detecting the parameters of LT from the normal law. These deviations were found to be small.

It is known that when testing general intelligence using the Eysenck test, the probability distribution for IQ parameter obeys the normal law. Since the IQ parameter is a fairly universal characteristic of the personality, it is suggested that rather general personality traits are manifested also in lateral thinking.

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