



ICEEPSY 2014

## Cognitive learning technology: DI-approach<sup>1</sup>

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### Abstract

The main difficulty of contemporary pedagogical practice lies in the fact that it is still based on empirical experience of their outstanding representatives, rather than on the objective laws of mental development. The purpose of the study was to prove that the organization of education according to the principle of systems differentiation and integration (DI theory) of mental structures as a substratum of mental development offers a more efficient way for the improving of education quality. To estimate the effectiveness of cognitive learning technology built on DI theory comparative forming experiment was organized. The control group consisted of the schoolchildren of the same age but studying chemistry without applying the DI law of development. Diagnostic system included techniques of assessment of intelligence, cognitive style, academic achievement (chemistry), and different aspects of special chemical abilities. The findings of formative experiments convincingly demonstrate that the organization of education according to the law of mental development (principle of system differentiation and integration) is more successful than education based on intuitive insight, art, and empirical experience of their outstanding representatives. The differentiation-integration theory of development helped us to devise an educational technology which ensures a natural course of cognitive development. Moreover, the techniques of assessment of quality of knowledge built on the DI theory allow us to define a zone of proximal development and thus to organize the education process which leads to the intellectual development of every student.

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Peer-review under responsibility of the Organizing Committee of ICEEPSY 2014.

*Keywords:* Technology, intelligence, conceptual structures, development, adolescents.

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<sup>1</sup> The study is supported by RSF grant (project №14-28-00087), Institute of Psychology RAS.

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## 1. Introduction

The human capital, namely, knowledge, skills, abilities of people which manifested in social and professional activities is a key factor in the development of innovative society. How intellectual competence is achieved and to what extent the strategy of management of human capital is realized is a "zone of responsibility" of psychological science.

It is generally accepted that in order to educate man in all aspects, the educator should know him in all respects. Nobody argues that psychological science is a methodological basis for pedagogical practice. Nevertheless, the main difficulty of contemporary pedagogical practice lies in the fact that it is still based on intuitive insight, art, and empirical experience of their outstanding representatives, rather than on the knowledge of the objective laws of mental development.

The goal of my research was to prove that the organization of education according to the principle of systems differentiation and integration (DI theory) of mental structures as a substratum of mental development offers a more efficient way for the improving of education quality.

This paper restricts itself to the study of methodological foundations of cognitive learning technology in chemistry classes.

Why do most of the students experience difficulties in learning chemistry? There are a lot of reasons for this (Lisichkin, Leenson, 2013). Such problems as 1) the contents of the textbooks, 2) professionalism of teachers, 3) educational technology, 4) students' personal traits (working memory, intelligence, motivation, and so on) are most often mentioned in scientific literature. As to the fourth reason, psychological data are well known that the less is the working memory span, the less successful is the student in chemistry (Danili, Reid, 2004). Moreover, according to our research (Volkova, 2011a), there is an intellectual threshold for successful mastering of chemical knowledge (IQ 110 points WAIS). The question arises how to help those students whose working memory and intelligence are insufficient for successful learning of chemistry?

The solution to this problem is connected with the quality of chemistry textbooks and educational technology.

As early as the beginning of the past century, L.S. Vygotsky wrote about the need to elaborate such educational programs that would be consistent with the laws of mental development. The scientist dreamed of developing of such a tool, with the help which one could be able, like with X-rays, to reveal changes caused by the learning process (Vygotsky, 1991).

Nevertheless, the analysis of the textbooks showed (more than 100 textbooks published in the United States, Great Britain, Bulgaria, Russia, Kazakhstan, Ukraine, etc.) that the logic of the contents of chemical knowledge does not match to the principle of cognitive development. This principal holds that cognitive development involves a passing from a state of relative globality and undifferentiatedness towards the state of ever-increasing differentiation and hierarchic integration (Werner, 1957; Chuprikova, 2007; Volkova, 2011b; et al.).

## 2. Structure of cognitive learning technology

Consider briefly cognitive learning technology. The structure of all educational technologies consists of three basic components such as 1) conceptual basis, 2) contents, and 3) technological process itself. These are presented in table 1.

Table 1. The principal components of cognitive learning technology.

Components	The main issues that should be addressed are
1. Conceptual basis of technology	1. What are the objective laws of cognitive development that should be taken into account when constructing the learning process?
2. Contents of the learning:	2. What result of teaching do we want to obtain?
<ul style="list-style-type: none"> <li>▪ learning goals,</li> <li>▪ educational material</li> </ul>	3. What should be the sequence of learning new knowledge (concepts, terminology), skills, and abilities?

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3. The technological process:	4. What are teachers doing?
<ul style="list-style-type: none"> <li>▪ organization of educational process,</li> <li>▪ diagnostics of the educational process</li> </ul>	5. What are students doing?
	6. How does teacher control over the process of new knowledge assimilation?
	7. What techniques are used for assessing the effectiveness of the educational process?

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### 2.1. Conceptual basis of cognitive learning technology

The differentiation-integration theory of development serves as a conceptual basis for cognitive learning technology. The general law of development and understanding of mental structures as a substratum of mental growth lies in the foundation of this theory. These theoretical ideas are not new, if we look at the papers of ancient thinkers (Ancient Greece, China, India and others (even the Bible)), we can find the roots of the DI theory. These ideas are so obvious and productive and received a lot of convincing empirical evidence in the studies of scientists around the world (Miller, 2005; Demetriou, Spanoudis, & Mouyi, 2011; Volkova, 2013a; et al.). I wonder why we do not use these ideas for developing effective learning technologies. Why do we call any change development? Indeed, development entails changes, but these concepts are not equivalent.

The general law or the principle of organic systems development holds that the developmental process involves a passing from states/forms of relative globality and undifferentiatedness towards new states/forms of ever-increasing differentiation and hierarchical integration (Werner, 1957; Chuprikova, 2007; Volkova, 2011; et al.).

We believe that the mental structures are the substratum of cognitive development (Vekker, 1981; Kholodnaya, 2002; Chuprikova, 2007; Volkova, 2011b; et al.). These structures (multidimensional representative cognitive structures in long-term memory) underlie human psychological development including the development of intelligence, competence and creativity.

Mental structures are an ontological model of the mind. The most important functions of mental structures are representation, selection and transformation of reality into abstract or 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, including abilities. 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 mental structures, as a result of the past and present experience, determine a range of possibilities of mental activity in the present and future time. The uniqueness of mental structures lies in the fact that mental structures are a kind of a "crossing point" of the past, present and future (Volkova, 2013b).

Conceptual structures form the highest level in mental structures' organization. The quality of thinking depends on conceptual structures organization. From the psychological point of view, we must distinguish the external concept from the internal one. The external concept is a concentrated expression of historically acquired knowledge about an object or a phenomenon. The internal concept is an integrated psychological formation that fixes the information about the features of mental reflection of an object and the historical knowledge about this object depending on the organizational peculiarities of person's mental experience.

Summing up the above, we can conclude that the formation of conceptual structures, which are adequate to the field of activity, should be the main goal and key result of effective teaching.

### 2.2. Content of cognitive learning technology

We devised a special educational technology which ensures a natural course of cognitive development of chemistry knowledge, i.e. a transition from operations by global, not differentiated images of chemical reality, to operations by more and more differentiated elements, properties and relations.

The findings of our earlier research convincingly demonstrated that there is an analogy between the development of the conceptual structure of chemistry in individual experience and the evolution of chemistry knowledge. Their development derives from a state of relative globality and undifferentiatedness towards the states of increasing

differentiation and hierarchic integration (Volkova, 2013a). Such is the law of nature. Such is the natural way of growing of knowledge and of individual development.

The main task of cognitive learning technology in chemistry classes is to teach students to think like chemist, to develop their thinking. The purpose of the cognitive learning technology is to form key conceptual relations of chemistry conformably with the evolution of chemical knowledge.

Content analysis of the evolution of conceptual systems of chemistry, each of which is a fundamentally new way for explaining the origin of substances, shows that the number of features, which define properties of matter, grows from one stage of evolution of chemistry to another one:

*Stage 1.* Composition of substance stands out to explain its properties (i.e., what elements and in what proportion these substances are composed?).

*Stage 2.* Composition and structure of the compound serve to explain properties of substance (i.e., elemental composition, the order of atomic bonds and their location in space).

*Stage 3.* Kinetic system of reacting substances as a whole is considered here: the nature and relative amounts of reagents; external environment in which the system is located; substances stoichiometrically not involved in the reaction (impurities, catalysts, solvents and etc.), but affecting the chemical process. Thus, properties of substance are determined by its composition, structure and organization of the kinetic system, wherein the substance is located.

The main features of cognitive learning chemistry technology are presented in table 2.

Table 2. Scheme of cognitive learning technology in chemistry classes.

Step	Technological process	Main focus
Step 1	Inception of conceptual systems of chemistry	On the “look-feel-act” level not only the composition, but also the structure and the entire kinetic system should be presented. However, the main focus should be on the composition of substance
Step 2	Systems differentiation of chemistry concepts and the emergence of qualitative-quantitative structures of chemistry relations	Emphasis is on the composition of compounds and their structure
Step 3	Systems differentiation and integration of chemistry concepts, formation of structures of qualitative-quantitative relations as a result of the analysis and synthesis of algorithms for solving of typical problems of chemistry	The main focus should be on composition, structure of substance and the kinetic system as a whole
Step 4	Checking-up of the maturity of conceptual structures as the basis of intellectual competence in chemistry	Application of existing chemistry conceptual systems in order to predict the properties of particular compounds
Step 5	Formation of schemes of the technological process	Formation of a basic understanding of industrial and technological schemes associated with the analysis of chemical technologies

As we can note, scheme of cognitive learning technology corresponds to the natural way of evolution of conceptual chemistry systems. This scheme opens up a wide space to pedagogical creativity for teachers. Every teacher, according to their own individual peculiarities and students' peculiarities, can fill in this scheme with such content and teaching methods that match both the teacher and the students. Thus, a framework of the teacher's skill and the flexibility of educational technology are created.

### 2.3. Technological process

Consider the psychological meaning of cognitive learning technologies in chemistry classes, that is, in what sequence and how we should introduce new knowledge so that they match the laws of mental development.

*Step 1.* At the end of 18th century, the founder of modern chemistry Antoine Laurent Lavoisier wrote that at the beginning of the study of some science we find ourselves in a situation very similar to the situation of the child and the road, along which we have to follow, is absolutely the same, like nature creating child's notions (Lavoisier, 1790).

At the first stage of knowledge, mastering key concepts of chemistry are introduced (chemical reaction, chemical compound, chemical properties, chemical bond, chemical structure, interacting atoms, elements, molecules).

Obviously, such concentrated and accelerated introduction of concepts does not yet lead to their full mastering.

However, the significance of this approach stems from the fact that the chemistry student gets used to the chemical language, to the fixing of features of the chemical process. The chemistry student obtains holistic and adequate understanding of chemistry, its state and problems. Then this representation of chemical knowledge will constantly be differentiated, connect with more particular theoretical and empirical knowledge, as well as with concrete facts confirming them.

A large number of laboratory manual operations at the initial stage of chemistry learning are the key to the future success. On the "look-feel-act" level not only the composition, but also the structure and the entire kinetic system should be presented. However, the main focus should be on the composition of substance.

Practical workshop contributes to the accumulation of experience with the substance, to the formation of "a sense of substance", to harmony and elegance of the chemical process. The primary adaptation of students to the methods of solving chemical problems occurs. Comparing various types of problem solving, the student comes to discovery that compounds react with each other not in all but in a strictly certain quantitative relations. Thus, further clarification of representations takes places regarding quantitative relationships between system components in relation to chemical changes of substance.

Formation of the mental structures reflecting, in the most general form, the fundamental principles of science, happens. Those are the principle of the opposite's existence as the basis for drawing up the chemical formula, the principle of proportionality and the principle of indestructibility of matter as a basis for making up equations of chemical reactions, etc.

It should be emphasized that the content of practical work must bear a personal meaning for the student and help him/her in everyday life.

The main feature of cognitive learning chemistry technology is the fact that the formulas of various classes of inorganic compounds are introduced at once rather than sequentially, one after another.

The formation of the hierarchy of the chemical concept "substance" is realized from the whole to the part:

*global level* - distinction of simple and complex compounds;

*basic level* - distinction of the classes of inorganic compounds (oxides, acids, bases, salts);

*detailed level* - further differentiation of classes of inorganic compounds (basic oxide, amphoteric oxide, acidic oxide, and so forth).

Simultaneously with the process of differentiation of the primarily global presentation about the substance, chemistry students learn to encode the qualitative and quantitative composition of chemical compounds by using chemical symbols, indices and coefficients.

In order to make up the formulas, the concept of "degree of oxidation" and "valence" is formally introduced as a certain number, by which the formulas of chemical compounds are to be composed.

Simultaneously with the formation of notions of substance, students are introduced to chemical phenomena. In that case, they identify substantial features of the chemical phenomenon, formulate its definition and acquire its logical structure.

Laboratory practicum with substances leads to the formation of anticipating schemes, which prepare students for perceiving and analyzing not only of the composition and structure of substances, but also of the entire kinetic system. Consistent identification and formulation of problems, according to the logic of the evolution of conceptual chemistry systems, promotes formation of the mind oriented to the world of chemical interactions. However, the students' representations of chemical phenomena and substance are still syncretic and global. A differentiated perception of these concepts emerges in students at the study of chemical processes.

*Step 2* is systems differentiation of chemistry concepts and the emergence of qualitative-quantitative structures of chemistry relationships (emphasis is on the composition of compounds and their structure).

The principle of the systems differentiation and integration is traced in the historical respect when studying preconditions and developmental milestones of the periodic law, the periodic system, and atomic structure.

Students acquire clearer understanding of the system that promotes the formation of systemic thinking as the basis for solutions of complex problems. It is well known that complex problems are the most common type of chemistry problems.

Knowledge of the regularities reflected in the periodic table allows students to predict properties of compounds on the basis of analysis of their composition and structure which contributes to the emergence of the structures of qualitative-quantitative chemistry relations in students.

These relations are defined by the position of the element in the overall hierarchy of elements, bonds which this element forms with other elements, the mutual influence of atoms in compounds, specificity of spatial structure, as well as the influence of the entire kinetic system.

Genuine knowledge of each element of the conceptual system of chemistry progresses all the time as the chemistry student masters other subsequent elements of chemistry as a science, and realizes the corresponding whole up to the end.

Concepts "oxidation number", "valence", "bond", "structure", etc., formally introduced at the first step of teaching, acquire their concrete content.

*Step 3* is the formation of structures of qualitative-quantitative relations as a result of the analysis and synthesis of algorithms for solving of typical problems of chemistry (composition, structure of substance and the kinetic system as a whole).

The main point of this step is the fact that the chemical properties of different classes of inorganic compounds are studied not sequentially, as is accepted in the traditional education system, but are deduced all at once on the basis of qualitative and quantitative analysis of substance, proceeding from the general principles:

- a cation is replaced with a cation (or anion is replaced with an anion),
- a positive is connected to a negative,
- an oxidant reacts with a reducing agent,
- a stronger reagent displaces a weaker one,
- the more active reagent displaces the less active one.

Initially, based on the experience, students get acquainted with the concepts of "electrolytes" and "non-electrolytes", "electrolytic dissociation".

They practice in writing formulas of chemical compounds, by combining cations and anions, in making equations of electrolytic dissociation, ion-exchange reaction, and so on.

Students acquire an understanding about a structure of chemical processes as a result of exercises.

Therefore, considering the chemical properties of the classes of inorganic compounds, we, first of all, represent a problem in an abstract, schematic way.

Further concretization, refinement and understanding of chemical processes, directed at gradually filling gaps in this structure, takes place with the support on sensual and visual material in practical and laboratory work.

Mastering of the concept "chemical process" is much extended in time.

However, this fact contributes to a better understanding of the principles of chemical interactions. As well it helps to form differentiated cognitive schema representing the system of chemical interactions with its hierarchical structure and genetic relations between classes of inorganic substances.

Step 3 ends up with solving computational problems.

At first, computational problems are solved by equations of reactions between pure substances, then substances containing impurities or in excess.

Then the student addresses to the more complex chemical processes that are parallel or sequential reactions, interactions with which occur in solutions.

The formation of conceptual structures takes place. Features of various types of problems and algorithms of solving them are differentiated from each other and represented in these structures.

*Step 4* is systems differentiation and integration of chemistry concepts. This step is checking-up of the maturity of conceptual structures as the basis of intellectual competence in chemistry, especially of its components such as chemical knowledge, chemical abilities/intelligence, and chemical intuition.

We believe that the emergence of chemical intuition is due to the formation of a higher level of differentiation and integration of chemistry conceptual structures (Volkova, 2014). Empirical research showed that the indicator of formation of conceptual structures (a measure of differentiation and integration of their cognitive composition) is connected with indicators of verbal (fluency, originality) and nonverbal (constructive activity) creativity (Kholodnaya, 2013). Thus, the more individual conceptual structures are differentiated and integrated, the higher is the creativity of person.

At this stage, formation of chemical intuition occurs due to the application of existing chemistry conceptual systems in order to predict the properties of particular compounds.

Students discover the basic regularity of changing of properties of compounds, find out the reasons for differences, compare their data with literature or check, using experiment, analyze. If the predicted data do not coincide with reality, students try to understand the reasons why the essential feature of the concept or conceptual relations had not been considered or identified.

*Step 5* is the formation of schemes of the technological process. At this step, analysis of chemical technologies is organized. Initially, perception of the technological process in students is global and syncretic. When analyzing chemical productions, students learn to identify an object of the process; its national economic significance; laws and phenomena underlying the chemical process, begin to form a basic understanding of industrial and technological schemes.

To estimate the effectiveness of the educational process we have developed a diagnostic system, theoretical and empirical substantiation which in detail presented in the works (Volkova, 2011b; Lisichkin, 2013; et al.). This diagnostic system included different techniques of assessment intelligence, academic achievement (chemistry), and different aspects of special chemical abilities.

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

Wechsler Intelligence Scale for Children (WISC; Wechsler, 1991) is used for young people under 16 years old (Russian version WISC by Filimonenko, Timofeev, 2006). It consists of 11 subtests: Information, Comprehension, Arithmetic, Similarities, Digit Span, Vocabulary, Coding, Missing details, Block Design, Object Assembly, Picture Completion, Digit Symbol, and Picture Arrangement.

"Embedded Figure Test" (EFT, Witkin, Oltman, Raskin, & Karp, 1971). The Russian version of EFT consists of twelve problems. This test is administered individually and requires detecting a simple embedded figure in a more complex one. The score determines a mean time (sec) of solving problems. The higher is the mean time, the higher is the degree of field dependence.

For the assessment of different aspects of special chemical abilities method "GreatChemist", method of long-term memory for the chemical information (%), method of "chemical" intuition (0-60 points); map of interests (-10 to +10 points) were used in our research (Volkova, 2011b).

The "GreatChemist" test was constructed for the estimation of organization of basic concepts of chemistry. For example, in order to reveal peculiarities of organization of the concept "substance" the formulas of chemical compounds appear on the screen at a random order. The participant is 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).

The purpose of the "GreatChemist" test is to measure the choice reaction time (T, sec), quantity of errors (n) and quantity of levels formed. We think that the level was formed, if the accuracy of responses reached at least 90%. The "GreatChemist" was built on the DI theory. It allows us to define a zone of proximal development and thus to organize the education process which leads to the increasing in competence of every student.

### 3. Research design

In order to estimate the effectiveness of cognitive learning technology the formative experiment was organized. The diagnostic system, which was mentioned above, was used in our research. Participants of the experiment were Russians. 60 teenagers aged 14 years (58.4% girls) were recruited in our research.

Students of the first group studied chemistry 4 semesters, an hour twice a week. They started to learn chemistry only in fourteen years old. The educational program that used in this group was elaborated in according with the DI-law of mental development.

The second group consisted of the schoolchildren of the same age but studying chemistry without applying DI-law of development. Adolescents in this group trained under the program "Ecology and Dialectics of Nature" since 11 year olds. It's a quite productive program, but built on empirical experience of their outstanding author. Students of this group studied chemistry 10 semesters, 2 hours twice a week.

Mathematical data processing was carried out by using the ABM SPSS software package 20. Statistical processing techniques of empirical data included descriptive statistics and parametric methods for identifying differences and relations.

## 4. Results

### 4.1. Dynamics of formation of the concept "substance" and chemical abilities in the conditions of formative experiment

The findings of formative experiment showed (table 3), that the time of chemical stimulus-objects distinction (T) decreases in all groups of adolescences in the process of age development and chemistry assimilation. The more successful is the participant in studying of chemistry the greater is number of levels of concept "substance" (the level is formed if  $n \leq 4$ ). The elder is the participant the greater is number of levels of concept "substance". Thus, the development of a concept "substance" occurs as moving from the global level through the basic level to the detailed one.

According to our data adolescents in the first group not only achieved the indicators in the second one, but also exceeded them. It is necessary to emphasis that significant increase in the indicators of abilities is observed only on the condition when the detailed level is formed (more successful adolescences in the first group); meanwhile the decrease in the indicators of abilities is observed in the other cases. Thus, not any teaching leads to the development of special abilities but only such a teaching that is organized according to the principle of systems differentiation and integration and provides the formation of the detailed level of chemical concepts.

High degree of integration (77.1% of correlations were significant between indicators of chemical abilities), high differentiation (the decrease in the choice reaction time) and the increase in the indicators of chemical abilities suggests that adolescents of the first group acquired not only knowledge and skills in chemistry but also chemical abilities that is a new quality.

Table 3. Age dynamics of chemical competence in adolescences.

Indicators		Mean		Independent - Samples T- test	Mean		Independent - Samples T- test
		first group			second group		
		14-year- olds	15-year- olds		14-year- olds	15-year- olds	
More successful adolescences							
Organization of the concept "substance"							
Global level,	T1, sec	66.44	31.16	2.326*	84.57	49.75	3.052**
	n1	2.66	0.5	1.237	3.42	2.16	0.664
Basic level,	T2, sec	148.88	47.33	2.178*	108.26	79.33	2.9*
	n2	2.33	0.833	1.274	3.76	2.66	1.083
Detailed level,	T3, sec	320.77	147.33	3.66**	371.73	342.75	0.556
	n3	19.33	4	3.481**	21	15.16	2.539*
Chemical abilities							
"Chemical" intuition, (points)		5.04	10.91	-4.1***	5.86	4.25	1.306



Long-term memory for the chemical information, %	simple	87.8	97.5	-1.734	84.5	80.8	0,746
	complex	54.3	95.8	-3.87**	61.3	62.5	-0,217
Interest in the study of chemistry		1.18	5.66	-3.67**	4.16	2.38	1.249
Less successful adolescences							
Organization of the concept "substance"							
Global level,	T1, sec	86.58	46.15	3.68***	100.22	45.87	2.811**
	n1	6.58	1.5	3.445**	5.88	2.28	1.905
Basic level,	T2, sec	182.66	88.85	5.078***	130.11	91.07	2.15*
	n2	16.75	7.7	2.617*	6.44	5.42	0.515
Detailed level,	T3, sec	448.83	276.26	2.818**	390.55	355	0.708
	n3	33.91	19.78	4.943***	25.88	23.28	1.244
Chemical abilities							
"Chemical" intuition (points)		3.26	5.07	-1.745	4.61	3.13	1.686
Long-term memory for the chemical information, %	simple	59.6	70.2	-1.643	77.7	72.3	0,877
	complex	17.8	40.4	-3.017**	42.3	38.2	0,572
Interest in the study of chemistry		1.07	0.55	0.337	4.66	1.8	1.117

Sig. (2-tailed)\*  $p \leq 0.05$ ; \*\*  $p \leq 0.01$ ; \*\*\*  $p \leq 0.001$

#### 4.2. Influence of the process of formation of chemistry structures on cognitive development in adolescents

As would be expected, indicators in the first group were significantly worse, than in the second one at the beginning of the formative experiment (table 4). Since the adolescents of the first group were in a worse educational conditions in comparing with adolescents in the second group before the experiment. Nevertheless, the results of the formative experiment revealed higher rates of development of the general abilities in the participants of the first group, as evidenced by the data of the tests (WISC, Embedded Figure Test). According to our data, a significant increase in indicator of field-independence as well as in indicators of verbal and general intelligence was observed in the first group of participants. That is, the purposeful formation of chemistry conceptual structures entails the development of intelligence.

It should be noted that the formation of conceptual structures providing successful mastering of chemical knowledge affects the development of both verbal and nonverbal intelligence (participants of the first group). Meanwhile we observed an increase in verbal intelligence indicators and the decrease in the non-verbal intelligence indicators in the second group.

Table 4. Age dynamics of intelligence in adolescence.

Indicators	Mean		Independent - Samples T-test	Mean		Independent - Samples T-test
	14-year-olds			15-year-olds		
	first group	second group		first group	second group	
Information	7.92	11.63	-5.744***	10.23	12.04	-2.416*
Comprehension	7	7.444	-0.795	9.31	10.07	-1.948
Arithmetic	9.92	11.22	-1.697	10.31	12.12	-1.990
Similarities	9.96	13.54	-5.188***	12.65	16.08	-4.190***
Digit Span	9.83	10.52	-1.06	9.77	10.15	-0.770
Vocabulary	6.69	7.58	-0.919	7.81	10.69	-3.394***
Coding	11	13.19	-2.109*	14.31	14.19	0.108
Missing details	11.33	11.93	-0.744	13.62	12.62	1.281

Block Design	12.375	13.48	-1.405	13.81	13.58	0.290
Picture Completion	6.38	6.70	-0.505	10.77	10.39	0.583
Object Assembly	10.33	9.48	0.995	11.19	10.54	0.756
IQ verbal	81.83	90.82	-3.717***	89.65	99.62	-3.585***
IQ nonverbal	90.14	93.30	-1.096	104.44	101.54	0.996
IQ general	89.88	97.17	-3.003**	102.38	107.62	-1.774
Embedded Figure Test, sec	68.42	51.53	2.460*	36.74	36.39	0.076

Sig. (2-tailed)\* p≤0.05; \*\* p≤0.01; \*\*\*p≤0.001

## 5. Conclusions

The findings of formative experiments convincingly demonstrate that the organization of education according to the DI-law of mental development (principle of system differentiation and integration) is more successful than education based on intuitive insight, art, and empirical experience of their outstanding representatives.

The present study revealed that the most important psychological condition of development of competence is the formation of conceptual structures of the detailed level of generalization relevant to the object of activities.

Of particular interest is the fact that the significant relation was revealed between the formation of detailed level of the concept and high creative achievements in professional activity (Volkova, 2014). Based on these arguments, we believe, that cognitive learning technology elaborated in according with the DI-law leads both the development of intelligence, competence and creativity.

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