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THE NATURE OF CREATIVITY: DIFFERENTIATION-INTEGRATION APPROACH

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This paper analyzes some facts of manifestation of creative achievements which are difficult to interpret both in terms of psychometric approach and from the point of view of cognitive approach. These facts allow us to take a new look at the nature of creativity. A hypothesis was put forward about the relationship between the emergence of new ideas and the formation of a detailed level of cognitive conceptual structures. The findings showed that the highly differentiated conceptual structures relevant to the object of activities are necessary for successful professional creativity. These structures are a systems factor uniting the properties of the creative person as a whole. The more differentiated and integrated are the conceptual structures of chemistry, the higher is the realization of chemists' creative talents. This relationship allows us to assess creative talent in adolescence and adult age authentically.

Keywords: Creativity, Intelligence, Competence, Conceptual structures, Differentiation-integration principle of development, Gifted chemists.

Introduction

The riddle of creativity has been attracting scholars in different academic disciplines for centuries. In general, creativity can be defined as an ability to produce novel, original work that fits with task constraints (Lubart, 1994). There are many different ways to produce an idea that may be novel or original. For example, to reiterate a known idea in a new way, to move an idea forward along its current trajectory, to move an idea forward in a new direction, or to integrate an idea in diverse trends (Sternberg, Kaufman, Pretz, 2002).

In this paper, we put forward a hypothesis about the relationship between the emergence of new ideas and the formation of a detailed level of cognitive conceptual structures relevant to the object of activities. This hypothesis is a consequence or by-product of our study of gifted chemists. Comparing student-chemists and student-psychologists, as well as more successful and less successful chemists, we obtained results that are hard to explain from the point of view of both psychometric and cognitive approaches. First, in spite of the fact that the real creative achievements of student-chemists compared with student- psychologists were higher, they had lower scores of creativity (Torrance's tests), than student-psychologists. Second, gifted chemists did not differ from less successful chemists by the indicators of intelligence, creativity and academic achievement scores (math, physics). However, we found quite a lot of data pointing to the peculiarity of chemical images in gifted chemists. The occurrence of chemical drawings in

Torrance's figural creativity test is interrelated with the formation of detailed level of conceptual structures of chemistry underlying chemists' special abilities. All gifted chemists, who took part in our research, successfully realized their potentials in professional activities. Our results revealed that the "chemical" images in Torrance's figural creativity test can serve as a reliable criterion for identifying gifted chemists. These facts allowed us to suggest a new approach to the comprehension of the nature of creativity.

Literature Review

The problem of creativity is extensively presented in psychological literature. The works are devoted to various aspects of this phenomenon, for example, the relationship between creativity and personality traits (Barron, Taylor, 1963; Feist, 1998; Houtz, Selby, Esquivel, Okoye, Peter, Treffinger, 2003; Sheblanova, 2011), creativity and intelligence (Guilford, 1967; Torrance, 1966; Ponomaryov, 1999; Druzhinin, 1998; Cho, Nijenhuis, Vianen, Kim, Lee, 2010.), creativity and thinking styles (Martinsen, Kaufmann, 1999; Wechsler, Vendramini, Oakland, 2012), creative styles and personal type (Houtz, Selby, Esquivel, Okoye, Peter, Treffinger, 2003). There are studies of gender differences in manifestations of creativity (Baer, 1999; Volkova, 2012).

Broadly speaking, all of these studies of creativity can be divided into three groups depending on the approaches: (1) well-known psychometric, (2) cognitive and (3) differentiation-integration approach, which is quiet a new field of creativity research.

Francis Galton can be regarded as the founder of psychometric approach to creativity. We can find roots and principles of psychometric approach to creativity in his famous monograph "Hereditary Genius" (Galton, 1869), where some basic assumptions of modern differential psychology were presented. The individual is viewed as a totality of fixed situation-independent attributes. For the assessment of mental excellence, Galton adopted statistical tools - the normal distribution. Instead of describing the ways, in which the creative person was extraordinary in its true sense, "mental excellence" was reduced to a single dimension, on which individuals are arranged according to their outcome in a series of comparisons. The set of interindividual differences determined thus the degree of mental excellence ascribed to the individual. Moreover, in psychometric approach, creativity is a domain-independent general-purpose ability that can be distilled from possible content. Gruber justifiably pointed to the controversial issue of the psychometric approach. In his opinion, the creativity, measured within this tradition, shows only poor correspondence to real-world achievements and that this approach suffers from a lack of validity (Gruber, 2005).

Psychometric analysis usially provides moderate correlations between "creativity" and "intelligence", between "openness to experience" and scores on the "Big Five". Unquestionably, correlations may indicate that some sort of relationship exists between creativity and the individual's traits, but they do not explain why and how creative working is brought about. The second, cognitive approach has its roots in Gestalt psychology: Köhler's description of insight (Köhler, 1976), Duncker's study of problem solving (Duncker, 1945) and Wertheimer's productive thinking (Wertheimer, 1945). In contrast to the psychometric approach, the cognitive research on creativity is focused on the creative process itself. Creativity is regarded here as an essential property of human thinking in general. The main purpose of the creative cognitive approach is to analyze the structural underpinnings of creative thought processes. Here, creative thinking was shown to occur as a conceptual combination, grouping, generalization, analogical reasoning, etc. In order to lay bare the essential features of creative thought in a standard setting, the individual is to perform a task that requires some sort of creative inventions, i.e. he/she is to solve classical insight problems, design new furniture, or construct a practical device of given geometrical forms. It should be noticed, there are a similarity between creative cognitive studies and the psychometric approach: the creative process is isolated from its possible content.

The differentiation-integration (DI) approach to creativity research, in comparison with psychometric and creative cognitive studies, is not so widely spread in psychological literature. The differentiation-integration methodology of creativity research is based on the similarity of mechanisms of growth of knowledge, evolution of science and ontogenetic mental development. For instance, according to Piaget and Garcia, conceptual development in childhood and the historical transformation of concepts share the same regulatory mechanisms (Piaget, Garcia, 1989). This similarity consists in moving from a state of relative "globality" and undifferentiatedness toward a new state of increasing differentiation and hierarchical integration (Werner, 1957ab; Chuprikova, 2007). The fundamental feature of DI approach is that creative process, intelligence and competence are included in individual's real mental activity as part of the whole, as part of the developing being.

The similarity between the "artist's organic creativity, who engenders works of art, and the nature (substantive actor) that give birth to organisms" testifies to the fact that human creativity and nature's creativity are based on the same principle of differentiation" (Lossky, 1995).

Y.A. Ponomaryov also noted that the form of child development in ontogeny and the form of child behavior are similar to the patterns of individual's behavior who is solving a complex creative task (Ponomaryov, 1999), i.e., creativity is an interaction process that leads to the development of new capabilities and new skills.

Howard E. Gruber, following Piaget's ideas, united the trajectory of intellectual development, the growth of thought and the question of how new ideas come into being in his research on scientific creativity (in particular, in his studies on the development of Darwin's theory of evolution (Gruber, 1974)). Gruber's case studies are devoted to the development of thought, to its structural make-up, the anatomy of conceptual changes as well as their cultural and historical preconditions. Gruber described the cognitive structures and mechanisms, i.e. the tools used in scientific thinking, and thus offered in-depth analysis of creative development.

The ideas of differentiation-integration approach already found their reflection in other studies. For instance, B.B. Kossov showed that "students with more differentiated and complex subjective semantic material proved to be more creative" (2003, p. 60). The results obtained by this author emphasize the important role of the processes of differentiation in learning, mental development and real creativity.

B.B. Kossov believed that higher noticeability and higher differentiation sensitivity to concrete conditions in problem situations connected to special human abilities underlies creative intuition (Kossov, 1997). The author concluded that the noticeability factor is linked to creative abilities and their development. This factor is a subjective aspect and, probably, is a cause for differentiation of mental structures.

Connection between the indicators of creativity and the level of differentiation-integration of mental structures was investigated in M.A. Kholodnaya's works (2013).

Metodology

Metodology of our approach to creativity research is based on two interrelated premises of differentiation-integration theory of development (DI theory):

1. General universal law or principle of organic systems development is the principle of systems differentiation and integration. It holds that development involves moving from

states/forms of relative globality and undifferentiatedness towards new states/forms of ever-increasing differentiation and hierarchical integration (Werner, 1957ab; Chuprikova, 2007).

2. There are some assumptions that certain mental structures (multidimensional representative cognitive structures in long-term memory) underlie human psychological development including the development of intelligence, competence and creativity (Vekker, 1981; Kholodnaya, 2002; Chuprikova, 2007; Volkova, 2011).

A lot of studies are known to have been devoted to the peculiarities of the organization and formation of mental structures ("cognitive maps" (Tolman, 1948), "plan" (Miller, Galanter & Pribram, 1960), "scheme" (Kant, 1855; Bartlett, 1932; Piaget, 1951; Neisser, 1976), "representation" (Chuprikova, 2007), "mental experience", "concept" (Kholodnaya, 2002) "core structure" (Sergienko, 2009) , "structure of individual experience" (Alexandrov, Alexandrova, 2007), etc.

Mental structure in our context is an ontological model of the mind. The most important functions of the mental structure are representation, selection and transformation of reality into abstract and concrete forms. These structures are integrated psychological formations that represent all the levels of information about the internal and external conditions of person's life.

Information about the external and internal conditions, contained in these mental structures, performs the function of selection and limitation of the initial conditions, thus defining the direction of the person's mental development. Empirical evidence suggests that the mental structures, as a result of the past and the present experience, determine the range of possibilities of mental activity in present and future (Volkova, 2013c).

The uniqueness of the mental structure lies in the fact the mental structure is a kind of a "crossing point" of the past, present and future.

The highest organization level of mental structures is the internal concept.We must distinguish the external concept and the internal concept.

The external concept is a concentrated expression of historically acquired knowledge about object or phenomenon.

The internal concept fixes the information about the features of mental reflection of an object and historical knowledge about this object depending on the organization peculiarities of person's mental structure of experience.

Research Design

A study was conducted in 2002–2006. Participants of the experiment were Russians. 374 second-year students (19-years-old, 60% female) of the Chemistry Department (Ural State University), 100 third-year-students (female, 20-21-years-old) of Psychology Department and 6 experts in chemistry (men, aged 40-47-years) were recruited.

A complex of methods were used in our research including different techniques of assessment of creativity (TTCT), intelligence (WAIS, SPM), academic achievement (chemistry, math, physics), personality traits (QFDTI, 16 PF) and different aspects of special chemical abilities.

Torrance Tests of Creative Thinking (TTCT). The Russian version of the TTCT (Tunick, 1998) is an adaptation of the American version (Ball & Torrance, 1992). It consists of a verbal (verbal creativity) and a figural (nonverbal creativity) test battery. Torrance's verbal creativity test consists of seven subtests which require the production of written words: asking, guessing causes, guessing consequences, suggesting new ideas for improving a elephant-toy (product improvement), using carbon boxes in an unusual way (unusual uses), asking unusual questions about them and the imagination of unusual situation (just suppose). The scoring system, used in this research, was based on the streamlined procedure presented by Torrance, which enabled to identify three indicators of verbal creativity (fluency, flexibility and originality).The Torrance's figural creativity test consists of three subtests which require the production of drawings: picture construction, picture completion and parallel lines. The use of this test permitted us to identify the well-known creativity indicators: fluency, originality, elaboration, resistance to premature closure and abstractness of titles.

"Fluency" reveals a person's ability to generate a great number of meaningful ideas.

"Flexibility" reflects an ability to apply different strategies to solve problems and ability to examine the information available from different perspectives.

"Originality" describes an ability to invent unusual unique responses that require creative power. The concept of "creative power", according to Guilford and Torrance, consists in the fact that common, obvious answers (more than 5% of subjects) do not require great mental tension in the process of their creation. Such answers are evaluated by a score of zero. For each subtest, the lists of answers are given: 0 points – common answers, 1 point - from 2 to 4,99 % of all the sample, 2 point - less than 2% of the subjects.

"Elaboration" reflects an ability to develop ideas in detail.

"Abstractness of title" allow us to determine the level of understanding of the essence of the problem and the ability to transform nonverbal information to verbal information.

"Resistance to premature closure" reflects an ability not to follow stereotypes and to remain for a long time open to various information when solving problems.

Since the transfer of the scores from the standardization sample to another sample gives mistakes, we elaborated standard scores for second-year students of chemical department and for third-year students of psycholody department (Volkova, 2011).

Raven's Standard Progressive Matrixes (SPM) is a well-validated measure of fluid reasoning ability (gF) (Carpenter, Just, & Shell, 1990). The Raven's Standard Progressive Matrixes contains 60 nonverbal items (Raven, Court, Raven, 1992). Each item consists of a 3 × 3 matrix with a missing piece to be completed by selecting an answer from six or eight alternatives.

Wechsler Adult Intelligence Scale. The WAIS is a general test of intelligence measuring the global capacity of a person to act purposefully, to think rationally, and to deal effectively with environment (Wechsler, 1981). The Russian version of the WAIS (Filimonenko & Timofeev, 1995) is an adaptation of the American version (Wechsler, 1955). It consists of 11 subtests: Information, Comprehension, Arithmetic, Similarities, Vocabulary, Digit Span, Block Design, Object Assembly, Picture Completion, Digit Symbol, and Picture Arrangement.

Academic achievement was estimated as a mean score on chemistry, math or physics (0-5 points). 5 points corresponds to an excellent knowledge, 0-2 points correspond to poor knowledge.

Questionnaire of Formal Dynamic Traits of Individuality (QFDTI, Rusalov, 2007) has 150 items presenting 12 temperamental scales: motor ergonicity, social ergonicity, intellectual ergonicity, motor tempo, social tempo, intellectual tempo, object-related plasticity, social plasticity, plasticity intellectual, object-related emotionality, social emotionality, intellectual emotionality.

Sixteen Personality Factor Questionnaire (16 PF, Kattell) has 187 items presenting 16 kinds of the personality traits. The Russian version of the16 PF (Rukavishnikov, Sokolov, 2006) is an adaptation of the American version (Kattell, Eber, Tatsuoka, 1970).

For the assessment of different aspects of *special chemical abilities* method “GreatChemist” (Volkova, 2011), method of short-term “chemical” memory (0-10 points; Volkova, 2011), method of direct scaling of components of chemical abilities (0-100 points, Volkova, 2011); method of “chemical” intuition (0-60 points); map of interests (-10 to +10 points) were used in our research.

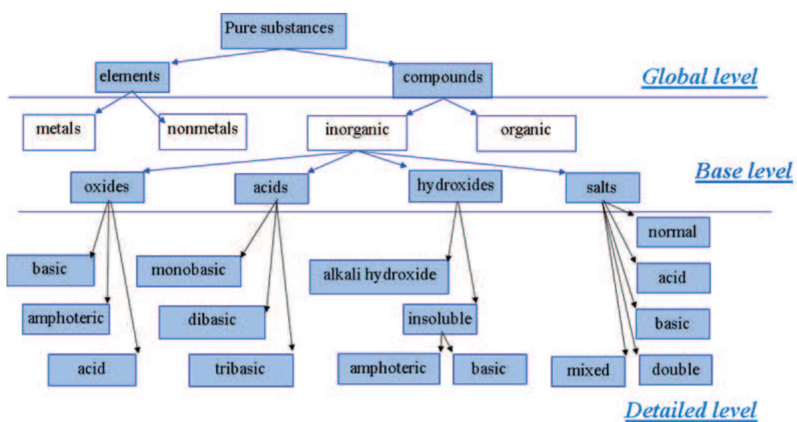
The “GreatChemist” test was constructed for the estimation of organization of internal concept "substance".

The formulas of chemical compounds appear on the screen at a random order:

HCOO – $(CH2)_4$ – COOH, $(NH4)_2SO_4$, Mn_2O_7, Rb_2O, Cu, C, Co, Cl, N≡N…

The participant was to divide these stimuli into groups according to the instruction: into two groups (global level), into 4 groups (basic level), into 14 groups (detailed level) (Picture 1).

The purpose of the test is to measure the choice reaction time, quantity of errors and quantity of levels formed. We think that the level was formed, if the accuracy of responses reached at least 90%.



Picture 1. Levels of Organization of the Concept “Substance”.

Results

In opinion of many scholars, chemistry is a creative profession. For example, John C. Olsen (1928, p. 1285-1286) wrote: “A successful career in the chemical field requires the ability to do original work. In this respect the work of the chemist is almost unique.” Mary M. Kirchhoff (Kirchhoff, 2011, p. 1), analyzing the problem of alarming drop in U.S. student creativity (while IQ scores have risen over time, creativity quotient scores have declined), proposed to study chemistry for solving the problem of creativity crisis: “Chemistry is a marvelous way to teach creativity. Chemists are molecular designers, applying their skills and knowledge to create new products and processes."

Hypothesis 1. Based on similar arguments, we assumed that the more chemists are successful, the higher are the indicators of creativity (by Torrance's test of creative thinking).

As is accepted at the early stages of research of special abilities, chemical academic achievement (4.7 points on 5-point scale) was used as a criterion for dividing students into 2 groups.

We were very surprised when our hypothesis was not confirmed. Mathematical analysis, both parametric and non-parametric methods, of the differences between two independent samples did not show any significant differences in the indicators of creativity (Table 1). The result can be explained by the existence of special abilities (or domain-specific creative thinking ability according to Hong & Milgram, 2010), not diagnosed by Torrance's test. As is well known, special abilities allow gifted chemists to achieve higher results in their professional activities.

Table 1. Differences between more successful and less successful students by Torrance's test

Indicators of creativity	Mean		Independent-samples T-test
	More successful	Less successful	
verbal creativity			
fluency	48.6	51.19	-1.733
flexibility	48.62	51.26	-1.602
originality	51.09	50.64	0.206
verbal creativity	49.43	51.03	-1.022
nonverbal creativity			
fluency	48.43	51.54	-1.337
originality	50.37	49.41	0.436
elaboration	52.00	49.76	0.882
abstractness of titles	50.28	49.98	0.140
resistance to premature closure	50.99	50.21	0.363
nonverbal creativity	50.43	50.03	0.227
number of chemical images	1.32	0.49	3.253**

Sig. (2-tailed)* p≤0,05; ** p≤0,01; *** p≤0,001.

However, we found quite a lot of data pointing to peculiarity of chemical images (round-bottomed flask, funnel, analytical balance, atomic orbital, benzol, etc.) in gifted chemists while processing the test results. Similar data were obtained in the studies of creative thinking in students with other special abilities. Highly gifted musicians often draw musical instruments (harp, piano, flute, drum, etc.). Gifted mathematicians draw geometric shapes and mathematical equations (Giftedness and age, 2004).

Our attention was drawn by the following unusual fact. By far not all students who studied chemistry for many years (6 years) drew chemical images (only 25 %). We wondered why only some students drew images of chemistry (We called such participants “depicting”), while the others who didn’t draw chemical images (“nondepicting”).

To understand why we didn’t find chemical images in the answers of all students-chemists, we divided the participants into two groups. The first group consisted of students who drew “chemical images” (“depicting” students). The second group included those who did not use “chemical image” at all (“nondepicting” students).

It is necessary to stress that the number of “chemical images” in Torrance’s figural creativity tests in more successful chemists was significantly higher than in less successful participants (Table 1).

Hypothesis 2. We assumed that the more chemists are successful, the more is the probability of drawing chemical images in the Torrance’s test.

Mathematical analysis did not reveal significant differences between “depicting” and “nondepicting” chemists in math and physics academic achievements, in the indicators of creativity as well as in the indicators of intellectual development (WIAS, SPM). There were no statistically significant differences in the span of short-term memory (words), in motor and social indicators of ergonicity, plasticity and speed (QFDTI).

The most significant differences were found in the indicators of maturity of conceptual structures of chemistry (organization of the concept “substance") and chemical abilities: chemical academic achievement, reaction time (simple, complex and most complex chemical differentiations), the span of “chemical” memory, chemical intuition, interest in the study of chemistry and the subjective assessments of chemical abilities. These data are presented in the table 2.

Table 2. Differences between “depicting” and “nondepicting” students in chemical abilities

Indicators	Mean		Independent-samples T-test
	“depicting” students	“nondepicting” students	
Chemical academic achievement	4.05	3.75	2.343*
Interest in the study of chemistry	8.14	6.30	2.788**
Organization of the concept “substance"			
Global level, T1, sec	37.68	51.79	-4.38***
Basic level, T2, sec	45.14	50.20	-2.096*
Detailed level, T3, sec	174.48	202.10	-2.453*
Methods of evaluating the short-term “chemical” memory (10 words)			
Memory span, (10 words)	8.25	8.27	-0.108
Memory span, (10 chemical elements united by group law)	9.85	9.68	2.095*
Memory span, (10 chemical elements united by periodic law)	9.34	8.97	2.243*
Memory span, (10 chemical elements)	8.22	7.61	2.484*
“Chemical” intuition, (0-60 points)	20.8143	16.0000	3.333***
Method of direct scaling of components of chemical abilities, (0-100 points)			
“Chemical” direction of mind	61.96	54.89	1.914
“Chemical” memory	66.46	59.33	2.051*
“Chemical” intuition	62.00	55.79	1.609
“Chemical” language	71.43	59.80	3.529***
“Chemical” thinking	67.00	58.16	2.518*
“Chemical hands”	66.03	63.71	0.536
Ability to solve chemical problems	74.50	60.01	4.67***

Sig. (2-tailed)* p≤0,05; ** p≤0,01; *** p≤0,001.

The “GreatChemists” test revealed a higher ability to differentiate physical and chemical phenomena, detect oxidation-restoration processes, the ability to forecast the direction of chemical processes in response to changes in the external medium.

The most important fact was obtained by comparing the organization of conceptual structures in the gifted and the less successful chemists (Table 3). It is necessary to emphasis that detailed level of concept “substance" is formed only in gifted chemists. This fact allows us put forward a hypothesis about the relationship between the emergence of new ideas and the formation of a new (detailed) level of cognitive conceptual structure. Apparently, the highly differentiated conceptual chemical structures cause a creative nature of chemical thinking and allow chemists to find new interesting facts in the substances “up and down investigated in usual chemical practice” (Chemists about themselves, 2001, p. 149).

Table 3. Time (T, sec) and accuracy (n - errors) of chemical stimulus-objects distinction in different groups of participants

Participants	Levels of the organization of the concept “substance"					
	Global level		Basic level		Detailed level	
	t1, sec	n1	t2, sec	n2	t3, sec	n3
	Less successful					
19- year-olds (260 persons)	**39.43**	**1.52**	**49.29**	**0.27**	153.1	6.97*
	More successful (gifted chemists)					
19-year-olds (68 persons)	**36.5**	**0.31**	**46.53**	**0.08**	**122.75**	**3.6**

6.97* – The level has been formed, if the accuracy of responses reaches at least 90%, that is less than 4.

The “depicting” students had higher values of Kattell’s factor G (responsibility, commitment and integrity, accuracy and self-control) and lower values of the factor F (reliability, seriousness of attitude toward life and work). The data obtained conform to the G.J. Clark’s and W.D. Riley’s study (Clark, Riley, 2011), biographical essays “Great chemists” (Manolov; 1976), "Chemists about themselves" (2001), etc.

Regression analysis shows that academic achievement in chemistry (y) and the level of special abilities of chemists (x) is determined by different personality traits. $y=4,598+0,038N$, $x=23,713+3,307F+3,475G$.

That is, academic achievements are associated with self-adaptive (N), meanwhile the chemical abilities are due to factors G and F.

It should be noted that the students who drew formulas of organic compounds later chose the Department of organic chemistry. The students who drew diagrams of chemical processes chose the Department of physical chemistry. The students who drew “analytical glassware” preferred analytical chemistry. Subsequently, all these students successfully realized their potentials in professional activities.

The results of testing of highly-professional chemists, who are “born to be chemists”, according to the experts, showed a great number of chemical images in the Torrance’s test and high level of differentiation-integration of the concept "substance”. That is, the date obtained corresponds to the date of gifted student-chemists. Thus, the "chemical" images in Torrance’s figural creativity test can serve as a reliable criterion for identifying gifted chemists.

Hypothesis 3. We assume that the occurrence of chemical drawings in Torrance's test can be caused by a higher degree of differentiation-integration of the conceptual structures of chemistry underlying chemists' special abilities.

The data obtained (One-Way ANOVA) have confirmed this assumption. The significant relationships were found between the number of chemical images and the reaction time of the most complex chemical differentiations (F = 2.315 *), the time of distinction of oxidation-restoration processes (F = 3.398 **), the time of distinction of the spatial structures (F = 2.479 **), the time of distinction of the reversible-irreversible chemical processes (F = 2.927**) and the time of differentiation of acidity of the solution (F = 2.603 **), and etc. It is necessary to emphasize that the ANOVA showed that there are links between the number of chemical images and the reaction time indicators in case of highly complex chemical differentiations (detailed level of concept "substance"). The more differentiated and integrated are the conceptual structures of chemistry, the higher is the probability of using chemical images.

Conclusion

The main drawback of psychometric and cognitive approaches to creativity research is that a creative process is isolated from its possible content. That is why these approaches suffer from a lack of validity. To improve their predictive validity, the domain-general and domain-specific creative thinking abilities were introduced (Hong & Milgram, 2010). However, the most important question about the relationship between the scores of these creative thinking abilities and realized creative talents in life remains unsolved. We believe that DI aproach to creativity research constitutes a significant contribution to the clarification of this issue.

1. As we noted above, this study was conducted in 2002–2006. Seven years later, we could estimate the prognostic capabilities of differentiation-integration approach as a predictor of creativity success. All of the "depicting" students who took part in our experiment have a successful career in the chemical field. They are creating new products and discovering new chemical processes. That is, the "chemical" images in Torrance's figural creativity test can serve as a reliable criterion for identifying gifted chemists.

2. The participants of our study had a high level of intelligence (above 120 IQ, WAIS). According to our research (Volkova, 2011), there are threshold of intelligence. At 115-120 IQ intelligence and creativity are independent factors. At 125-129 IQ intelligence and chemists' special abilities become independent factors, too. Consequently, the indicators of special abilities have the most predictive power with chemists' IQ above 125-129.

3. Our findings revealed that there is the relationship between the emergence of new ideas and the formation of a new (detailed) level of cognitive conceptual structures relevant to the object of activities. It is probable that this fact underlies the operations of the mechanism of clue or the emergence of a hypothesis in the conditions of the creative process. That is, a certain kind of "adjustment" of conceptual structures with the help of a clue is taking place like musical tools or voice is adjusted to a tuning fork. The highly differentiated structures are able to form a larger variety of new temporary relationships and unusual combinations. The probability increases of the formation of integrative structures which correspond to a higher degree to invariant characteristics of the object under study. This phenomenon is well known under different names such as "sudden inspiration" or "insight". This phenomenon can be explained as a result of the coincidence of external conditions of thinking with the conceptual structures reflecting relevant properties of the object.

4. The highly differentiated conceptual structures reflecting relevant properties of the object are a systems factor uniting all the traits of the person as a whole, which are necessary for successful professional creativity.

5. Our research revealed that detailed level of the concept “substance" is formed only in gifted chemists. This fact allowed us to develop an educational program which provides the transition from operation by global, not differentiated images of chemical reality to the operation by more and more differentiated elements, properties and relations (Volkova, 2013 a). Thus, the present work convincingly demonstrates a great possibility of the differentiation-integration approach to creativity resrarch both in understanding how new ideas appear and what should be done to develop human creative abilities.

References

1. Aleksandrov Y., Aleksandrova N. (2007). Subjective Experience and Culture. Structure and Dynamics. *Social Sciences. A Quarterly Journal of the Russian Academy of Sciences,* V. 38, № 3, 109–124.
2. Baer, J. (1999). Gender differences. In M. A. Runco & S. F. Pritzker (Eds.). Encyclopedia of creativity (pp. 753-758). Vol. 1, San Diego, CA: Academic Press.
3. Ball, O. E., Torrance, E. P. (1992). Torrance Test of Creative Thinking. Scholastic Testing Service, Inc., Illionois.
4. Barron, F., Taylor, C. (1963). Scientific creativity, its recognition and development. New York: McGraw-Hill.
5. Bartlett, F. C. (1932). Remembering. Cambridge: Cambridge University Press.
6. Carpenter, P. A., Just, M. A., & Shell, P. (1990). What one intelligence test measures: A theoretical account of the processing in the Raven Progressive Matrices test. *Psychological Review*, 97, 404-431.
7. Cho, S. H., Nijenhuis, J. T., Vianen, A. M. V., Kim, H. B., Lee, K. H. (2010). The relationship between diverse components of intelligence and creativity. *Journal of Creative Behavior*, Vol. 44, Number 2, 125-137.
8. Chemists about themselves. (2001). Moscow. (in Russian).
9. Chuprikova, N. I. (2007). Psychology of cognitive development: Principle of differentiation. St.-Petersburg. (In Russian).
10. Clark, G. J., Riley, W. D. (2001). The Connection between Success in a Freshman Chemistry Class and a Student's Jungian Personality Type. *Journal of Chemical education,* Vol. 78, № 10, 1406-1411.
11. Druzhinin, V. N. (1998). Intelligence and productivity activities: model of intellectual range. *Psychological Journal,* Vol. 19, № 2, 61-70. (in Russian).
12. Duncker, K. (1945). On Problem-Solving. Psychological Monographs 58:1-13.
13. Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review*, 2, 290–309.
14. Filimonenko. Yu., Timofeev, V. (1995). Manual for D. Wechsler’s intelligence test for adult (WISC) / Ed. O. I. Muliar. SPb.: Imaton.
15. Galton, F. (1869). Hereditary Genius. London. (in Russian).
16. Giftedness and age. (2004).The development of the creative potential of gifted children. Moscow–Voronezh.
17. Gruber, H. E. (1974). Darwin on Man: A Psychological Study of Scientific Creativity. Together with Darwin's Early and Unpublished Notebooks transcribed and annotated by Paul H. Barrett; Foreword by Jean Piaget. New York, NY: E. P. Dutton.
18. Gruber, H.E., Bödeker, K. (eds.) (2005). Creativity, Psychology and the History of Science, 1-18. Springer.
19. Guilford, I. P. The nature of human intelligence. (1967). New York: McGraw-Hill.

20. Hong, E., Milgram, R. M. (2010). Creative Thinking Ability: Domain Generality and Specificity. *Creativity research journal*, 22(3), 272–287.

21. Houtz, J. C., Selby, E., Esquivel, G. B., Okoye, R., Peter, K. M., Treffinger, D. J. (2003). Creative styles and personal type. *Creativity Research Journal*, 15, 321–330.

22. Kirchhoff, Mary M. International Year of Chemistry: An Educational Opportunity (2011). *Journal of Chemical Education,* Vol. 88, No. 1, 1-2.

23. Kattell, R., Eber, H., Tatsuoka M. (1970). Handbook for the Sixteen Personality Factor Questionnaire (16 PF). Champaign, lllinois, Institute for Personality and Ability testing.

24. Kholodnaya, M. A. (2002). Psychology of intelligence: paradoxes of research. St.-Petersburg. (In Russian).

25. Kholodnaya, M. A. (2013). Differentiation and integration in organization of conceptual structures in connection with creativity manifestations. In differentiation-integration theory of development: Philosophical interpretation and application to psychology, linguistics and education. (pp. 28-29). M.: Publishing House "Institute of Phychology RAS".

26. Kossov, B. B. (1997). Creative thinking, perception and personality. Moscow – Voronezh. (in Russian).

27. Kossov, B. B. (2003). Some laws of perception, differentiation and identification of simple and complex objects. *Psychology,* 1, 50-60. (in Russian).

28. Kant, I. (1855). Critique of Pure Reason. Translated from the German by J. M. D. Meiklejohn,

29. Köhler, W. (1976). The Mentality of Apes. New York: Liverighi.

30. Lossky, N.O. (1995). Sensual, intellectual and mystical intuition. M: Republic. (in Russian).

31. Lubart, T. (1994). Creativity. Thinking and problem solving (pp. 289–332). New York, NY: Academic Press.

32. Lubart, T. I. (2001). Models of the creative process. *Creativity Research Journal*, 13, P. 295–308.

33. Martinsen, O., Kaufmann, G. (1999). Cognitive styles and creativity. In M. A. Runco & S. R. Pritzker (Eds.), Encyclopedia of creativity (pp. 273-282). Vol. I. New York, NY: Academic Press.

34. Mumford, M. D., Hester, K. S., Robledo, I. C., Peterson, D. R., Day, E. A., Hougen, D. F. & Barrett, J. D. (2012): Mental Models and Creative Problem-Solving: The Relationship of Objective and Subjective Model Attributes. *Creativity Research Journal*, 24(4), 311-330.

35. Manolov, K. (1976). The great chemists. Moscow: "Mir", Vol. 1, 2. (in Russian).

36. Miller G. A., Galanter E., & Pribram K. H. (1960). Plans and the structure of behavior. N. Y.: Holt, Rinehart and Winston.

37. Neisser, U. (1976). Cognition and reality: principles and implications of cognitive psychology. WH Freeman.

38. Olsen, John C. (1928). The work of the exceptionally gifted student in chemistry and chemical engineering. *Journal of Chemical Education*, Vol. 5, No. 10, 1282-1286.

39. Piaget, J. (1951).The Psychology of Intelligence. London: Routledge and Kegan Paul.

40. Piaget, J., Garcia, R. (1989). Psychogenesis and the history of science. New York: Columbia University Press.

41. Ponomaryov, Y.A. (1999). Psychology of creation. Moscow: MPSI, Voronezh: MODEK. (in Russian).

42. Raven, J. C., Court, J. H., Raven, J. (1992). Manual for Raven's Progressive Matrices and vocabulary scales. Oxford: Oxford psychologists press LTD.

43. Rukavishnikov, A. A., Sokolov, M. V. (2006). Factor personality questionnaire R. Kattell (C): guidance. SPb.: Imaton. (In Russian).

44. Rusalov, V. M., Trofimova, I. N. (2007). The structutre of Temperament and its Measurement. Toronto, Canada: Psychological Services Press.

45. Sergienko, E. A. (2009). Principles of differentiation-integration and continuity-discrete mental development. In The theory of development: differential-integration paradigm. (pp. 131-150). Moscow: Languages of Slavic Cultures. (In Russian).

46. Sheblanova, E. I. (2011). The influence of IQ on the personality traits of gifted teens. In Psychology and differential psychophysiology today (pp. 349-352). Moscow. (in Russian).

47. Sternberg, R.J., Kaufman, J., & Pretz, J.E. (2002). The creativity conundrum. New York: Psychology Press.

48. Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review*, 55, 189-208.

49. Torrance, E.P. (1966). The Torrance Tests of Creative Thinking. Norms, Technical manual. Research Edition. Verbal and Figural Tests (Forms A and B). Princeton, NJ: Prentice Hall.

50. Ball, O. E., Torrance, E. P. (1992). Torrance Test of Creative Thinking. Scholastic Testing Service, Inc., Illionois.

51. Tunick, E. E. (1998). Diagnosis of creativity, Manual for test E. Torrance. St. Petersburg: Imaton. (In Russian).

52. Vekker, L. (1981). Mental processes. Leningrad. (In Russian).

53. Volkova, E. V. (2011). Psychology of special abilities: differentiation and integration approach. Moscow: IP RAS. (In Russian).

54. Volkova, E.V. (2012). Gender difference of creativity. In Development of psychology in the system of integrated about the human nature. (pp. 785-789). M: Publishing House “Institute of Psychology RAS”. (in Russian).

55. Volkova, E.V. (2013a) Developmental Learning: Theoretical and Empirical Considerations. *Procedia - Social and Behavioral Sciences*, 82, 81 – 86.

56. Volkova, E. V. (2013b). Differentiation-integration mechanism of development of conceptual structures as the central link of creativity. In differentiation-integration theory of development: Philosophical interpretation and application to psychology, linguistics and education. (pp. 30-32). M.: Publishing House “Institute of Phychology RAS”.

57. Volkova, E. V. (2013c). Triune aspect of the functional organization of the concept: Past, Present and Future. *World of Psychology*, 2, 29-41. (In Russian).

58. Wechsler, D. (1955). Manual for the Wechsler adult intelligence scale. New York.

59. Wechsler, D. (1981). WAIS manual; Wechsler Adult Intelligence Scale-Revised. New York: The Psychological Corporation.

60. Wechsler, S. M., Vendramini, C. M. M., Oakland, T. (2012). Thinking and Creative Styles: A Validity Study. *Creativity Research Journal*, 24(2–3), 235–242.

61. Werner H. (1957a). The concept of development from a comparative and organisms point of view. In The concept of development (pp. 125-148). Minneapolis.

62. Werner, H. (1957b). Comparative psychology of mental development. New York.

63. Wertheimer, M. (1945). Productive Thinking. New York: Harper & Row.