

# *The development of students' creativity by expanding the modal experience with ternary information signals*

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**Abstract — Relevance.** The student's personal creativity is a socially significant quality. The importance of expanding the psychophysiological basis of the individual for productive creative activity has been proved in the studies of a number of scientists. The effectiveness of the ternary presentation of information for the functioning of information systems of various nature is confirmed by the results of experimental work by researchers of various scientific fields. There is an obvious need for the definition and justification of organizational and pedagogical conditions based on the psychophysiological characteristics of thinking, but taking into account the properties of information processes and systems.

**The aim** of the publication is to present the results of the stages of the search for organizational and pedagogical conditions based on the laws of psycho-physiological and information processes and contributing to the development of students' creativity.

**Methodology and Research Methods.** The work was carried out based on the provisions of system-activity and information approaches, the theory of foreign psychologists on convergent and divergent types of thinking (G. Gilford, J. Taylor, E.P. Torrance); philosophical and psychological teachings on the problems of creativity, creativity and giftedness (N.A. Berdyayev, D.B. Epiphany, V.N. Druzhinin, A.G. Maslow, A.M. Matyushkin, Ya.A. Ponomarev, R. Sternberg, M.A. Kholodnaya and others); psychophysiology of creativity (N.P. Bekhtereva, O.M. Razumnikova, D.Z. Shibkova and others). Methods such as analysis and generalization of the content of psychological, pedagogical and methodological literature were used; mathematical modeling of the educational process; psychodiagnostic methods: E.E. Tunik methodology, questionnaires, tests, etc., experiment (ascertaining and formative), methods of mathematical statistics for processing experimental data — application of criterion  $\chi^2$ , Student criterion, one-factor analysis of variance, etc.

**Results.** The conditions of the experimental verification are described, the logic of the research work, its results, diagnostic tools and processing and evaluation methods are presented.

**Scientific novelty** consists in the theoretical justification and experimental verification of the conditions for the development of creativity by expanding the modal experience of students through the ternary presentation of informational educational signals, developing a mathematical model for optimizing the time

resource of the educational process for the development of student creativity.

**The practical significance** lies in the fact that the organizational and pedagogical conditions for the development of individual creativity are substantiated and experimentally verified, taking into account the characteristics of information systems in the educational process.

**Keywords —** *creativity, ternarity, modal experience, information signals, optimization model, organizational and pedagogical conditions.*

## I. INTRODUCTION

The problem of the development of creativity of students does not lose its relevance for many years in psychological and pedagogical research [1–4]. Scientists [5–8] established the relationship of intelligence, creativity and success: these personality characteristics are considered as attributes of a mental resource. Studies [9–14] proved the importance of expanding the psycho-physiological basis of an individual for productive creative activity. Consideration of the impact of a set of information signals on students in the educational process is consistent with the idea of a creative field [15] and can be converted into empirical constructs for pedagogical purposes of creativity development.

The educational process is implemented by regulated information procedures, the formats of which are determined by the forms of training sessions. In order to develop individual creativity, it is necessary to synthesize the totality of educational information flows in such a way as to represent them in the maximum modal variety of educational signals. In this case, it is necessary to coordinate private information processes and optimize the educational time resource in the interests of the formation of the planned educational competencies with the simultaneous development of individual creativity by expanding the modal experience of the student. In terms of content, the problem is formulated as the need to develop a strategy for integrating diverse types of information processes for educational activities with activities

to expand the modal experience of students, which is the psycho-physiological basis of creativity. The problem becomes especially relevant with the digitalization of the educational process.

## II. FORMULATION OF THE PROBLEM

Creative researchers highlight the phenomenon of creativity as a procedural aspect of the realization of creative abilities [21–23].

The relationship between creativity and psycho-physiological factors has been investigated in the psychophysiology of creativity [9–12, 14, 26]. The perception of information depends on the experience of the individual, on the modality of sensory images stored in his memory. M.A. Kholodnaya indicates the importance of the process of perceiving information, noting that adequate representation, that is, individual transcoding of information coming from outside, is the foundation of all subsequent transformations, associations and convolution of information [24].

The experience of modal sensations is due to the dominant sensory channels of the individual but is not identical to them. As indicated by N.P. Bekhtereva: “If any phenomenon of consciousness is both information and brain function, then the material carrier of such information is certain brain processes that are described by the concept of a neurodynamic system” [31, p. 51–52]. The experience of the individual, presented in modalities obtained through sensory sensations, is an integral component of the mental resource [13, 23, 24, 32].

Considering the educational process as a process of transmitting and translating educational informational signals, it is important to take into account the property of informational streams that have specific characteristics that affect the thought process. Scientists V.M. Petrov, G.A. Atamanov, E.V. Klochkov and others [16–20] highlighted such a fundamental property of human thinking as ternarity (synonyms — trinitarianism, trinity). The indicated feature of thinking, apparently, is objective: ternary presentation of information is most comfortable for perception and contributes to the effectiveness of thought processes, which, in turn, will have a positive impact on the development of creativity.

## III. MATERIALS AND METHODS

During all stages of the study, the object was the educational process, and the subject of the study was the dynamics of changes in creative indicators of students, as the main diagnostic tool for assessing changes in creativity, the method of E.E. Tunik. As a rule, several diagnostic sections were performed: initial, intermediate and final. Processing of experimental data was carried out by methods of mathematical statistics using the chi-square criterion, Student’s and Spearman’s criteria, one-factor analysis of variance. Tests, educational and creative tasks, mental maps, complex creative tasks were used as stimulus material for diagnosis. To substantiate the optimization model, a mathematical model was built that takes into account the modality of educational information signals and the features of the educational process. The experimental work was carried out in the natural

environment of the functioning of educational organizations during propaedeutic (at senior pupils of a comprehensive school) and vocational training (at students) at the university.

## IV. RESULTS OF THE STUDY

Identification of the most effective organizational and pedagogical conditions for the development of creativity of students was carried out in several stages.

At the first stage, theoretical prerequisites were identified for the organization of training aimed at enhancing the creative qualities of the individual by expanding the variety of modal experience of students.

The hypothesis of this stage was the assumption of a significant increase in creativity while expanding the modal experience of the student (I). At the same time, by modal experience, we understood an individual psychic education, which provides, under conditions of a person’s cognitive contact with the world, selective perception and interiorization of information presented in a certain form, based on research by scientists [6, 10, 11, 13, 14, 24, 31, 32]. The organizational and pedagogical conditions of this stage included the requirements for maintaining a comfortable information mode, when the set of formats for informational educational signals corresponds to the preferences of students as much as possible, and the use of a set of creative exercises grouped according to the characteristics of multimodal stimulus material.

An experimental verification of the effectiveness of the mentioned organizational and pedagogical conditions on a sample of senior pupils of a comprehensive school studying information and communication technologies (ICT) showed a significant increase in the creative indicators of students in experimental groups. The dynamics of creativity growth was measured by us through diagnostic tests E.E. Tunik [33].

Similar results were obtained in the 2015/2016 academic year on the basis of the Professional — Pedagogical Institute of the Federal State Budget Educational Establishment of Higher Education “Chelyabinsk State Pedagogical University” (hereinafter — the PPI) in the framework of teaching students IT disciplines. Testing with the chi-square criterion confirmed the hypothesis (I) of the stage.

The next step in the search for opportunities for the development of creativity in the educational process was the development of a mathematical model of optimization by time resource. We wondered: is there a possibility to optimize the study time for the development of individual creativity of the student through the synthesis of different types of information signals, how to distribute information flows of different modality among academic disciplines, subject to the restrictions imposed by the implementation of the work programs of the disciplines and curriculum?

In order to formalize the problem and solve it, a lot of informational conditions  $Z = \{z_i \mid z_i \in Z, i = 1, 2, \dots, |Z|\}$  were defined that characterize the sequential change in the level of creativity in the process of forming the components of educational competencies; and many

$M = \{y_m \mid y_m \in M, m = 1, 2, \dots, |M|\}$  psycho-physiological influences of various modality. Each element  $z_j$  has a set  $Z$  of elements corresponding to a  $y_m$  set of  $M$  actions. In each academic discipline, many are defined:

$$F_m^{(u)} = \{f_{mj}^{(u)} \mid f_{mj}^{(u)} \in F_m^{(u)}, m = 1, 2, \dots, |M|, j = 1, 2, \dots, |F_m^{(u)}|\} \quad (1)$$

informative signs of training signals expressed in various modalities. In addition, for the entire set of sets,  $\bigcap_{m=1}^{|M|} F_m^{(u)}$  the set is defined:

$$F^{(s)} = \{f_j^{(s)} \mid f_j^{(s)} \in F^{(s)}, j = 1, 2, \dots, |V|\}, F^{(s)} \subseteq \bigcap_{m=1}^{|M|} F_m^{(u)}, \quad (2)$$

consisting of a subset  $f_j^{(s)}$  of significant informative features that uniquely determine the effect of training signals of a particular modality (audio, visual, synthetic, etc.).

In the general case, the set of informative features of a multidimensional  $F_m^{(u)}$  topic of a discipline does not provide the completeness of a diverse modal effect, which leads to the need to assimilate informative features included in the  $F_{m+1}^{(u)}$  set when studying the next topic, etc. until the set of informative features is significant for completeness of completing the pattern of the student's internal representation.

Each subset of significant informative features  $f_j^{(s)}$  has been associated with many possible  $X^{(r)} = \{x_j^{(r)}(f_j^{(s)}) \mid x_j^{(r)}(f_j^{(s)}) \in X^{(r)}, j = 1, 2, \dots, |F^{(s)}|\}$  ways to implement these features. The educational process in the general case is formally presented as a process of changing the states of the information process  $\vec{U}^{(o)} = (u_1^{(o)}, u_2^{(o)}, \dots, u_{|Z|}^{(o)})$ , the formation of components of educational competencies  $\vec{U}^{(m)} = (u_1^{(m)}, u_2^{(m)}, \dots, u_{|X^{(r)}|}^{(m)})$ , the process of generating educational signals of various modality, the impact of which significantly affects the development of creativity.

Assuming that for the implementation of the information process,  $\vec{U}^{(o)}$  educational activity has the full amount of a temporary resource, we put in correspondence with the information process a  $\vec{U}^{(o)}$  vector of a temporary resource.  $\vec{Q}^{(o)} = (q_1^{(o)}, q_2^{(o)}, \dots, q_i^{(o)}, \dots, q_{|Z|}^{(o)})$  In this case, each element of the  $q_i^{(o)}$  set  $Q^{(o)}$  is associated with a set  $F_m^{(u)}$ , and each element  $q_i^{(m)}$  of the set is  $Q^{(m)}$  one of the elements of the set  $X^{(r)}$ , i.e.

$$F_m^{(u)} = F_m^{(u)}(q_i^{(o)}), i = 1, 2, \dots, |Z|, m = 1, 2, \dots, |M|, \\ x_l^{(r)} = x_l^{(r)}(q_l^{(m)}), l = 1, 2, \dots, |X^{(r)}|.$$

Then the implementation of the educational process of the information state  $z_j$  within the framework  $y_m$  of the educational topic is described by the equation:

$$y_m(z_i) = u_i^{(o)}(z_{i-1}) \cap u_i^{(m)}(F_m^{(u)}) \cap S_n, \quad (3)$$

when  $f_i^{(s)} \notin S_{m-k}$  and the equation:

$$y_m(z_i) = x_j^{(r)}(S_n), \quad (4)$$

when  $f_i^{(s)} \in S_{m-k}$ ,

where  $S_m$  is a structural unit of the educational process, reflecting the number and form of classes.

Further, under optimal management of ensuring the development of individual creativity, we formally agreed to understand a certain set of  $w_h^{(c)}(\vec{Q}^{(m)})$  data characterizing the distribution of elements of a vector-time  $\vec{Q}^{(m)}$  resource, as well as ways to implement this resource in the interests of the information process.  $\vec{U}^{(m)}$

The results are described in more detail in [35–37].

At the next stage, we put forward a hypothesis about the possible significant influence of the factor of ternary presentation of educational information on the positive dynamics of creativity (II).

The base of the experimental verification was the Professional Pedagogical Institute (hereinafter referred to as the PPI) of the Federal State Budget Educational Establishment of Higher Education SUSU, the department of "Professional Training: computer science and computer technology."

During the formative stage of the experiment in the control groups, the presentation of the educational information was carried out in binary representation: auditory modality (teacher's speech) and kinesthetic modality (student's lecture recording), and in experimental groups in ternary presentation: visual modality (presentation, video), audio modality (teacher's speech, accompanying voiceover) and kinesthetic modality (recording lectures, working on a PC, doing practical work). To diagnose the dynamics of creativity, we compared the samples of the control and experimental groups for each indicator - fluency, flexibility, originality, using a one-way analysis of variance. No significant differences were found in the fluency and originality samples; therefore, the null hypothesis of the equality of group means was adopted. According to the sample, the flexibility for the significance level  $\alpha = 0.05$ , the numerical value of the degrees of freedom from 1 to 52, the estimate of the factor dispersion turned out to be larger than the estimate of the residual dispersion, since  $f_{\text{observe}} = 133.8 / 8.02 = 16.68$ , and  $f_{\text{eq.}}(0.05; 1; 52) = 4$ .

Due to the fact that  $f_{\text{obs.}} > f_{\text{eq.}}$ , we adopted the hypothesis that the factor of ternary presentation of educational information significantly influences the positive dynamics of

flexibility as components of creativity. The conditions and results are described in more detail in [38].

Since we were convinced of the effectiveness of taking into account the property of ternarity in the format of the modality of the information signal of information when organizing the educational process, we tested the assumption about the possible positive effect of ternarity of the presentation of educational information through the semantic structure on the dynamics of changes in the creativity of students.

The basis of the experimental verification was also made by PPI, students of the vocational training area in the field of Informatics and Computer Engineering and Information Security Management in Vocational Training. The selection of students was 112 people. For the purposes of experimental verification, we adapted the model proposed in [39], and by educational message we understood the verbal reproduction of the meaning of the educational material. When formalizing the semantic content, the message was divided into several semantic signals, the signals, in turn, were divided into terms, and terms into terms. By a set of educational message signals, we understood a list of what the sender-teacher intended to transmit to the recipient-student.

Thus, any message  $M$  will be a collection of meaningful signals:

$$M = \bigcup_{i=1}^n S_i. \quad (5)$$

Further, each signal is a set of  $S_i$  terms  $T_{ij}$ , and each term, in turn, is a block of terms expressing the concept of a term.

$$S_i = \bigcup_{j=1}^{n_i} T_{ij}. \quad (6)$$

$$T_{ij} = \bigcup_{k=1}^{n_{ij}} t_{ijk}, \quad (7)$$

where  $n$  is the number of signals in the message  $M$ ,  $n_i$  is the number of terms in the  $i$ -th signal,  $n_{ij}$  is the number of terms in the  $j$ -th term of the  $i$ -th signal. Thus, we provided a ternary semantic presentation of educational information in a message from teacher to student. The main characteristic of the effectiveness of the term (training micromodule) will be the reception function  $g_{ij}$ :

$$g_{ij} = \text{sgn} \sum_{k=1}^{n_{ij}} f_{ijk}, \quad (8)$$

where  $f_{ijk}$  is the frequency of the term  $t_{ijk}$  in the related term  $T_{ij}$ .

For definiteness, we will accept that in the educational process the term of communication can be accepted by the recipient - the student as a whole, which will correspond to the complete assimilation of the educational material, partially accepted, or not accepted at all.

As a measure of signal reception, we will use the indicator  $h_i$ :

$$h_i = (1/n_i) \times \sum_{j=1}^{n_i} g_{ij}, \quad (9)$$

where  $n_i$  is the number of signals.

Obviously, in a real educational process, the value of the signal reception measure can vary from 0 to 1. Formally, the task was to establish a hypothetical relationship between the individual characteristics of the educational signal reception measure in ternary semantic representation and the indicators of the dynamics of creativity of students who are the receivers of such signals. The dynamics of creativity was diagnosed by the technique of Tunik E. [33], with the emphasis on figurative and verbal creativity. The null hypothesis ( $H_0$ ) consisted in the assumption that there is no connection between the indicators of signal reception and indicators of the dynamics of creativity, while the average indicators of the measure of signal reception were first associated with the series of dynamics of changes in verbal creativity, and then with the series of dynamics of changes in figurative creativity. The hypothesis was tested by using the Spearman rank correlation coefficient. It was revealed that there was a statistically significant relationship between the measure of signal reception and the dynamics of increasing the verbal creativity indicator, and no statistically significant relationship was found between the measure of signal reception and the dynamics of the indicator of figurative creativity. The results are described in more detail in [40].

We considered hypothesis II proven.

Thus, according to the results of many years of research, we have formulated and justified the following provisions:

1. for the purpose of developing the creativity of students, it is necessary to assess the diversity of the modality of educational information signals, while ternary representation is effective both in terms of modality format and semantic representation format.
2. finding options for using a temporary resource is based on the calculation of the maximum impact of multimodal training signals to expand the modal experience of students.

## V. DISCUSSION AND CONCLUSIONS

It can be summarized that for the development of students' creativity it is not necessary to organize special training outside the framework of the study of academic disciplines, it is enough to implement a strategy of a variety of educational information signals, taking into account the provisions found. ICTs can be used as learning tools to achieve the goals of creativity development, as their functionality allows the implementation of a variety of information signals, their accounting and ternarity. The specific content of the didactic tools varies depending on the subjects taught, the age and level of training of students.

Further research areas may include checking the didactic conditions for the presentation of tri-gradation signs of basic concepts, the use of three-parameter storage mechanisms and reliable fixation of periodic events when they are repeated three times, as well as the study of the possibility and conditions for the presentation of educational information signals using digital technologies.

The found correlation in the optimization model can be the starting point for finding pedagogical conditions for the development of creativity in distance and digital learning, when educational information signals are realized through ICT [41], and the number of modalities of basic educational signals is determined by the technical characteristics of computer equipment and peripheral equipment.

The task of determining the optimal synthesis of multimodal, but limited by the implementation of ICT, information processes in the interests of mastering a specific academic discipline is an urgent research task in the framework of digitalization of pedagogy.

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