UDC 378.6(571.16)

V. F. TOROSYAN, *Associate Professor, Candidate of Pedagogic Sciences, torosjaneno@mail.ru*
E. S. TOROSYAN, *Senior Lecturer*
A. N. LAZAREVA, *Assistant*

Tomsk Polytechnic University, Tomsk, Russia

INTERACTIVE METHODS AND MODELING AS EMPIRICAL AND THEORETICAL APPROACHES TO TEACHING NATURAL AND MATHEMATICAL SCIENCES TO STUDENTS IN MINING ENGINEERING

Modern vocational education for the training of students of mountain specialties has been given the task of improving the educational process in the direction of finding new technologies, methods, techniques, means and forms of education that will generally improve the quality of education of students.

The training of highly qualified specialists for mining enterprises sets the technical university the task of introducing more efficient ways of organizing the educational process, improving the structure and content of natural-mathematical training of students. It is important to note that the informatization of modern society and the development of high technologies impose on graduates the requirements of professional growth and professional mobility.

The article discusses the main characteristics and features of interactive methods and modeling, as effective ways of knowing when studying the disciplines of the natural-mathematical cycle by students of mining specialties. At the same time, the basis of the modeling is the mediating link - the model - the object — substitutes and the original object — the original. The basis of interactive methods is an empirical and theoretical combination in learning, aimed at forming an active, socially adapted personality that is able to effectively act, compete, compete and compete on the path to truth, while manifesting such a psychological phenomenon as infection, when a thought expressed by a neighbor , can cause its own, similar or opposite.

Key words: *innovation, technology, interactive training, process of cognition, research projects, modeling, graph, structural-logical scheme.*

DOI: *10.17580/em.2019.01.13*

Introduction

The kingpin of the modern society is a human being—independent and responsible, thinking and adaptable to variable social and economic conditions, sophisticate and capable to generate ideas and operate scientific information. In this respect, profession education sets the self-challenge to improve the education process by finding new technologies, techniques, approaches, methods and form of teaching towards higher quality training of future specialists. It should be emphasized that graduates of technical universities socialize better when their cognitive and spiritual needs are satisfied within the educational process. At the same time, experience shows that students of technical universities are very poorly motivated to study natural and mathematical sciences, which results in weakening of their cognitive capacities, increased memory load and, as a consequence, loss of education efficiency. For making learning feasible and meaningful, it is necessary treat students differentially and individually while teaching [1]. In this case, the structure, content and arrangement of education will more comprehensively appreciate concerns and likes of students. The introduction of interactive training and modeling in education will create a reality framework such that acquired knowledge is assimilated through perception [2].

The main characteristics and features of interactive methods and modeling

The National Research Tomsk Polytechnic University is one of the initiators of the international system CDIO based on the model of engineering as Conceive–Design—Implement—Operate real systems, processes and products on international market. Thus, the emphasis in education of future engineers is laid on practical training. Such educational approach rests upon methods of active learning, as well as on innovative forms and means of teaching, which are in total can be assumed as interactive methods [3].

At the present time, the Tomsk Polytechnic University trains students in mining in the area of mining machines and equipment. Basic training programs in this area contain many subjects from natural and mathematical sciences: mathematics, physics and chemistry. In this regard, it should be specified that with reduced class hours and with stress laid on self-training, students are to be able both to analyze information, perform calculations, plot and model, as well as to find and scrutinize latter-day data [4–6].

It is a feature of contents of the most natural and mathematical sciences that the essence of many processes is hidden from direct observation, and a student can perceive these processes only by modeling an invisible object using indirect data. Modeling makes it possible to display and reproduce, in a simpler and visible form (scheme, physical structure, sign forms, formulas, etc.), structure, and properties of an object or phenomenon, as well as internal interaction between its components [7, 8].

In his monograph entitled Modeling and Philosophy, Stoff presents reference definition for the Western philosophy: “A model is understood as a system, either imaged in thought or embodied in material form, such that, by imaging or reproducing an object, can substitute it so that study of the model offers new information on the object" [9].

Natural and mathematical subjects are complicated with ample theoretical information and practical exercises. Training is mostly based on reproductive and reproductive–variational styles of teaching. In the meanwhile, solution of many applied problems assumes using reconstruction–variational, partly exploratory and constructive methods which shape research activities [10, 11]. However, as practice shows, learning of natural and mathematical sciences has no linkage with solution of professional problems. Naturally, this fact infuses in students a sense that these subjects are abstractive. In the first years of leaning, a to-be specialist finds no answer to the question: What for? Modern pedagogy possesses means to teach natural and mathematical sciences interactively and innovatively, using approaches and facilities making the basis of interactive training techniques [12, 13]. Interactive means to inter+act. According to Leontiev: "It is commonly critical in acquisition of any knowledge to comprehend what the cognition means for an individual, is it a part of a real life, or just a compulsory, dictated condition."

Interactive methods and modeling in theory and practice

Cognitive activity of students is an active and creative process of mental reflection of connections and regularities of the outward, the process of transformation of the social realm. Only practice-oriented knowledge acquired not by simple overlearning but by conscious processing, will enable students to realize its professional significance [14, 15]. Orientation of the teaching process at potential of a student and this potential implementation compels the student to master new skills, assimilate new knowledge and create new solution schemes and new modes of action [16].

Interactive methods and modeling ground the training process on the living or professional situation, and allow involvement of business games and conversational resolution of educational (or professional) problems. Within such practice-oriented environment, an engineering science student is able to extend his practical reasoning to the educative process, having the opportunity to be selective, self-ruling and self-correcting.

For example, the pedagogical facilities available for interactive training in natural and mathematical sciences using Kolb's experimental learning style theory (**Fig. 1**) makes it possible to involve problematic job tasks, case-studies etc. in practical exercises [17, 18].

Our research findings allow a statement that based on Kolb's learning style, it is possible to present such intellectual quality of students in engineering as cognitive activity with the key component being content-richness and operating (**Fig. 2**).

Forms and methods of training mining students at the Tomsk Polytechnic University include IT Methods, Case-Study Methods, Experience-Based Teaching, Problem Teaching, etc.

Case Method stimulates inductive/deductive thinking.

Structured logic schemes (SLS) were tested in the process of teaching mining engineering students in natural and mathematical sciences.

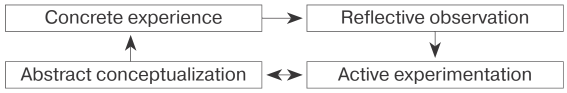

Fig. 1. David Kolb's learning style

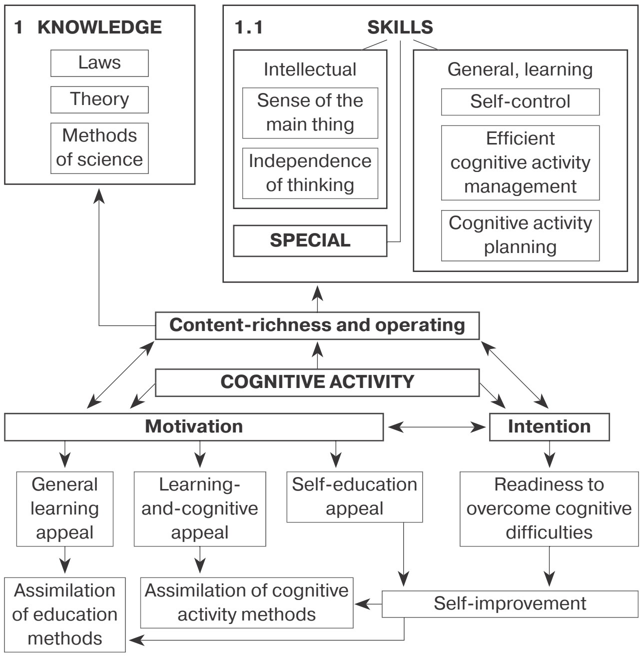

Fig. 2. Components of cognitive activity

SLS, aka mind maps, diagrams, memory maps, mental maps, etc., are the convenient mechanism of data structuring and visual reflection of thinking process. They allow thinking using entire intellectual and creative potential. Intelligence charts write data *in the language of brain*. Ability to present information in a structured form is one of the top modes of personality self-actualization, which is very important for young specialists [19–21].

SLS became widely popular thanks to the famous writer Tony Buzan after publication of his book *Use Your Head.* Tony Buzen emphasized that mind mapping process essentially engages the right-brain responsible for esthetics and holistic approach (based n the whole rather than components). In this respect, drawing an SLS of problem solving, we consider the problem from many viewpoints and engage both cerebral hemispheres.

The experiment consisted in drawing of SLS for better memorization and assimilation of studied subjects.

For example, when teaching the subject of Chemical Kinetics (natural and mathematical science cycle of Chemistry), the first year students were presented with the related information in the form of SLS. Such chart is a compact and visual representation of a subject's contents. The framework is generalization of perception, which enables a student to see features of separate questions, topics or sections of the course under study [22, 23].

The scheme in **Fig. 3** accentuates factors which have influence on the rate of chemical processes, namely: concentration of reaction substances, temperature, catalyst, pressure (for gas systems). Students were set a task to find

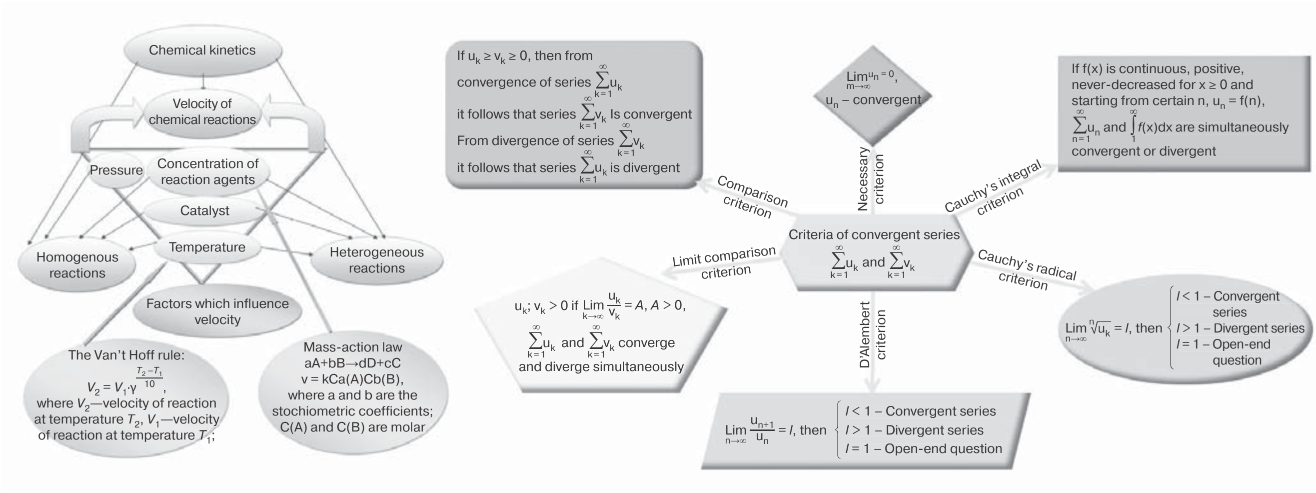

Fig. 3. Structured logic scheme to study Chemical Kinetics and Features of Convergent Number Series

possible errors of experimental determination of the effect of the factors.

Case Method is the analysis of cases [24, 25]. Students of the Mining Machines and Equipment course were offered practical exercises on chemistry and mathematics with short (100–200 words) incomplete description of a problem case. Students were grouped into teams, and each team defended its point of view. The problem case was the incident the chemical practicum on finding properties of nitric acid, when some first year students failed to understand the difference between nitric acid and other acids. The teams were given the task to set a list of possible answers for a first year student (having analyzed the laboratory practicum results and taking into account specific properties of nitric acid).

The educational information may be presented as a graph.

Graph is a hierarchically structured presentation of information to be studied. The graph nodes are the educational elements, the graph ribs are the connections between the elements. The teaching information is highly diverse, and there are many options of forms of graphs:

1) Linear graph is a teaching information structure when each element is only connected with the subsequent element.

The linear graph of studying the Structure of Substance subject is demonstrated in **Fig. 4a**.

2) Deductive (tree) graph. The node of this graph is the base teaching element. Information is presented from the general to the special, from the whole to the components. An illustration of the deductive graph on the Chemical Equilibrium subject is given in Fig. 4b.

3) Inductive (tree) graph. The nodes of this graph are directed downward. Presentation goes from the special to the general. An example of such graph studying amphoteric hydroxides is offered in Fig. 4c.

Figure 4d shows the model of a binary molecule in the form of graph. This model can be used to learn molecular physics, or structure of substance in chemistry. The graphs are better to include in the introductory or final stages of teaching. Student may draw graphs themselves at the stages of generalization, reinforcement and check the learnt material.

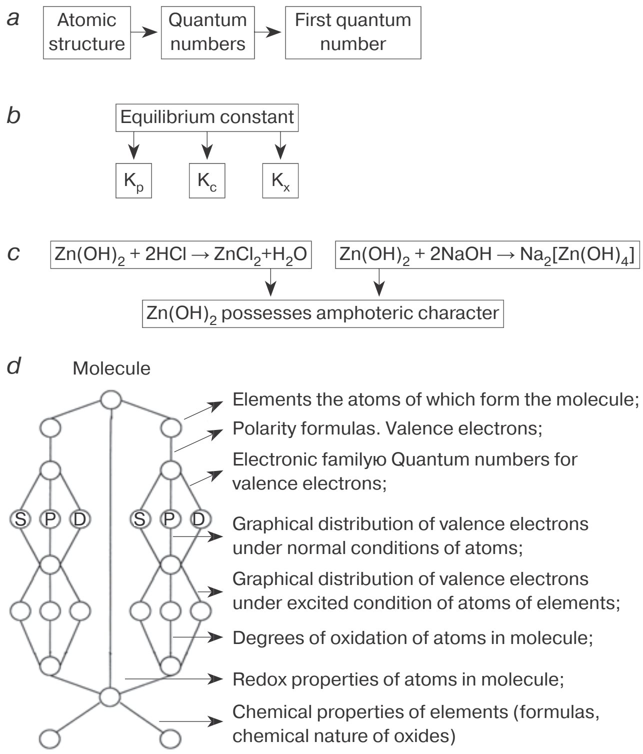

Fig. 4. Graphs:
a—linear; *b*—deductive; *c*—inductive; *d*—structural

Conclusion

During the research, we tested creative potential and intelligence in the experimental group before introduction of interactive educational techniques in the training processes and within the experimental period (1 academic year). The tests show considerable growth both in the creative potential and intelligence (**Fig. 5**).

Our experimental group was regrettably small and consisted of 14 persons.

The experimental data were qualitatively and quantitatively analyzed using the mathematical statistics methods.

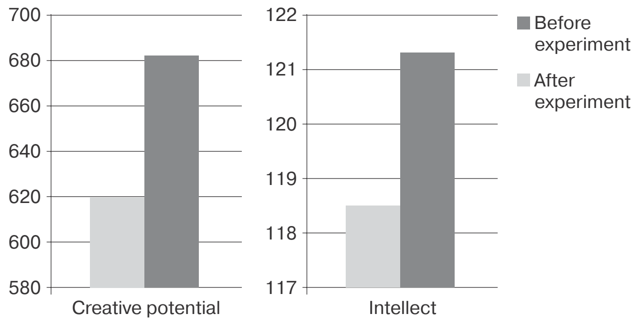

Fig. 5. Experimental results

Statistical validity of the mind map efficiency was estimated by the sign test G. We obtained the number of 'typical' positive shifts (difference between an n-th observation values before and after experimental exposure) in the direction anticipated by the investigator as n = 13 and the number of 'untypical' negative shifts as $G_{emp} = 1$.

From the table of the criterion, we determined the critical value of G:

$$G_{\lim} = \begin{cases} 3, P \leq 0{,}05 \\ 1, P \leq 0{,}01 \end{cases}$$

The hypotheses are:

N0: Direction of predominant shift is random.

N1: Direction of predominant shift is non-random.

In our case, the empirical and critical values are equal, the typical shift falls in the domain of significance, and it is possible to draw the conclusion that the hypothesis on the mind map efficiency is statistically valid.

References

1. Stoff V. A. Models and perception. 1963.
2. Skvirskiy V. Ya. Instructional guidelines to structure educational information. Moscow : MADI, 1980. 80 p.
3. Earnest D., Amador J. Lesson planimation : prospective elementary teachers' interactions with mathematics curricula. *Journal of Mathematics Teacher Education*. 2019. 22(1). pp. 37–68.
4. Torosyan V. F., Tishchenkova A. V. Personnel training for regional social and economic system as the mutually beneficial university-and-business interaction. *Professionalnoe obrazovanie v Rossii i za rubezhom.* 2012. No. 4(8). pp. 84–90.
5. Frolov M. T. Epistemological problems of modeling, Moscow : Nauka, 1961.
6. Chernikova A. A., Petrov V. L. Training of mining engineers at the Russian research universities. *Gornyi Zhurnal*. 2015. No. 8. pp. 103–106. DOI: 10.17580/gzh.2015.08.22
7. Vinevskaya A. V. Case method in pedagogy. M.A. Puilova (Ed.). Rostov-on-Don : Feniks, 2015. 141 p.
8. Ustunel H., Keles F. Design of a touch sensation application including surface tension sample using a haptic device in engineering education. *Computer Applications in Engineering Education*. 2019. Vol. 27(2). pp. 344–350.
9. Glushkov V. M. Epistemological nature of information modeling. *Voprosy filosofii*. 1963. No. 10. pp. 12–18.
10. Gurina R. V., Sokolova E. E. Frame representation of knowledge : Monograph. Moscow, 2005. 176 p.
11. Eretskiy M. I. Improvement of elementary vocational training. Moscow : Vysshaya shkola, 1987. 264 p.
12. Menekse M., Purzer S., Heo D. An investigation of verbal episodes that relate to individual and team performance in engineering student teams. *International Journal of STEM Education*. 2019. 6:7.
13. Barak M., Hussein-Farraj R. Integrating model-based learning and animations for enhancing students' understanding of proteins structure and function. *Research in Science Education*. 2013. Vol. 43(2). pp. 619–636.
14. Erdniev P. M. Agglomeration of didactic units as educational technology. Moscow, 1992.
15. Erganova E. M. Professional education procedure : Teaching aid for university students. Moscow : Akademiya, 2007. 160 p.
16. Klaus G. Cybernetics and philosophy. Berlin, 1961.
17. Kopeina N. S. Teaching style as supportive tool of successful learning of students. Problems of academic performance enhancement and reduction in attrition rate. Leningrad : LGU, 1983. pp. 23–29.
18. Kuzmina N. V. Integrated research of pedagogical factors in academic performance. Ways of improving efficiency of university education. Didactic elements of special procedures. Gorky : GGU, 1980. 144 p.
19. Matyash N. V. Innovative pedagogical technologies. Project teaching : Teaching aid. Moscow : Akademiya, 2014. 160 p.
20. Nemov R. S. Psychology : Textbook for students of pedagogical universities. Moscow : VLADOS, 2001. Book 3 : Psychognosis. Introduction in scientific psychological research with elements of mathematical statistics. 640 p.
21. Sakharoova V. I., Khlupina N. O. (Collectors). Arrangement of self-training at professional education institutions. Kemerovo : GBU DPO KRIRPO, 2016. 126 p.
22. Pastukhova I. P., Tarasova N. V. Learning and exploratory activities of students : Elementaries. Moscow : Akademiya, 2014. 160 p.
23. Harran M., Theunissen H. W. Navigating the engineering literacy divide: design report collaboration practice realities. *Journal of Engineering, Design and Technology*. 2019. Vol. 17(1). pp. 77–101.
24. Torosyan F. F. Formation of cognitive self-dependence of students. Theses of Candidate of Pedagogical Sciences Dissertation. Kemerovo : KemGU, 2006. 192 p.
25. Torosyan V. F., Politsinskiy E. V., Sokolova S. V. Criteria and values of cognitive self-dependence assessment of technical university. *GIAB*. 2011. No. S2. pp. 439–448. EM