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# The Effectiveness and Application of Innovative Pedagogical Approaches in Teaching Chemistry

**Abstract**

In the contemporary era, traditional teaching methods no longer adequately address the demands of modern education, leading to a growing reliance on innovative approaches.Educational innovation encompasses new strategies, tools and practices within the learning system.Among these, the use of online platforms, digital technologies, STEAM education, as well as project- and problem-based learning, has gained considerable significance.These approaches foster students' creative and critical thinking, enhance collaborative skills, and encourage independent exploration.

In the context of chemistry education, innovative pedagogical technologies- particularly project-based learning- play a vital role.When students engage in experiments and simulations during the learning process, the retention and understanding of acquired knowledge are significantly improved.Incorporating innovations into education makes the learning experience more engaging, interactive, and outcome-oriented.This article examines the role of such innovations in teaching chemistry within general education schools.

***Keywords:*** *innovation, student, development, project, chemical experiment, learning, application*

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# Kimya fənninin tədrisində innovativ pedaqoji yanaşmanın effektivliyi və tətbiqi

**Xülasə**

Müasir dövrdə ənənəvi tədris üsulları müasir dövrün tələblərinə cavab vermədiyindən təhsildə innovativ yanaşmalardan daha çox istifadə olunur. İnnovasiya təhsil sistemində olan yeniliklərdir. Təhsil prosesində istifadə olunan innovasiyalar — onlayn platformalar, rəqəmsal texnologiyalar, STEAM təhsili, layihə və problem əsaslı öyrənmə — günümüzdə böyük əhəmiyyətə malikdir. Bu


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saydıqlarımız şagirdlərdə yaradıcı və tənqidi təfəkkürü, kollektiv işləmə bacarıqlarını və müstəqil kəşf etmə bacarıqlarını inkişaf etdirir. Kimya fənninin tədrisində innovativ pedaqoji tehnologiyalar, xüsusilə də layihə əsaslı təlim mühüm əhəmiyyət kəsb edir. Şagirdlər öyrənərkən təcrübə və simulyasiyalardan istifadə etdikdə öyrənilən məlumatlar daha uzun müddət yadda qalır. Təhsil prosesində innovasiyalardan istifadə olunması bu prosesi daha əyləncəli, interaktiv və nəticəyönümlü edir. Məqalədə ümumi təhsil məktəblərində kimya fənninin tədrisində innovasiyaların rolu təhlil olunmuşdur.

***Açar sözlər:*** *yenilik, şagird, inkişaf, layihə, kimyəvi təcrübə, öyrənmə, tətbiq etmə*

## Introduction

In the globalized world of the 21st century, where information and technology are rapidly advancing, significant transformations are also taking place in the field of education. Since traditional teaching models do not fully meet the demands of modern times, the need has emerged to apply innovative approaches and utilize contemporary teaching methods in the learning process.

The word innovation originates from the English term “innovation”, which means “novelty” or “renewal”.Pedagogical innovation refers to the introduction of new practices within the educational system aimed at improving the course and outcomes of teaching, upbringing, and learning.Innovation takes place through the internal resources of the pedagogical system itself, which is also reflected in the prefix “in”, meaning “inside”. In modern education, innovation implies the use of new technologies, methods, and approaches in the teaching and learning process.Such innovations serve to enhance the quality of education, make it more accessible, efficient, and engaging.

**Research**

Innovative teaching methods applied in the classroom are among the key factors that foster students’ interest in the subject and enable them to discover knowledge independently.In this process, the teacher acts as a facilitator, or guide, while students become not passive listeners but active participants.

As in every sphere, the application of digital technologies in education has become one of the major priorities of recent years.The use of new online learning platforms is increasingly integrated into the teaching process.These tools enhance interactivity, make distance learning possible, and support personalized learning.One of the innovative approaches in education is the STEAM model, which involves the integrative teaching of science, technology, engineering, arts, and mathematics.This approach develops students’ critical and creative thinking.At the same time, lessons in robotics and coding provide students with broad opportunities to master the technologies of the future.(Aliyev, 2009)

In addition, several other innovative learning models can be highlighted, which foster students’ cognitive activity and provide broad opportunities for the independent discovery of knowledge.Among them, project-based learning deserves particular emphasis.Methods such as problem-based learning and the flipped classroom approach encourage students to engage in independent study, research, and teamwork.The main advantage of these methods is that they enable students to carry out various processes without constant reliance on the teacher.(Mammadova, 2012, p. 13)

Exploring the key innovative approaches in education is particularly interesting:

1. Application of digital technologies
- Use of electronic boards, tablets, and mobile applications
- Online learning platforms (Zoom, Google Classroom, Moodle, etc.)
2. STEAM education (Science, Technology, Engineering, Art, Mathematics)
- Promotes practical, research-based learning for students
3. Flipped classroom method
- Students watch video lectures at home and engage in discussions and practice during class
4. Robotics and coding lessons

- Provide students with deeper insights into technology while developing logic and problem-solving skills

5. Adaptive learning systems

- Offer individualized learning pathways tailored to each student's level

6. Project-based and problem-based learning

- Facilitate knowledge acquisition through the exploration of real-life problems

Innovation, in essence, is the implementation of novelty for the purpose of high efficiency and progress - in other words, the presentation of the final outcome or improved version of human intellectual activity, discovery, or invention to society.In modern times, the categorization and levels of innovation are determined through the "Innovation Matrix".This matrix, consisting of four sectors (revolutionary, sustaining, simple, and disruptive innovation), examines the relationship between the area requiring innovation and the problem that necessitates it.Since innovation is not a spontaneous process, measuring its inevitability and evaluating its potential outcomes in terms of efficiency is of exceptional importance for achieving success (Maharramov, Bayramov & Mammadov, 2011)

The five main stages of successful innovation are as follows:

1. Generation and mobilization of the idea
2. Evaluation of the idea
3. Experimentation and testing of the idea
4. Commercialization of the idea
5. Implementation of the idea

Over 2,500 years ago, the great Chinese philosopher Confucius stated that a nation that knows how to benefit from science and education will live in prosperity.

The science of management studies the governance of innovations.This field, known as innovation management, is developing rapidly.During the last two decades, discussions on innovations have intensified.This is linked to the rapid development of ICT, the creation of numerous new innovations through its application across various fields, the increased access of these innovations to global markets, the speed of their implementation, and the growth of competitiveness and economic efficiency (Abbasov & Aliyev, 2015, p. 39)

The terms "innovation" and "novelty" are often used synonymous and, in many cases, interchangeably.Innovation refers to the process of creating and applying something new- a complex intellectual process that unites science, technology, economics, and management.It encompasses the entire system of production and consumption relations.In a broader sense, innovation means the profitable use of novelties- whether new technologies, products, services, production methods, financial solution, commercial practices, or administrative, organizational, technical, and socio-economic decisions.Therefore, the terms "innovation" and "novelty" can be considered equivalent.Those who create and implement innovations are called innovators.An innovator must possess creativity, non-standard thinking, extensive knowledge and erudition, as well as entrepreneurial skills. Such qualities can only be formed through high-quality education.

The science that studies innovation processes is known as innovatics. Innovatics represents the scientific foundation and theoretical basis of innovation activity.It focuses on developing the methodology and methods for forecasting and generating innovations.Innovatics also encompasses the planning and organization of innovation activities and their application.The analysis of the current development of innovatics, along with forecasts for its progress, makes it possible to address many fundamental scientific problems.Solving these problems has contributed to the advancement of the theoretical and methodological foundations of innovatics as a research field.Therefore, as a scientific discipline, innovatics represents a structured system of new knowledge, technologies, methodologies, and methods.This system provides a logically integrated conceptual framework of innovation processes as a unified, interconnected, and comprehensive whole.

As in all other areas of human activity, innovations also play a significant role in education.In fact, all educational reforms throughout history have served the systematic implementation of innovations in response to societal development.

In education, innovation refers to the introduction of various novelties into the objectives, content, methods, and forms of teaching and upbringing, as well as the organization and management of education through the join activity of teachers and learners based on new knowledge.Educational innovations may be implemented at the national or regional level, within the framework of educational reforms or targeted development programs, either in a centralized manner or locally at the initiative of an educational institution.In such cases, experimental activities may be organized within the framework of pilot projects.Naturally, all these processes must be carried out on the basis of a legal and regulatory framework.

An innovative approach to the teaching of chemistry is of particular importance. In order to spark students' interest in the subject and enhance their cognitive engagement, it is crucial to conduct experiments related to the topic being taught.For this purpose, the use of cooperative learning technologies becomes even more significant.(Nikitina & Orzhekovskiy, 2016, p. 42)

One of the essential conditions for conducting experiments in small groups is to provide appropriate facilities and ensure compliance with safety regulations.The investigation and interpretation of experimental results by students, as well as the organization of project-based seminars using new simulations, represent innovative processes of great interest.

Let us focus on several examples where knowledge is discovered by students themselves through project-based learning and experimentation.(Goldinshtein, 2015, p. 22)

The project method, as a component of learner-centered educational technologies, has recently gained widespread application. It is used to systematize, generalize, and reinforce theoretical knowledge, skills, and competencies.The primary purpose of this teaching method is to develop learners' creative, logical, and critical thinking while providing them with essential knowledge of the subject under study.Furthermore, this method plays a vital role in helping students systematize the knowledge they acquire.

Based on the experience of chemistry teachers, it can be concluded that if generalization and systematization are not carried out regarding the subject being taught, even the highest-quality instruction will fail to provide learners with the necessary knowledge.This is because theories, laws, and facts acquired by students cannot be transformed into a coherent and structured body of knowledge without systematization (Aliyev & Azizov, 2006).

The project method mainly implemented in upper-grade classes and typically covers theoretical topics.For the successful implementation of a project, students must prepare thoroughly.Teachers, in tum, need to study the subject comprehensively, establish connections with other topics, and deepen their own knowledge by making use of additional scientific, methodological, and popular literature.The teacher's primary objective is to foster students' ability to think independently, conduct research, and develop their initiative and autonomy (Gurbanov, Khalilova & Velizade, 2018).

For this purpose, the topic and plan of the project must be prepared in advance, along with a bibliography.The plan should be structured in such a way that the answers to the questions are based not only on textbooks but also on additional literature and the results of the experiments carried out by the students.Students may present their answers in the form of reports or essays.

Let us consider an example of a project lesson on the topic of alkali metals. This lesson begins with a general overview of the properties of alkali metals based on their position in the periodic system and the structure of their atoms.The initial overview is presented by the students themselves.To accomplish this, they prepare a report in advance on "the general chemical properties of alkali metals," as indicated in the assignment.Each student prepares their own report, but the teacher divides it into several parts and suggests that two or three students present together.(Guliyev & Agazade, 2018, p. 4)

When discussing the atomic structure in their reports, attention should be given not only to the similarities but also to the differences between the structures of various alkali metals.While describing the common chemical properties of alkali metals, it is important to note that they all have the same valency, form only ionic bonds in their compounds, readily lose electrons, produce only basic oxides when reacting with oxygen, form salts with other nonmetals, and displace hydrogen from water.Their

differences in properties should also be clarified.Furthermore, the reports should highlight the characteristic features of the compounds formed by alkali metals.(Agayev & Mammadova, 2010)

It is noted that alkali metals form positively charged ions. In compounds formed with hydrogen, the metal ions combine with negatively charged hydrogen ions.When hydroxides react with water, the following reaction occurs:

$$NaH + H_2O \rightarrow NaOH + H_2$$

In the crystal lattices of alkali metal oxides, there are $O^{2-}$ ions. Similar to hydroxides, oxides cannot remain stable in aqueous solutions.When oxides react with water, the following reaction takes place:

$$Na_2O + H_2O \rightarrow 2NaOH$$

The general properties of alkali metal hydroxides include their high solubility in water, dissociation with the formation of hydroxide ions, the ability to change the color of indicators in a specific way, corrosive effects on skin and tissues, and their reactivity with acids and salts.(Republic of Azerbaijan, 2009)

In their reports, students should not only mention these properties individually but also provide examples and, most importantly, explain the existence of each property from the perspective of electronic theory or the theory of electrolytic dissociation. For example, the good solubility and disassociation of alkali metal hydroxides in water should be considered as two interrelated properties.It must also be emphasized that these characteristics depend on the relatively large sizes of the ions in the crystal lattices of the hydroxides.(Republic of Azerbaijan, 2010) (Novruzova & Qambarov, 2014, p. 16)

The teacher reminds students that they were introduced to the physical properties of alkali metals in the 8$^{th}$ grade. By showing the metals themselves (such as sodium and potassium), as well as a table or notes written in advance on the board that reflect their properties, the teacher explains that all alkali metals have relatively low melting points and are soft metals.The students are then encouraged to explain these properties based on their knowledge of metallic bonding.

The teacher further draws attention to another general property of alkali metals: when exposed to flame, each metal colors it with a distinct hue - for instance, lithium produces a crimson color, sodium a bright yellow, potassium a pink-violet, rubidium a red, and cesium a violet-blue flame. To illustrate this, students conduct a laboratory experiment demonstrating the flame coloration of sodium and potassium salts.

Once the study of alkali metals is completed, students analyze how the properties of these metals change as their atomic number increases, from lithium to cesium. They explore why the density of the metals increases, while their melting points and hardness decrease, and why their chemical reactivity rises.

To carry out the experimental part in small groups, students are organized into teams of four to five members. In project-based learning, achieving independent results to the topic.

**Interaction of Alkali Metals with Water**

Students take three test tubes and fill them with water.Small pieces of lithium, sodium, and potassium are cut, dried using filter paper, and placed separately into the test tubes containing water.

**Methodology for Studying the Regularities of Chemical Reactions**

Let us consider the methodology for studying the regularities of chemical reactions.From the earliest lessons, students are made aware that under the same conditions, some substances undergo chemical changes while others do not (e.g. heating stearin versus sugar), and in certain conditions, only physical changes occur (e.g., the melting of sugar).

Students are informed that chemical reactions are indicated by observable signs such as color changes, the formation of precipitates, gas evolution, and other phenomena.These are evidence that a

chemical reaction is taking place.Sometimes, the release or absorption of heat, or the appearance of light or flame, can also indicate that a chemical reaction has occurred.

After becoming familiar with the signs of a chemical reaction, the teacher makes the first generalizations regarding the conditions under which chemical reactions occur.Students are asked to answer the following questions:

1. The conversion of sugar to carbon
2. The burning of a magnesium strip
3. What conditions are required for a copper wire to develop a black coating?

In their answers, students note that heating is involved in all the mentioned cases.During the discussion, the teacher emphasizes that heating alone is not sufficient for the burning of magnesium or the darkening of copper wire.The metals must interact with oxygen in the air.

To demonstrate this, the teacher heats shiny copper wire that is either twisted together or compressed into a packet.After cooling, it is observed that the copper wire is blackened on the outside while remaining shiny inside.The reason for the inner shine is that oxygen molecules could not penetrate into the interior.

Next, the teacher carefully adds ammonium hydroxide to a test tube containing copper(II) sulfate solution.Students' attention is drawn to the formation of a light blue color in the middle of the test tube, indicating that the chemical reaction occurs in that specific area.If the substances were thoroughly mixed, the chemical reaction would occur throughout the entire volume.This observation allows students to form initial ideas that contact between reactants is a necessary condition for a chemical reaction to take place.

Finally, the teacher summarizes the discussion by identifying the main conditions required for a chemical reaction to occur:

- The presence of a substance undergoing a chemical change
- Contact and mixing of the reactants
- Heat

To assess the knowledge acquired by the students, the following tasks are assigned:

1. List the main conditions necessary for a chemical reaction to occur and provide examples.Why is it important to study these conditions in practice?
2. a) What conditions are required for the darkening of a copper wire?
   b) What conditions are necessary for the clouding of lime water?
3. When a spirit lamp is ignited, which condition for chemical reaction is being created?

## Conclusion

In chemistry, the transformation and interaction of substances are confirmed through the genetic relationships among major classes of inorganic compounds. Depending on their chemical properties and class, a complex substance can form a chain of transformations from simpler substances.(Abbasov, Maharramov, Abbasov, Babanli & Tagiyeva, 2001)

After completing the experiments, students are assigned a project based on the topic. They are given five to six days to prepare and present their results.

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