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Ways of Students Training Aimed at Analytical Skills Development while Solving Learning Tasks

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Abstract

The article considers the problems of students training to solve learning tasks in technical universities, as well as training of high-school students, who are going to enter technical universities. The functions of tasks, causing the importance of their application in learning process, are specified. The system of methods is given which allows a successful development of analytical skills of students during solving physics and chemical problems. The features of analysis during solving physics and chemical problems are demonstrated. Results of experimental work, supporting the effectiveness of the stated methods, are given herein.

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Keywords: Activity approach; generalized plan; analysis; method of actions; orientation in the problem structure.

1. Introduction

Physics and chemistry are the basis of natural sciences. Here the main component of learning process, not only for physics and chemistry, but for exact sciences learning in general, is the problem solving.

During solving various problems a student performs thinking actions, going from knowledge of law formulations and initial conditions of the researched process to establishing the interrelations between the known and unknown characteristics of the process, explanation and quantitative evaluation of the result.

Thus, the problem solving process facilitates the deeper comprehension of obtained knowledge and formation of a comprehensive idea of reality. The skill of problem solving is a professional quality required for any engineer and

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the best criterion for evaluation of degree of material learning and mastering.

Problem solving allows: - understanding and learning the basic laws and equations, forming of the idea about their peculiarities and boundaries of application; - developing the skills and ability to use general laws for solving specific and practical tasks.

2. Subject and method of research

Many researchers, not only in Russia, but also foreign authors devoted their researches to the problem of formation of thinking activity and methods during learning problems solving (Gavrin, 2008; Redish, 2003; Schmitt & Lattery, 2004).

Analysis of tasks application for studying natural science disciplines allows specifying their main functions: - cognitive, it allows expanding the student minds, using the facts about life and activity of scientists, interesting facts, related to physical phenomena and chemical objects; - developmental, it consists in improvement of skills of working with various types of information display (tables, figures, graphs, diagrams, etc.), as well as development of logical thinking, as problem solving involves such logical operations as analysis, synthesis, comparison, abstraction and generalization; - function of theory and practice unity, expressed in developing skills to apply laws of physics and chemistry to solving practical tasks in professional activity, as well as in everyday life; - function of demonstration of interdisciplinary connections of physics, chemistry, mathematics and professional disciplines; - function of knowledge quality evaluation. Correctness of problem solving allows reflecting the objective level of material learning and testing how well it had been mastered.

The given functions show how important the problem solving process is for natural sciences learning.

3. Survey Results Analysis

In our view, training of both school and university students to solve problems in physics and chemistry should be based on activity approach. As Atanov (2001, p. 25) writes, namely this approach, based on "… problem solving, … allows organizing the student activity clearly and effectively". The process of problem solving is the process where methods of actions are mastered, and knowledge is learnt by the students in the process of applying the knowledge, that is during the process of problem solving. The method of teaching the physics problems solving, based on activity approach, developed for high school students and pre-entry course trainees is successfully used for students as well, and what is important – it helps obtaining good results during training (Politsinsky, 2007).

This method includes the following stages: 1) preparatory; 2) algorithm development for this type of problems; 3) diagnostics and teaching of undeveloped actions; 4) solving of problems; 5) testing and reflexive (Politsinsky, 2007).

During the researches the learning activity design was based on diagnostics of difficulties experienced by the students during problem solving and performing independent actions and operations. Here the conclusion was made that students were more successful in problem solving when the expanded operational basis for solving was available, and subgoals were sorted and formulated during solving with support of "key features" in the considered problem structure.

One of the main goals of solving activity, particularly of physics problems, is development of algorithms for solving problems in specific cases with further generalization and systematization of experience – obtaining of a detailed plan for solving a random physics problem. This detailed plan of a random physics problem solving is systematized and presented as the diagram (Politsinsky, et al., 2011). The diagram reflects the sequence of specific logical steps at every of the three stages: physical, mathematical, analysis and check of solution. The physics stage of problem solving can be conventionally divided into preliminary and basic, mathematical into obtaining of calculating formulae in general and obtaining of numerical answer.

In addition, during solving the certain type of problems, besides finding the peculiarities of their solution and practicing the specific operations for their solving, their folding in generalized actions is performed. Learning of content of general methods of actions, aimed at problem solving, is very important as mastering of these very operations and methods should be the goal of student learning activity. With support of key features, students explain the purpose and content of each step in solution that results in free orientation in the problem structure.

1. *Point moves in the plane XOY, and its coordinates vary in time according to the law:* $x = 2 \cdot \sin \omega t$ *and* $y = 2 \cdot \cos \omega t$ *, where* ω *- constant. What is the trajectory of the point?*
2. *Find the linear speed of points rotation on Earth's surface in the latitude* $\varphi = 60^0$.
3. *Body is projected at angle α to the horizon with initial velocity* υ_0. *Find the range of throw.*

Figure 1. Conditions of physics problems.

Thus, for instance, when considering *Problem 1* (Fig.1) the students specify "mathematical transformations", "elucidation and recording of problem requirements". In *Problem 2* – "analysis for presence of hidden data", "use of reference data" (as the problem considers the motion of point on earth surface, then they can and should write down the Earth radius, besides, its period of revolution – 24 h). In *Problem 3* – "drawing of figure", analysis "object – process – surroundings". When discussing the second logical stage, the methods of simplification and complication are considered. So, the idealization, estimation and rejection of secondary phenomena, neglecting of insignificant details are used for the process of simplification, for the complication process – accounting and consideration of previously rejected details, objects and phenomena. When solving this problem, we introduce a simplifying condition – to neglect the air resistance. By removing this condition, we complicate the problem. Trajectory will be different from parabola and movement to axis *x* will not be even. Besides, we think that: a) body is projected from the ground surface; b) body can be taken as material point; c) we do not consider the Earth movement around the Sun and its own axis; d) we calculate the acceleration of free-fall g = 9.8 m/s^2 = const, etc. By considering any of the given simplifications, we complicate the problem.

Analysis is a logical operation, consisting in that object under study (in our case, a learning task) is mentally divided into components (features, properties and relations), each of them is investigated separately as a part of the whole. Synthesis is a logical operation, using which elements are combined in the whole. Ability to think is very often linked to ability to analyze. This is quite fair as the drawing of consequences, expressing new properties of the object under study, often requires analysis of the known facts about it. Detailed plan of a random physics problem solving reflects the special importance of skills and ability to analyze at every specified stage of problem solving. At the preliminary, physics stage the very first step is "study and retelling of problem content" (retelling, that is a comprehensive reproduction of conditions and requirements of a problem, but not word-for-word reproduction), which is based on skills to perform analysis. Failure of a student to reproduce the problem content says that the problem is not accepted and they cannot start solving it immediately.

Certainly, when solving a problem, it is difficult to separate analysis or synthesis per se, they are interrelated. Therefore, the analytical-synthetic method of solution is often spoken of. Nevertheless, "… when solution is based on the question (requirements) of the problem, the analysis is placed in the forefront". (Kamenetskiy & Orekhov, 1987, p. 18) Selection of a certain system of problems and their consideration with focus on the content of their solving activity, allows developing the recommendation about obligatory attempt to build solution on the basis of the question or problem requirements. It helps to remove one of the major difficulties for students, consisting in that many of them often do not know and do not understand what to begin with.

Majority of standard tasks can be solved by analytical method, building the solution on the question (requirements) of problem, but not all of them. When solution cannot be built in such way, the synthetic method is used, and synthesis is brought to the forefront, as different ratios, which can be found using the data and statement of the problem, are synthesized. Thus, it is reasonable to start solving the calculation problem either from question, or from the basic law (laws), describing the physics phenomenon (phenomena), considered in the problem. In general, no matter the selected method, the success in problem solving is determined by the skill to perform analysis of physics situation, described in the problem, which is based on the skill to sort out the main thing.

The system of main methods used for development of student skills to perform analysis during problem solving, which is conventionally divided in two groups, is given in Table 1. The first group is connected with activities of teacher and students during problem discussion and solving, the second – with reconstruction of initial content of the problem.

Table 1. System of the main methods used for development of student skills to perform analysis during problem solving.

Group of methods	Description of method	Main idea and principles of method
1	1.1. Step-by-step explanation of every stage of problem solving	Formulation of all objectives and content of every step in problem solving out loud. Special attention is given to – analysis of physics situation, described in the problem.
	1.2. Search of analogy	Search of similarity in the content, sequence and methods of actions in the solution with the previously considered problems
	1.3. Creation of problem situation using "incidental" error	Teacher makes a purposeful mistake, leading to an absurd result; "does not notice" the mistake made by a student
	1.4. Evaluation of solution rationality	Attempt to solve using different methods, search of the optimal one
2	2.1. Exclusion of "excess" data from the statement and requirements of the problem	Ready specified values, their ratios (p = ; L_1 = 1.5 L_2), reference data, etc., are excluded from the problem text
	2.2. Transformation to the problem with insufficient or excess data	Introduction of excess data in the problem statement and vice versa exclusion of the necessary
	2.3. Simplification (complication) of the described situation	Idealization, estimation and rejection of secondary phenomena, neglecting of insignificant details (accounting and consideration of previously rejected details, objects and phenomena)
	2.4. Variation in methods of problem content presentation	Transition from textual description of the statement to requirements given by the table, graph, diagram and vice versa

In comparison to physics, the problems in chemistry use less values, required for solution. However, the stated method of teaching the problem solving based on activity approach can be successfully applied in chemistry teaching. In the generalized plan of a random problem solution the chemical stage is specified instead of the physics, where substances and their conversion are considered qualitatively. One of the most important stages during chemical problem solving, resulting in understanding the point, we think that preliminary analysis of the text, assuming the clarification of certain terms, paraphrasing and reformulation of the statement, which helps to clarify what chemical process or specific substance is meant in the problem statement.

4. Conclusion

The applied methods, facilitating the development of skills to analyze during solving problems in chemistry, include: Comparison. Statements for two problems are given (for example, 1) to calculate the mass of aluminum chloride, required for preparation of 2 l of solution with molar concentration of the dissolved substance 2 mole/dm^3; 2) to calculate the mass of aluminum chloride, required for preparation of 2 l of solution with molar concentration of the dissolved substance 2 mole/dm^3), comparing which a student acquires the skills to specify the features and properties of objects, establish the similarity and difference among features, and specify the grounds for comparison;

Selection (of the correct answer / calculation formula for problem solving), facilitating the learning of problem structure, establishing of interconnection between data and sought quantities, and justifying the judgments; Construction (for example, what data should be added to the problem statement), using which the student transfers the learnt knowledge to a new knowledge area, is involved in active search activity, structuring the data, analyzing and transforming the mathematical model of the problem; Schematic modeling of the problem, allowing translating the text into language of signs and symbols, which can be performed by physical and graphic means, thus increasing

the accessibility for understanding the connections and relations, hidden in the text, as well as a correlate the results with obtained models, reality (with texts).

Sometimes text translation into the language of signs and symbols of chemical formulae and reaction equations makes the dependences between values, stated in the problem, so obvious that immediately facilitates the solution finding. For the process of model building we used the approach of Vernier (1998), in which categories of object state, described in the problem text and its transformation, are used. Here the data are expressed as geometric figures and relations among objects in the form of lines and arrows. Application of the same signs and symbols for model building for various problems facilitates development of general methods of actions during the problem analysis, sorting out of constituents and solution finding.

It should be noted that learning effectiveness both for school and university students considerably increases when individual learning routes are built (Politsinskaya, 2013), based on systematic diagnostics of difficulties arising during learning tasks solving.

Dynamics of developing the skills to perform analysis during solving problems in physics and chemistry were regularly detected with purposefully developed exercises and the system of problems (Demenkova, 2012), (Politsinsky, 2011). Results of conducted researches allow making the statement (Politsinsky & Demenkova, 2015), (Politsinsky, 2007), that teaching school and university students to general methods of mental activity, and particularly, analysis, is the most effective during organization of problem solving training.

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