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Potential of Technology of Critical Thinking Development for Upgrading University Lecture Course of Chemistry

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The work covers the issue of expedience of using mechanisms, methods and strategies of the technology of critical thinking development (TCTD) at chemistry lectures at university. The survey proved that using TCTD during a lecture course of chemistry disciplines alongside with other innovative technologies, in particular, with information and communication technologies leads to increasing the level of comprehension, understanding of information, as well as improvement of skills of independent processing of training material.

Keywords: methods, mechanisms, strategies of the technology of critical thinking development via reading and writing, chemical disciplines, lecture form of studying.

Introduction

Training a professionally competent specialist capable of unassisted acquiring of required knowledge and applying it to solve various professional and everyday tasks brings about the need to create a favourable environment for students' educational and cognitive activity, which requires updating all organizational types of studying at university.

The analysis of information sources on teaching chemistry disciplines proved that improvement of lecturing type of studying shall be primarily aimed at elimination of passive perception of information, encouragement of feedback and increasing the students' self-

sufficiency. Introduction of topical study elements, using hand-outs, application of information and communication technologies (ICT), conducting express control, and initiation of dialogue comprising elements of individual and group work – all this is aimed at eliminating the illustrating and explanatory nature of a lecture [Bezrukova, 2006; Gavronskaya, 2005]. Moreover, a lecturer is still the main source of information during a lecture, whereas a student is basically involved in a reproductive speculative activity. We believe that shifting a student into a subjective position during a lecture can be facilitated by methods and strategies of a technology of critical thinking development via

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reading and writing, which is shortly named the Technology of Critical Thinking Development (TCTD).

Materials and Methods

The analysis of literature on pedagogics proved the viability of using this technology for studying the humanities, the process of which is characterized with processing a considerable amount of text information. Internet and modern literature on pedagogics provide us with information on some pilot projects on TCTD application during school lessons of literature, history, mathematics, and chemistry. Our interest was aroused by the practicability of using TCTD methods for studying chemistry at university, in particular, in the course of teaching chemistry to first year students majoring in metallurgy at Siberian Federal University.

The main idea of the technology is generating skills of independent processing of information, its critical apprehension and development of reflexive abilities. The technological foundation of TCTD is formed by a basic model of three stages: challenge – apprehension – reflection that allows students to make their own decisions on goals they pursue in studying, perform an active search of information and reflect on what they have learned. Thus, the first stage – “challenge” – provides for updating one’s knowledge, making assumptions, defining the goals of studying and forming a cognitive interest. The second stage – apprehension – is aimed at unassisted monitoring of the process of training material understanding. The final third stage – reflection – includes synthesis of information, providing for consolidation of the material and comparing it with previously obtained knowledge (Zagashev, 2003).

In the course of using methodological mechanisms and TCTD strategies, the material of the lecture is subdivided into semantic units,

and conveyance of each of them follows the technological cycle “challenge – apprehension – reflection”. According to psychologists, such a structure of a lecture corresponds to stages of human perception: first one needs to ‘tune in’, recall what is already known on this topic, then ponder what this information can be useful for and how it can be applied.

When giving lectures within the basic course of chemistry to students majoring in metallurgy we used such strategies as “Advanced lecture”, “Logbook”, “What we Know – What we Want to know – What we Learned”, and such mechanisms as “Cluster”, “INSERT”, “Logbook”, “True-false statements”, “Conceptual table” etc (Zagashev, 2003).

Cluster mechanism is a graphic method of organizing the training material. It allows outlining large or small semantic units, names of which are written in rectangles with circles radiating from them forming the so-called cluster branches that disclose the meaning of these semantic blocks. The resulting clusters with branches reflect interrelations between these blocks.

We used this mechanism when studying the topics “Oxidation-reduction reactions”, “Chemical bond”, and “Electrolyte solutions”. The example of a cluster generated in the course of discussing the topic “Oxidation-reduction reactions” with students at the end of a lecture is shown in Figure 3. It can be seen that this cluster does not represent bonds between, for instance, properties of reagents (ionization energy, electron affinity) and element location within Mendeleev periodic table; ionization energy and reducing agent, electron affinity and oxidizing agent; half-reaction method and medium, measurement of oxidation and reduction potential and galvanic element.

Students can saturate cluster branches with information both during the lecture and while

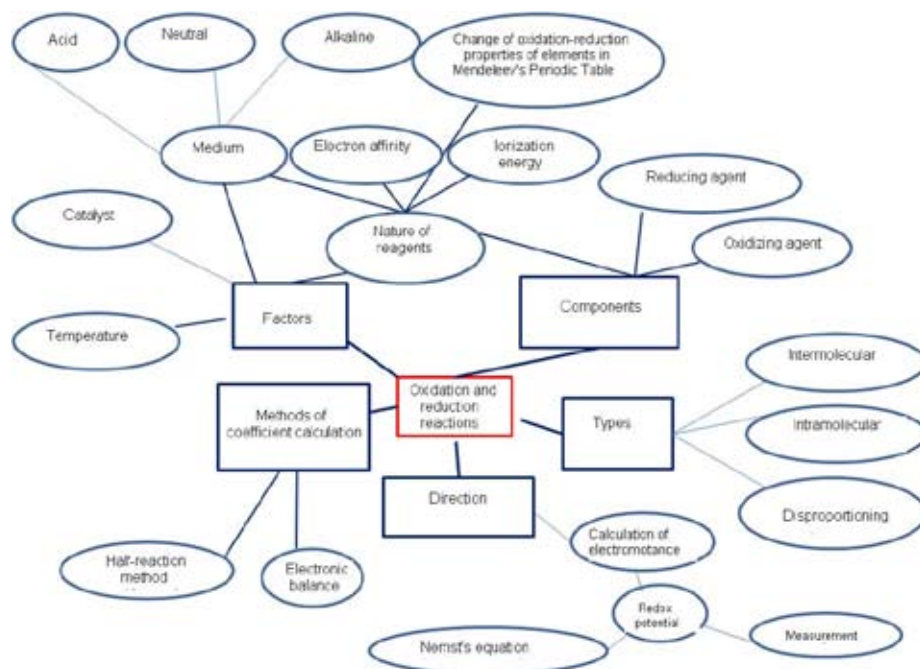


Fig.1. Cluster for studying the topic “Oxidation and reduction reactions”

studying the material independently, as well as in the course of analysing electrochemical processes. We believe the applicative aspect of this topic to be important for metallurgy students. Thus, the future metallurgists shall be able to select an oxidizing and reducing agents for processing the particular type of raw material depending on their oxidation and reduction potential, as well as forecast the reaction products depending on the medium the reaction goes in. Basing on this, main trusses can be outlined within a cluster, the subordinate ones can be removed, and more attention can be paid to interrelation of selecting an oxidizing and reducing agents depending on their oxidation and reduction potential. This will definitely change the look of the cluster. Thus, creating a cluster enables a student to apprehend the applicability and structure of the topic being studied, see the connection between main chemical notions, discern main information from subordinate data, which, in general,

facilitates the systematic comprehension of the training material.

Mechanism “True-false statements” is one of the methods used to actualize basic knowledge that has been acquired long before this training session. This method suggests evaluating understanding of logic assertions, statements of planned training material. For instance, students have learned back in school that hydrogen evolves during inter-reacting of metals standing before hydrogen in metal activity series with solutions of diluted acids (hydrochloric acid and sulphuric acid). By analogy they assume evolving of hydrogen from nitric acid solution as well, not taking into account the oxidizing properties of nitric acid depending on its concentration and metal activity. The example of making statements on metals dilution in nitric acid of various concentrations is given in Table 1 below.

Application of this method at the challenge stage facilitates formation of the ability to express one’s point of view on the issue being discussed

Table 1. True/False statements on the topic “Chemical properties of metals”

Statement	Answer
1. Dilution of active metals in diluted nitric acid is accompanied by evolution of gaseous hydrogen.	yes
2. Hydrogen is never evolved during inter-reacting of metals with nitric acid solutions.	yes
3. Ammonia is primarily generated by diluting active metals in diluted nitric acid.	?
4. Low-active d- metals of period 4 and 5 of the Periodic Table do not dissolve in the solution of diluted nitric acid.	?
5. Low-active d- metals of periods 4 and 5 passivate in the solution of high-concentrated nitric acid with formation of metal oxide in the highest oxidation degree, nitrogen oxide (IV) and water.	no

Table 2. KWL on the topic “Oxidation and reduction reactions”

Know	Want to know	Learned
Oxidizing agent	How can an oxidation-reduction reaction be defined by the equation?	1. One shall define elements that change their oxidation rate. 2. One should know formulae of typical oxidizing and reducing agents.
Reducing agent	How should reaction products be registered?	One should take into account the medium, characteristic oxidation rates of chemical elements, acid-base nature of element compounds.
Oxidation process	What is the method of placing coefficients within equations of reactions passing in a solution?	Electronic balance method, electronic-ionic method (half-reaction method).
Reduction process	How can the direction of an oxidation-reduction reaction be defined?	Calculation of the process electromotive force, one shall know the value of oxidation and reduction potential of half-reactions.
Electronic balance method	Other methods. What are they for?	Electronic-ionic method is applied for reactions passing in solutions.

by evaluating one's own knowledge, whereas in case of studying new material this helps forming a skill of forecasting basing on one's own chemistry background. Students appear to have great difficulties in reasoning statements made at the challenge stage, while using this mechanism at the reflection stage is accompanied by reasoned confirmation of statements.

One of the main methods of material graphic arrangement is a table. According to the strategy “What we Know – What we Want

to know – What we Learned (KWL)” invented by Donna Ogle in 1986, a lecture starts by filling in a KWL table. This strategy develops students' skills of goal-setting. Individual filling in of the first table column “Know” is aimed at actualizing the knowledge a student already has, the second column “Want” – at activating mental processes for studying new material, whereas filling in of the third column “Learned” develops the skill of making conclusions, which allows integrating the knowledge obtained into one's personal system

of knowledge while receiving subjectively new piece of information (Table 2).

Group compilation of questions and notions of this table enables students together with a teacher to distinguish the following categories of training material that can form boxes of a new table and act as a plan of next lectures:

Categories of information we plan to use	3. References
A. Basic concepts B. Types of oxidation and reduction reactions C. Impact of different factors on oxidation and reduction reactions D. Methods of placing coefficients in equations of oxidation and reduction reactions E. Direction of oxidation and reduction reactions	1. N.G.Korzhuikov General and non-organic chemistry (in Russian). Textbook for universities (Text) / ed.by V.I.Delyan// Moscow: MISIS. INFRA-M, 2004. – 512p – in Russian 2. S.D.Kirik, G.A.Koroleva, N.M.Vostrikova et al. Non-organic chemistry: electronic teaching materials on the discipline// Registration certificate No.14934 dd 22.12.2008 Federal State Unitary Enterprise INFORMREGIST Research and Development Center.

With account of this topic being studied within the school course of chemistry, as well as considering the significant reduction of university lecture hours, this strategy allows separating issues and topics that can be allocated to be studied by students in an extra-curricular mode.

Another form of tabular ways of material graphic arrangement is characterized by distinguishing general and specific properties by comparing three and more notions and objects. A horizontal line of such a “concept table” is formed by things being compared, whereas a vertical row represents various properties and features this comparison is based on. Distinguishing a series of objects to be compared is possible in the course of studying element chemistry and types

of chemical bond. For instance, a concept table compiled together with students during a lecture on electrochemical processes that go within a galvanic element in case of electrochemical corrosion of metals and electrolysis looks as follows (Table 3).

A concept table can be filled both in the process of a lecture and at the reflection stage. In case there is not enough time during a lecture, some main criteria can be distinguished as key words, the chemical context of which a student can disclose by him/herself outside the curriculum.

Detection of main criteria of objects under study facilitates development of main logic operations: discretion of the main essence, definition, comparison and classification, generalization and systemizing, definition of possible interrelations and interdependencies, which all leads to comprehension of the material and its systematic understanding. This table acts as an approximate basis for students to understand chemical reactions in the course of laboratory experiments and individual tasks, as well a specific basis for understanding the new material of even higher level of generalization, in particular during studying such specialized disciplines as “Theory of electrometallurgical processes”, “Rare metal metallurgy” etc.

A specific feature of a strategy called “Logbook” is fulfilling short written tasks during 10-15 minutes of a lecture with students selecting various methods of graphic representation of the material (Zagashev,2003).

Information is registered in its simplest form in a table that students fill in with answers to the following questions: What do I already know on this topic? What do I need to learn about this? Why? Another option is a table comprising two questions: What do I know? What have I learned? The method of filling in the latter type table given below was used during a lecture devoted to

Table 3. Concept table on the topic “Electrochemical processes”

Comparison criterion	Galvanic element	Electrochemical corrosion of metals	Electrolysis
Anode sign	Negative	Negative	Positive
Cathode sign	Positive	Positive	Negative
Electrode type	Metal	Metal	Metal (cathode)
	Hydrogen		Inert: graphite
	Oxidation-reduction		Active anode (metal)
Processes at a cathode: reduction	Metal cations: $M^{n+} + ne^{-} = M^0$		Metal cations: $M^{n+} + ne^{-} = M^0$
	Hydrogen ions: $2 H^{+} + 2e^{-} = H_2$	Hydrogen ions: $2 H^{+} + 2e^{-} = H_2$	Hydrogen ions: $2 H^{+} + 2e^{-} = H_2$
	Molecular oxygen: $O_2 + 2H_2O + 4e^{-} = 4OH^{-}$	Molecular oxygen: $O_2 + 2H_2O + 4e^{-} = 4OH^{-}$	Water molecules: $2H_2O + 2e^{-} = H_2 + 2OH^{-}$
Processes at an anode: oxidation	Metal (anode): $M^0 - ne^{-} = M^{n+}$	Metal (anode): $M^0 - ne^{-} = M^{n+}$	Acid residue: $2Cl^{-} - 2e^{-} = Cl_2$
			Water molecules: $2H_2O - 4e^{-} = O_2 + 4H^{+}$
			Active anode: $M^0 - ne^{-} = M^{n+}$

forecasting products of oxidation and reduction reactions passing in various media (Table 4).

As we can see from the table above, the information that is new for a student is represented in the form of short statements or conclusions in comparison with the knowledge the student already has on this topic.

At the apprehension stage during processing of new training material a very active thinking activity is registered in case of using INSERT mechanism. As Table 5 shows, while reading a text or perceiving the information verbally, a student performs reflexive activity by comparing the incoming information with knowledge that he/she already has and pointing out the unclear aspects.

Theoretical material is represented mainly in the form of a polylogue “lecturer – audience” with creation of problematic situations and is accompanied by lecture demonstration experiment, as well as periodic switching to solving practical professionally oriented tasks.

The students are given an opportunity to solve problems independently, then do text tasks and then discuss and come up with a group solution. This method widely uses digital educational resources that allow combining verbal and visual method of information comprehension, as well as provide for a lecturer getting feedback from the audience. During a lecture students are provided with a chance to apprehend material that represents any difficulties.

The critical moment is reflection at the end of a lecture that is aimed at detection and digestion of most important aspects of the lecture, development of skills on formation of statements, thesis representation of material, wording of conclusions or questions, which in general contributes to apprehension of chemical information. Main types of written reflection include: written work, written interview, essay, theses, analysis of a logbook, completing a cluster, formation of logical and semantic models and mental maps, discussion of challenging

Table 4. Mechanism “Logbook” used for studying the topic “Products of oxidation and reduction reactions in various media”

What do I know?	What have I learned?																
Medium influences the direction of an oxidation-reduction reaction.	Products of oxidation-reduction reactions depend on medium.																
Solution of potassium permanganate in an oxidation-reduction reaction gains on different colours in different media.	<table border="0"> <tr> <td>Medium:</td> <td>Colour of solution</td> <td>Product of reaction</td> <td>Oxidation</td> </tr> <tr> <td>acid</td> <td>colourless</td> <td>salt: MnSO_4</td> <td>(+2)</td> </tr> <tr> <td>neutral</td> <td>grey-brown</td> <td>oxide: MnO_2</td> <td>(+4)</td> </tr> <tr> <td>alkaline</td> <td>green</td> <td>salt: K_2MnO_4</td> <td>(+6)</td> </tr> </table>	Medium:	Colour of solution	Product of reaction	Oxidation	acid	colourless	salt: MnSO_4	(+2)	neutral	grey-brown	oxide: MnO_2	(+4)	alkaline	green	salt: K_2MnO_4	(+6)
Medium:	Colour of solution	Product of reaction	Oxidation														
acid	colourless	salt: MnSO_4	(+2)														
neutral	grey-brown	oxide: MnO_2	(+4)														
alkaline	green	salt: K_2MnO_4	(+6)														
Products of reaction in alkaline medium are salts, poorly soluble residues (oxides, hydroxides, salts), and water.	Salts containing metal cations are mostly generated in acid medium: Mn^{2+} , Cr^{3+} , V^{2+} , Fe^{3+} . Formation of acids is also possible: HMnO_4																
Salts are generated in alkaline medium.	Complex salts are formed in a concentrated solution of alkaline. During sintering salts are formed in alkaline media; metal goes to an acid residue in the highest degree of oxidation.																
Hydroxides and salts are formed in neutral medium.	Oxides and hydroxides are formed in neutral medium.																
In order to balance an oxygen atom, H^+ or H_2O shall be added to an equation.	According to ionic-electron method, strong electrolytes are written in their ionic form, whereas weak ones – in molecular form. Balancing of oxygen atoms in the left and right parts of a half-equation depends on the medium: acid: $\text{H}_2\text{O} \rightarrow \text{H}^+$ neutral: $\text{H}_2\text{O} \rightarrow \text{H}^+$ or $\text{H}_2\text{O} \rightarrow 2\text{OH}^-$ alkaline: $\text{H}_2\text{O} \rightarrow 2\text{OH}^-$																

Table 5. INSERT mechanism

«V» -Already known	«-» – Thought differently	«+» – new information	«?» – did not understand

✓ – information that is already known;

+ – information that is new;

- – information that differs from the knowledge the student already has, something he/she has a different idea of;

? – information that remained unclear to the student and requires additional explanation encouraging the student to look for details.

questions, making questions and cinquains, doing test tasks.

Discussion

Questioning of students was used as a method to evaluate efficiency of a computer-based lecture with application of TCTD. Fig. 2 shows

diagrams plotted on the basis of results of the survey on evaluation on the lecture “Definition of products of oxidation and reduction reactions in different media”. A control group included 20 students that studied chemistry in 2007-2008 academic year (lectures were given with use of computer programs) and an experiment group

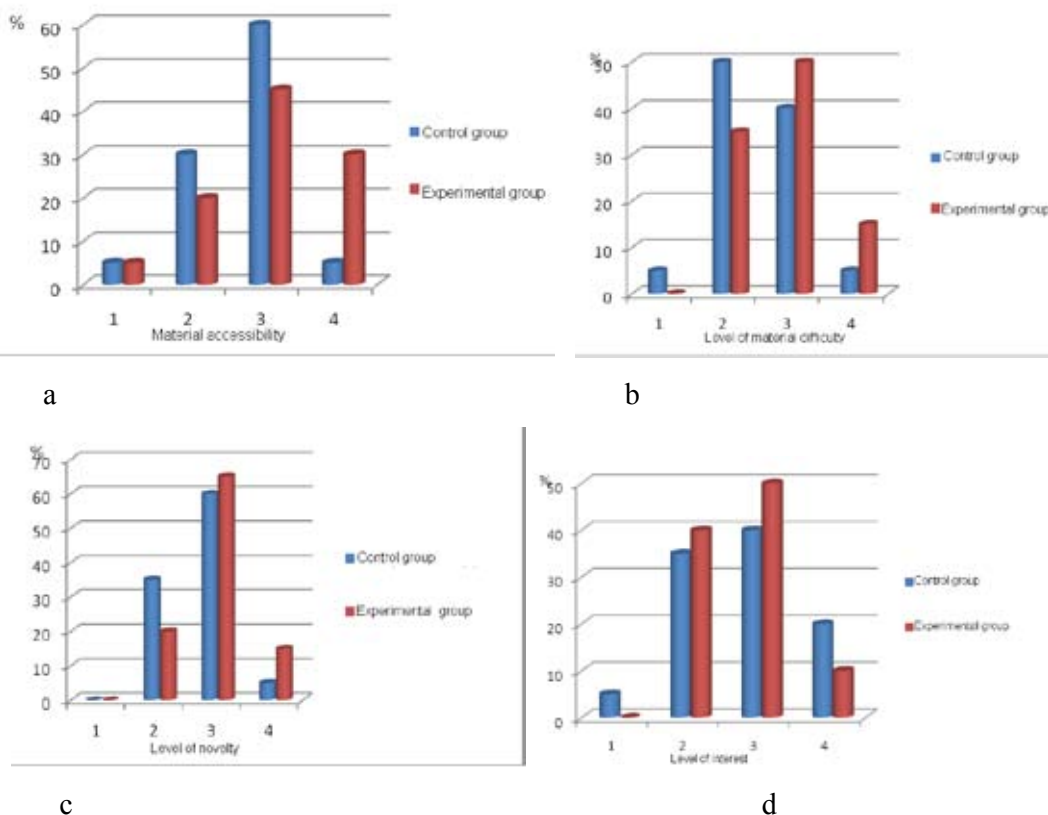


Fig.2. Results of questioning of students on evaluation of accessibility (a), level of difficulty (b), level of novelty (c) and level of interest (d) for the material given at the lecture “Definition of products of oxidation and reduction reactions in various media”: in the control group (2007-2008) the lecture was given with the help of computer programs; in the experimental group (2010-2011) – with use of computer programs and TCTD

of 20 students that studied chemistry in 2010-2011 academic year (lectures were with use of computer programs and TCTD).

It should be noted that this material always caused difficulties in understanding and comprehension. Questioning of students according to the approved method (4, p. 377) showed that students of the control group (in total 90% for two items) and experimental group (in total 65% for two items) noted high level of difficulty of the material (2- quite difficult, 3- medium level of difficulty), a 25 % increase was registered in the number of experimental group students that marked item 4 (practically no unclear moments). Accessibility of the material in the experimental group is higher (30%) if compared with the

control group (5%) as the students noted that there were practically no unclear moments (item 4); the number of students, for whom practically everything was clear except for some specific aspects (item 3) increased by 15%.

The number of experimental group students, for whom less than a half of the material was clear (item 2) decreased by $\approx 10\%$ (almost 1.5 times); the percentage of students who practically did not understand the material (item 1) remained the same.

High level of novelty was noted by students of both the groups. Thus, the sum of answers of item 3 (I have learned a lot of new things) and 4 (practically all material has been new to me) accounts for 65% of total answers given by

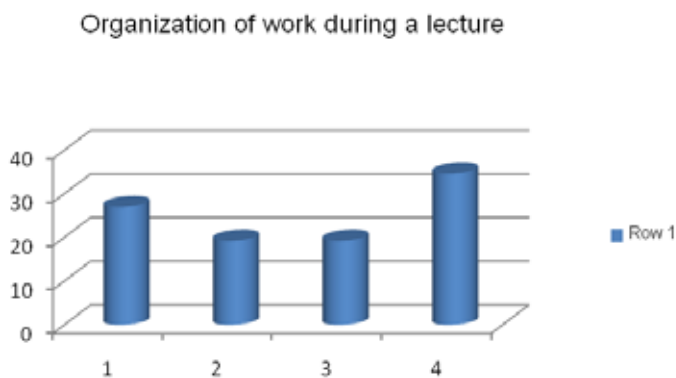


Fig.3 Results of questioning students on evaluation of organizing unassisted work during the lecture “Definition of products of oxidation and reduction reactions in various media” in the experimental group (2010-2011 academic year), the lecture was given with use of computer programs and TCTD

students of the control group and 80% – of the experimental group.

~10 % increase in the number of students that marked item 4 (practically all material has been new to me) can be explained by low level of school chemistry course.

According to respondents’ evaluation, the level of interest in the experimental group is 15% higher than in the control group. Thus, the sum of answers of item 2 (something has caused interest) and 3 (a lot of interesting aspects) accounts for 90% of answers in the experimental group and for 75% of answers in the control group. However, the number of respondents that gave answers of item 4 (very interesting) in the experimental group decreased by 10% in comparison with 20% of answers in the control group; the number of answers of item 1 (non interesting) decreased by ~ 5% .

The results of the survey on questioning students in 2010-2011 academic year with the purpose of evaluating the organization of unassisted work during lectures showed that 40% of students liked to work in pairs (item 1), while 40% of respondents liked to work independently (sum of items 2 and 4): formulate their own conclusions and statements, and check their correctness (Fig 3).

15% of them though mentioned that they like independent work during a lecture but such a mode of working is quite difficult for them; 20% (item 3) that prefer just listening to a lecturer’s detailed explanation and making notes are likely to have problems with independent work during a lecture as well.

The given results lead to a conclusion that application of TCTD at a lecture with use of computer programs provided quite high theoretical level considerably increasing accessibility and level of interest for the material being delivered. It is in particular proved by the fact that over 50% of students did individual works on this topic and got higher attestation results. The development of students’ personal qualities was evaluated indirectly by some outward indicators: time and quality of fulfilling individual tasks, eagerness to reason one’s answer and to find methods to eliminate unclear aspects of topics being studied, as well as the desire to make talks, implement and represent mini-projects.

Conclusion

We believe it necessary to use TCTD mechanisms and methods during the lecture course of chemistry disciplines at university depending on a didactic goal set alongside with

other innovative technologies, in particular, with information and communication technologies that allow increasing the visual expression of training material within the context of chemical information. Since TCTD mechanisms and methods are aimed at developing a student's thinking abilities, increase of comprehension level, understanding of information is also registered, as well as improvement of skills of independent processing of training material.

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Возможности технологии развития критического мышления в модернизации лекционного курса химии в вузе

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В статье изучается целесообразность применения приемов, методов, стратегий технологии развития критического мышления (ТРКМ) на лекции при изучении химии в вузе. Исследование показало, что применение ТРКМ в лекционном курсе химических дисциплин, совместно с другими инновационными технологиями, в частности с ИКТ способствует повышению уровня восприятия, понимания информации, совершенствованию умений самостоятельно работать с учебным материалом.

Ключевые слова: технология развития критического мышления, дисциплины химии, лекция.
