Asian Journal of Multidisciplinary Research
(AJMDR)
ISSN: 2395-1729

THE ROLE AND PRACTICAL SIGNIFICANCE OF THE PROBLEM-BASED LEARNING METHOD IN TEACHING CHEMISTRY

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Abstract. This article presents the theoretical foundations and significance of the problem-based learning method. It describes the methods, goals, and objectives of problem-based learning. The problem-based learning method was used to explain topics studied in inorganic and organic chemistry to students. Students' skills and competencies in independent thinking and experimental skills were improved. The essence of chemical reactions and experiments were explained using problem-based learning. Conclusions were drawn and suggestions were made.

Key words: problem-based learning, problem situation, logical and critical thinking, analytical thinking, oxides, indicators, solution environment, mesomeric effect, electrophilic and nucleophilic substitution, electron density.

Introduction. Clause 4 of the Decree of the President of the Republic of Uzbekistan No. PF-6108 dated November 6, 2020 “On measures to develop the spheres of education, upbringing and science in the new period of development of Uzbekistan” [1] and a number of other resolutions provide for the implementation of tasks including improving the quality of education in our country, increasing the knowledge and experience of students, and training qualified personnel in the interests of the state. Ensuring the implementation of the above resolutions and decrees can be achieved through the use of innovative technologies, pedagogical and information technologies, and modern educational technologies in the educational process.

Nowadays, many types of modern educational informations are widely used in the educational process [2]. These include problem-based learning, interactive learning, distance learning, modular learning, computer-based learning, innovative learning, and other learning methods.

Problem-based learning [3] refers to the creation of a problem situation under the guidance of a teacher. This method refers to the organization of an educational process that allows students to creatively master knowledge, skills and competencies as a result of their active independent activity and to develop intellectual activity.

Therefore, the essence of problem-based learning is to teach new knowledge by creating a problem situation in the educational work of students and solving educational tasks, problems and questions. This creates a scientific research method of mastering knowledge.

In the 1960s, problem-based learning was further deve-loped based on the views of researchers such as S. L. Rubinstein, M.I. Makhmutov, V. Okon, I. Ya. Lerner. S. L. Rubinstein's idea that "Thinking begins with a problem situation" was accepted as the psychological basis of problem-based learning.

In the traditional pedagogical method, from knowledge to problem, students cannot independently develop scientific research, skills and competencies, because they are presented with ready-made results for assimilation. Solving the problem requires creative thinking. Reproductive mental processes associated with the repetition of assimilated knowledge patterns are not effective in problem situations.

If a person is constantly taught to assimilate ready-made knowledge and skills, it is possible to suppress their natural creative abilities, they “forget” about independent thinking. The thinking process is best manifested and developed in solving complex problems.

Problem-based learning refers to the learner-centered educational ttechnologies since here the person is considered a subject, the purpose of problem situations is to arouse their own interest in the pedagogical process. The psychological mechanism of the processes taking place in problem-based learning is a kind of immersion: a person encounters a contradictory, new, unknown problem, in which a state of surprise and bewilderment arises.

Problem-based learning consists of three stages. Proof is based on finding the connection between the problem established principles. Verification is based on justifying the correctness of the problem being solved as a result of the chosen reason [4]. Explanation is based on identifying reasons that justify the correctness of the solution.

This approach , as well as interactive methods [5], integration methods [6], didactic games [7], develop analytical thinking and independent research skills in students. One of the effective teaching technologies in modern higher education is problem-based learning. Its task is to stimulate active cognitive processes and form a scientific and research style of thinking. The method of problem-based learning improves students' independent work. It helps to conduct a deep logical analysis of the material grounded in scientific concepts and supports the formation of practical skills and competencies.

Problem-based learning can be used as the most important element in implementing a systematic-activity approach to studying chemistry and forming a universal learning activity that students must master.

This method is a set of actions such as organizing problem situations, formulating problems, providing students with the necessary assistance in solving problems, checking these solutions, and finally, managing the process of systematizing and consolidating the acquired knowledge. The essence of problem-based learning is the creation of a chain of problem situations in various types of creative

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educational activities of students and the management of their mental (search) activity in order to master new knowledge through independent (or collective) problem-solving under the guidance of yhe teacher [8].

In the organization of problem-based learning, it is necessary to combine group and individual work of students. In the model scheme of a problem-based lesson, problem solving naturally occupies the main place. At this stage, work with students can take the following forms [9]:

1) frontal work with the whole class; 2) group work; 3) individual work.

The choice of one or another type of work is influenced by the nature of the task, the available educational tools, as well as the time available to the teacher. The following three methods of organizing problem-based learning are considered the most effective: problem presentation, search (heuristic) conversation, independent search and research activities of students.

Problem presentation. This method of organizing problem-based learning is suitable in cases where students do not have sufficient knowledge, encounter a certain phenomenon for the first time, and cannot establish the necessary associative connections. In this case, the search is carried out by the teacher independently.

The success of problem-based learning depends mainly on the following factors: problematizing the educational material; activating the cognitive activity of students; combining the educational process with play and labor activities; the teacher’s ability to effectively apply problem-based methods; forming a chain of problem questions to solve a problem situation and presenting them to students in a logical sequence [10].

When studying the topic “Carbohydrates”, you can ask such a problematic question: why does bread taste sweet when chewed for a long time? Or when demonstrating an experiment comparing the properties of glucose and fructose, students encounter a problem: glucose reacts with copper (II) hydroxide, while fructose does not. Why? Before the teacher answers the question posed, students can already answer themselves and verify it against the teacher's assessment. If schoolchildren have the minimum knowledge necessary for active participation in solving an educational problem, an investigative conversation is used.

Exploratory (heuristic) conversation. A heuristic conversation is a system of logically connected questions of the teacher and answers of students, the ultimate goal of which is to reveal an entirely new problem or part of it for students. An exploratory conversation is usually conducted on the basis of a problem situation created by the teacher. At the same time, students independently determine the stages of the search, formulate various hypotheses, and put forward options for solving the problem. For example, there is a genetic connection between the principal classes of inorganic substances. Understanding the existence of a genetic connection and teaching students about it are of great practical importance in inorganic chemistry. How can the existence of a genetic connection be explained?

For this purpose, if the lesson on the topic “Genetic relationship between the main classes of inorganic compounds” is conducted in the form of a demonstration experiment based on a problem assignment, students themselves will come to the conclusion that there is a relationship between substances of different classes.

Students are asked to prove through an experiment that nitrogen (V) oxide and barium oxides are acidic and basic oxides.

s and discussion. Solution: Through the experiment, students carry out the following reactions:

1. $BaO + H_2O = Ba(OH)_2$.In the solution, the color of litmus changes to blue, the color of methyl orange to yellow, and the color of phenolphthalein changes to pink. This phenomenon indicates that a soluble base is formed in the reaction product, therefore, barium oxide is a basic oxide.

2. $N_2O_5 + H_2O = 2\ HNO_3$. The solution changes the color of litmus to red, which indicates that an acid is formed, therefore, it is proven that nitrogen (V) oxide is an acidic oxide.

3. The resulting solutions react with each other. In the resulting solution, litmus paper turns yellow, which indicates that a salt was formed when a base and an acid reacted.

$Ba(OH)_2 + 2\ HNO_3 \rightarrow Ba(NO_3)_2 + H_2O$

Analyzing the results of the experiments, students draw a diagram reflecting the genetic relationship between the principal classes of inorganic compounds:

Ba (metal) → BaO (basic oxide) → $Ba(OH)_2$ (base) → $Ba(NO_3)_2$ (salt)

N_2 (nonmetal) → N_2O_5 (acidic oxide) → HNO_3 (acid) → $Ba(NO_3)_2$ (salt)

Problem statement. Why are carboxylic acids weaker than inorganic acids? Carboxylic acids are not stronger than a number of inorganic acids, because they are usually weak and do not completely dissociate in aqueous solution. Unlike strong inorganic acids, they reversibly dissociate. Inorganic acids are relatively stronger because they usually completely dissociate, forming a large number of hydrogen ions in solution. The strength of inorganic acids is due to the ease of ionization of the hydrogen atom in their molecule. Carboxylic acids contain saturated hydrocarbon radicals bonded to the carboxyl group. These radicals exhibit electron-donating properties and reduce the degree of dissociation of the carboxylic acid. Among carboxylic acids, picric acid exhibits the strongest acidity, and its strength is equal to that of hydrochloric acid. The strength of carboxylic acids depends on the structure of the hydrocarbon radical.

Independent research by students. Electrophilic substitution reactions in hydrocarbons of the homologous series of benzene [11] occur more easily than in benzene. How can the reason for this phenomenon be explained?

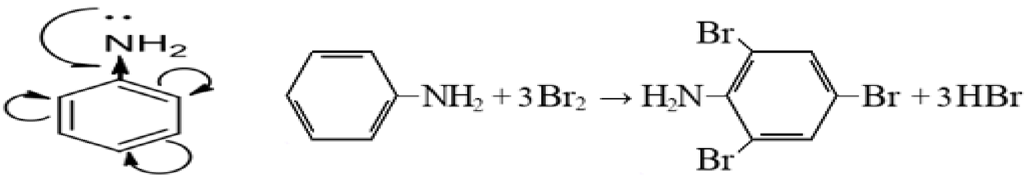
Results and discussion. This problematic situation is explained on the basis of theoretical assumptions. Despite the presence of a double bond in the arene molecule, it does not tend to react under ordinary conditions with reactions charac-teristic of unsaturated hydrocarbons. For example, benzene does not decolorize bromine water and $KMnO_4$ solutions under ordinary conditions. This feature is explained by its electronic structure. The 6 C atoms in benzene are connected to each other by bonds of the same length (0.140 nm). This distance corresponds to the distance between the lengths of a single (0.154 nm) and a double bond (0.134 nm). The 6 C atoms with sp-hybridized orbitals (including the H atoms bound to them) lie in one plane and form a regular hexagon, the valence angles being 120°. Due to the mutual overlap of the unhybridized p-orbitals, a single π-electron sys-tem is formed along the lower and upper sides of the molecular plane. The ben-zene nucleus, formed by the delocalization of π-bonds, is symmetric and has a unique stability. The benzene molecule has a resonance energy of 150 kJ/mol. To break the bond in benzene, an equal amount of energy must be expended. This explains the stability of the aromatic ring [12]

When the benzene nucleus contains type I substituents (except halogens), the substitution is easier than for benzene, while it contains type II substituents and halogens, the substitution is more difficult than for benzene. This is explained by the redistribution of electron density in the benzene ring under the influence of these substituents.

The electron-donating substituent interacts with the benzene nucleus in two ways: the inductive effect (±I-effect) and the mesomeric effect (±M-effect). As a result of these effects, a significant change (increase or decrease) in the electron density in the benzene ring is observed. For example: I-type substituents increase the electron density in the ortho- and para-positions of the benzene ring, since these substituents are electron donors and move electrons from themselves to the ring side. Here, the (+) M-mesomer and (-) M-mesomer effects occur. The figure shows the example of phenol and benzaldehyde [12].

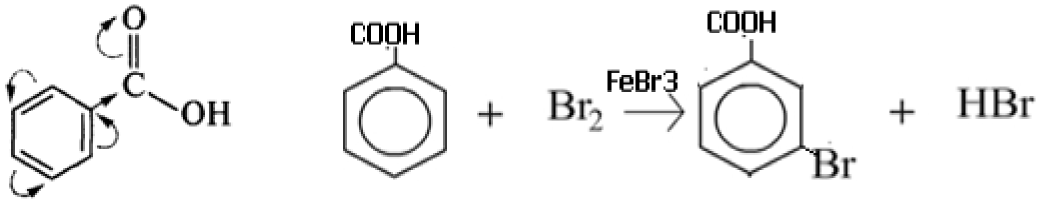
1–phenol 2-benzaldehyde

In the aniline molecule, the NH_2 amino group increases the electron density in the ring in the ortho and para positions, and electrophilic substitution occurs more easily in the ortho and para positions.



Due to the polarization of the carbonyl group of benzoic acid, the electron density at the carbon atom bound to the nucleus decreases (σ+). This leads to a shift of the σ-bond electrons in the nucleus towards the carboxyl group (-I effect) and a relative electron “deficiency” of the nucleus.

Also, due to the mesomeric effect, the electron affinity in the ortho- and para-positions is greater. The coupling of the double bond electrons of the carboxyl group with the π-electrons in the nucleus (mesomeric effect) can be shown as follows:



Although the overall electron density of the aromatic nucleus decreases under the influence of the carboxyl group and electrophilic substitution reactions become more difficult, the reaction proceeds at the meta-position, since the electron density at the m-postion is greater than at the o- and p-states.

Results and discussion. Information about “Properties of Calcium and Magnesium” is explained to students through a problem-based approach. The study of the properties of calcium and its biological significance is carried out on the basis of interdisciplinary connections by repeating the topic “Composition of Bones” in the 8th grade biology subject. It is known that bones consist of appro-ximately 35% protein matrix and 65% mineral content. The protein structure helps the bone to stretch, and the mineral salt calcium gives the bone its hardness. When the protein composition in the bone decreases, they become brittle.

When calcium salts are reduced in the bone, the bones become loose, porous and soft. The biological importance of calcium for bone health can be studied through the following experiment (this experiment can be done independently by the student at home based on the teacher's recommendation).

Procedure for conducting the experiment. A thin raw bone (from the wing) of one chicken is taken and cleaned of meat (the bone should fit freely in the jar. This can be done with the help of adults). The bone is left to dry for several hours. Then the bone is placed in a jar, household acetic acid (50-70%) is poured into it and the jar lid is closed and left for two hours. After the specified period, the bone is taken out and washed in cold water. This procedure is repeated 2-3 times per week. During the week, the bone is regularly checked for flexibility. Initially, the tip of the bone is flexible, but over time its flexible area increases. Eventually, the entire bone becomes easily flexible [11].

Results and discussion. As mentioned above, bone is hard and strong mainly due to the mineral substances that make up its composition, calcium. Acetic acid dissolves the mineral substances. This causes it to become pliable and soft. A deficiency of calcium phosphate ($Ca_3(PO_4)_2$) can lead to weakening of the bones, an increased risk of fractures, and diseases such as osteoporosis and rickets. Calcium phosphate salt is insoluble in water, but when bone is left in an acetic acid environment, it turns into calcium acetate salt, which is highly soluble in water.

$$Ca_3(PO_4)_2 + 6\,CH_3COOH \rightarrow 3Ca(CH_3COO)_2 + 2H_3PO_4$$

In summary, calcium phosphate salt plays a crucial role in maintaining bone, ensuring its strength, and performing important biological functions in the body.

Results and discussion. Why does only methanoic acid in the homologous series of carboxylic acids repeat the qualitative reactions characteristic of aldehydes, the "silver mirror" and "copper mirror" reactions? To find a solution to the problem, students reread the topic "Aldehydes and their properties". Having determined that the reactions noted above occur only in molecules whose molecule contains an aldehyde functional group, they draw the structure of the methanoic acid molecule. The methanoic acid molecule can be considered as an aldehyde on the one hand and as an acid on the other. Therefore, methanoic acid can also undergo the silver mirror and copper mirror reactions. This can be demonstrated this by constructing reaction equations.

$$HOCHO + Ag_2O\ (NH_4OH) \rightarrow CO_2 + Ag\downarrow + H_2O$$

$$HOCHO + Cu(OH)_2 \rightarrow CO_2 + Cu_2O\downarrow + H_2O$$

Analysis. Organic acids are weaker than inorganic acids. How can this be explained? Students explain the phenomenon, knowing that acidity is a property that depends on the concentration of hydrogen ions in the solution. The number of hydrogen ions in solutions of carboxylic acids is less than the number of hydrogen ions released in solutions of mineral acids. This is due to the presence of the carbonyl group C=O in organic acids. This functional group has a strong polarization, the electron density shifts towards the oxygen atom, since the relative electronegativity of oxygen is 3.5. Strong polarization occurs in the acid molecule, and the O-H bond in the OH group weakens due to the electron transfer. Hydrogen ions are released into the solution [12]. Organic acids are weak acids, since a small amount of hydrogen ions is released into the solution.

The teacher creates these and similar life problem situations based on the topic and develops the competence of students during the lesson. Problem-based learning equips students with methods of exploring the world around them, develops purposeful observation skills and competencies, cultivates the ability to generalize and draw conclusions from basic laws by substantiating them, and arouses interest in possible research work.

Recommendations. The main goal of problem-based learning is to help students fully understand and solve problems related to the subject being studied. One of the main issues in applying problem-based learning in practice is to create a problem situation related to the subject being studied. The main idea of problem-based learning is not to provide students with ready-made knowledge, but to ensure that they acquire it through their own research and study of problems related to the subject matter.

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