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PROBLEM-ORIENTED APPROACH IN CHEMISTRY TEACHING AND ITS INFLUENCE ON PUPILS' LEARNING ACHIEVEMENTS

Abstract. *This article examines the distinctive features of a problem-oriented approach to teaching chemistry and its effect on students' academic performance. Enhancing the teaching process to boost academic success continues to be a key objective in secondary education. This study aims to explore how a problem-based approach influences students' academic achievement in chemistry. The main directions of the study include a review of existing theories and practices of the problem-based approach in the educational process, implementation of this methodology in chemistry lessons at school, and identification of factors contributing to its effectiveness.*

As a result of the study, the effectiveness of this methodology, which includes the use of technologies and tasks based on the problem-oriented approach, was established. Pupils of the experimental group demonstrated a higher level of learning achievements. The application of this approach, using three chemistry topics as examples, it was demonstrated that students enhanced their academic knowledge and analytical skills, enabling them to effectively tackle complex problems and apply what they have learned in practical situations. Problem-based learning in chemistry has positive feedback among students. The authors of the article recommend using more cases, introducing modern digital tools, structuring discussions and increasing the number of projects, which can further enhance chemistry learning.

Keywords: *problem-based learning, problem-oriented approach, chemistry, learning achievements, pupils, case studies, digital technologies.*

Introduction

Relevance of the problem outlined in the research topic. Currently, the scientific examination of challenges and possibilities within secondary education is grounded in the growing integration of contemporary theories and approaches into the educational process. These aim to apply the principles of developmental learning, one of which is problem-based learning. This situation is determined by two factors. On the one hand, the society, in the form of its social order, containing new requirements to the modern school, regarding the preparation of a more diversely developed personality, capable of creatively solving educational and other tasks set before it. On the other hand, there is a need for a significant increase in the productivity and quality of the learning process itself, expressed in the improvement of educational achievements of schoolchildren, both in general and in some of the most important profile subjects.

The problem of improving the learning process to enhance academic achievement remains one of the most important tasks for secondary schools. Most often the solution to the problem of improving learning is proposed to be solved in different ways. Among the ways to improve learning, first of all, is the introduction of new modern approaches. One of these approaches is currently considered to be problem-oriented. Therefore, a new approach such as problem-based learning is considered more and more interesting in theory and practice. This approach, like any other, requires the development of new methods, programmes and textbooks, using more progressive methods, technologies and teaching tools. It is also considered important to take into account the peculiarities of individual subjects, including chemistry.

Problem-based learning assumes orientation on purposeful and consistent putting forward to students of various cognitive tasks, in the course of the resolution of which, students, under the guidance of the teacher, obtain new knowledge. Intrinsic motivation is considered to be the key to success in such an educational process.

It is generally accepted that when teaching children chemistry in a modern school, the educational process should also be problem-oriented. Since it is important to teach children to think critically, solve educational problems independently and use the acquired skills in real life during the study of chemistry. Problem-oriented learning is considered especially important in the modern information age, which is characterised by a large amount of information and other changes that are constantly occurring in society. In such conditions, students have to not only memorise facts, but also apply them in the course of analysing complex chemical problems and to obtain reasonable results. In this regard, it becomes urgent to find more effective teaching systems that can motivate the meaningful activity of students and promote their learning achievements in chemistry.

The degree of development of the investigated problem concerning the problem-oriented approach in school teaching is rather high. As questions of use of problem-oriented approaches in education as a whole and in school education in particular, are investigated by many researchers, both foreign and Kazakhstani, quite actively, for the last several decades.

To foreign researchers, who first investigated problem-based learning from the position of psychology, it is necessary to refer necessarily S.L. Rubinstein [1], E. Samsudin [2] and K. Kalagurka [3]. While the scientists of pedagogy highlighted the main functions of learning in a problem situation: J. Pozuelo-Muñoz [4], J. Valdez [5], N. Lukashova [6] and S. Abeuova [7] developed methods of teaching problem-based learning as the main components of the process of developing students' research skills. The problems of teaching at school with the help of problem-based learning methods were actively researched and discussed in the works of E.M. Karimulaeva and E.M. Karimulaeva [8], D.V. Korchagin [9]. The evolution of problem-based learning and its prospects for development in modern school is shown by S. Suyanta in a collective monograph [10].

Let us also note some Kazakhstani studies. The 2022 Concept for the modernization of pedagogical education in the Republic of Kazakhstan highlights the significance of employing contemporary approaches. This is essential because the current pedagogical education system in the Republic still largely relies on traditional subject theories and teaching practices, which are inadequate for addressing the demands of a rapidly evolving world. Traditional types of teacher education and school teaching organisations are still used and there is a low level of innovation-oriented development of students' abilities in each subject [11]. In the research conducted by L.V. Chepelyan and I.V. Grishko regarding the development directions of the education system in the Republic of Kazakhstan, project-oriented analysis of the country's educational preparation revealed several key issues: challenges in the educational content, the organization of the learning process at both basic and senior levels, the separation of learning from other activities, and a lack of consideration for students' capabilities and preferences, among others [12]. Problem-oriented education in mathematics lessons in Kazakhstan was considered by G.I. Sologub, with emphasis on the use of this approach through the use of STEM-approach for the development of functional literacy in students [13]. A.S. Rakisheva discusses the significance of problem-based learning in helping students acquire knowledge. The author emphasizes that problem-oriented learning not only requires a restructuring of the educational process but also encourages both students and teachers to engage in ongoing development [14]. M. Ashirimbetova and D. Shayakhmetova examined the experiences and potential of problem-oriented learning within the context of foreign language education. They argue that problem-based learning, as a teaching methodology, enables students to develop their cognitive abilities by utilizing existing or provided information, knowledge of the problem, and their own experiences. Additionally, it helps them apply these abilities in formulating strategies essential for addressing applied and professional challenges [15]. A.S. Aidarbekova, A.T. Ermekbayeva, and B.N. Kalshorayeva analyzed the key challenges in teaching chemistry and biology in schools across Kazakhstan. They believe that one significant issue is the lack of adequate technical and interactive resources in classrooms for these subjects. They emphasize the need to provide students with more practical information in chemistry and biology. Equipment and information should make the modern learning process a continuous process. As their use gives an opportunity to develop students' ability to navigate in information flows about chemical and biological processes and to get practical abilities [16].

It should be noted that the issues of problem-based learning in chemistry education remain insufficiently studied. In the available studies there are some discrepancies between the theoretical foundations of this approach and the conditions of practical use of problem-based learning technologies. There are contradictions in assessing the effectiveness of the used methods of problem-based learning. Besides, the existing scientific and applied studies most often emphasise on the consideration of separate aspects of the learning process in separate subjects, while a comprehensive assessment of the impact of problem-based learning technologies on the learning achievements of schoolchildren in chemistry has not been carried out. Thus, there is a need for additional research to establish more effective strategies for introducing problem-based learning into the school chemistry curriculum.

The purpose of the study is to determine the impact of problem-based learning approach on students' academic achievement in chemistry.

The objectives of the study are:

1. Consideration of existing theories and practices of using problem-oriented approach in the educational process;

2. Introduction of the problem-oriented learning methodology at school during chemistry lessons;

3. To establish the influence of problem-oriented learning techniques on pupils' performance in studying chemistry;

4. To evaluate the obtained results and identify factors contributing to the effectiveness of the problem-oriented approach in academic performance.

Scientific novelty is characterised by the fact that this study differs from other works as it is more comprehensive and aims to establish the impact of problem-based approach on the learning process in chemistry. This study focuses on specific problems and offers a holistic approach to solving the problem at hand, including the selection of an effective methodology and the evaluation of the results obtained during the pedagogical experiment. Thus, a more complete picture of the problems of the possibilities of applying problem-oriented technologies in school practice is obtained.

The object of the study is the process of teaching chemistry at school. The subject of the study – processes aimed at the formation of learning achievements in schoolchildren during the use of the principles of problem-oriented approach.

Theoretical significance lies in the expansion of knowledge on the research topic, which can be used for further research.

Practical significance consists in the possibility of introducing the problem-oriented approach in the curricula of chemistry teachers. Their use can allow to increase students' interest in studying chemistry as an important educational subject, increase the understanding of chemical processes and form the ability to work independently with information. They can also be used to develop new educational programmes and methods of teaching chemistry, aimed at improving the quality of education and academic achievements of schoolchildren.

Methods and materials

The materials of this study were theoretical sources: works of famous psychologists and teachers S.L. Rubinstein, J. Piaget, J. Dewey and others who developed theoretical foundations of problem-based learning or learning through problem solving. As well as textbooks and didactic methodological developments in the field of problem-based learning. Monographs and scientific articles on problem-oriented approach in the education system were considered. Modern researches and scientific publications on the use of problem-oriented approach in teaching natural science disciplines and chemistry in particular were studied.

Methodological literature in the field of chemistry teaching, oriented on problem-based learning and state educational standards were analysed.

We used: practical developments on the development of curricula and lesson plans in chemistry, using problem-oriented technologies; the results of research by other authors; programmes and textbooks on chemistry, approved by the Ministry of Education and Science of the Republic of Kazakhstan; examples of tasks and exercises aimed at learning through problem solving and the development of critical thinking in students; test tasks for problem-based learning.

And also the materials of the study include: technical means and materials supporting problem-based learning; laboratory equipment and reagents necessary for conducting experiments and so on

The methods of research are defined: literature analysis, methods of observation, survey, methods of statistical and analytical analysis.

Research methods:

– literary analysis aimed at studying the available sources on the topic of the study and at establishing the main provisions of the problem-based approach that can be used to improve learning achievement at school.

– observation method – used to observe the behaviour of students during the experiment;

– survey methods: testing, aimed at collecting data on students (on their performance and motivation) before and after the experiment and questionnaire survey of students;

– static analysis – to process and calculate the obtained data;

– analytical analysis to summarise and interpret the data obtained.

At the first stage, a literature analysis is conducted to study the available sources on the topic of the study and to establish the main provisions of the problem-based approach that can be used to improve school performance.

At the second stage, the method of observation of students' behaviour in and out of lessons and during the experiment is used. At the same stage, survey methods are used: testing aimed at collecting data on students (on their academic performance) before and after the experiment. In the experiment participated pupils of 8 classes (A and B) Secondary General Education School №22 named after B. Momyshuly of Pavlodar city, a total of 52 people. They are divided into two groups: experimental and control group.

To test the level of knowledge, all pupils are tested on the subject before the experiment. Then the final level of pupils' subject knowledge after the experiment is assessed.

The experimental study of learning achievements is conducted on three topics:

1) the structure of the atom;

2) chemical bonds;

3) classification of inorganic substances.

Provided that the students of the control group used classical chemistry textbooks, according to which the teacher used traditional teaching methods. While pupils of the experimental group were studying the same topics using the problem-oriented teaching methodology. This method includes case studies, digital technologies, discussions, and projects, in which all chemical experiments, discussions, and projects are visually demonstrated.

Additionally, student opinion surveys on satisfaction with the technology used were conducted. To survey pupils' opinions on satisfaction with the problem-based learning methodology in 8th grade chemistry, the following survey questions were asked: 1. Do you like the problem-based learning methodology? 2. What elements of problem-based learning methodology do you like the most? 3. Would you like the problem-oriented approach to be used in all chemistry lessons? 4. Did you become more interested in chemistry after the introduction of problem-based learning? 5. What element of the problem-based approach methodology would you like to improve? 6. Do you have any suggestions for improving the problem-based approach methodology?

The third stage involves static analysis – to process and calculate the data obtained, and analytical analysis to summarise and interpret the data obtained.

Results

The results are aimed at proving the following working hypothesis: the introduction of problem-oriented approach in the educational process of chemistry learning can help to increase the level of students' learning achievements. Since the use of this approach encourages students to be more active in the learning process, develops their analytical skills in working with information, and develops the ability to solve complex problems more easily and apply the acquired chemical knowledge in practice.

Problem-based learning (or PBL, as problem-based learning) was first used by Howard Burroughs and Robin Tamblyn in 1969 in Canada at McMaster University. It is Howard Burroughs who is considered to be the founder of problem-based learning. In his opinion, problem-based learning should be considered as a learning process that results in the understanding of the importance of solving a problem. A problem is understood as an element of the learning process [17].

The process of problem-based learning can be different, but in general all the schemes of classes according to this approach are similar to the scheme proposed by Cornell University, as indicated in Figure 1.

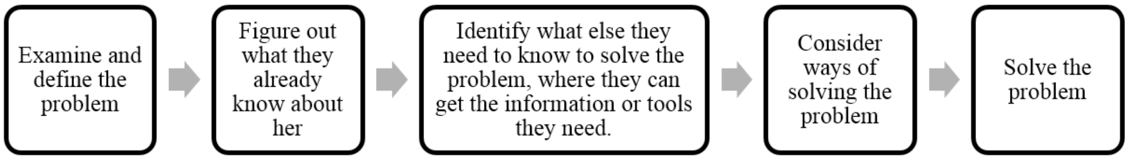

Figure 1 – The process of problem-based learning in the classroom [17]

However, the definition of PBL or problem-based learning appears to be an umbrella term as it refers to a large number of independent methods.

Features of problem-based learning:

– the advantage of problem-based learning is considered to be the authentic problem that underlies it and is used to teach students to solve similar problems in their upcoming professional life;

– learning is based on a problem presented in the form of cases, where information is presented step by step. Students are given the opportunity to research the problem independently, find the necessary information and propose their own solutions. Only after the previous stage of the proposed work has been completed and the pupils have been given answers to the questions posed, the next information for further solution is revealed to them. In addition, after each stage of the work is completed and the results are presented, discussion and analyses are conducted to deepen the understanding of the material and consolidate the acquired skills;

– small groups (no more than 10 or 15 students) are considered an important feature, as small groups are easier to form a joint discussion of the problem task and allow for correct joint solutions.

There is also a change in the functions of teachers:

– create a bank of problem-oriented cases;

– comment on students' work;

– maintains a positive atmosphere in the classroom;

– evaluates the results of problem solving together with students.

Other definitions of problem-oriented learning are also given, which gives us the opportunity to outline its complex definition. Problem-oriented learning should be understood as a methodological approach in education, which emphasizes the active involvement of students in discovering solutions to both real and simulated problems.

The methods of problem-oriented learning focus on presenting students with complex tasks or real-life situations that necessitate the application of essential knowledge and skills for resolution. Furthermore, this approach, in contrast to traditional teaching methods, fosters students' independence and enhances their critical thinking abilities, ultimately improving their level of understanding.

The main principles of problem-oriented teaching in chemistry we have defined the following:

– problem-oriented methodology involves the use of such a principle as activity and independence of students. This principle is based on the fact that students themselves should create and express questions to the problem, as well as search for answers and develop their own strategies for the correct solution;

– the principle of knowledge integration, according to which the problems proposed for solving require a meta-subject approach, which enables students to make connections between them;

– the principle of critical thinking, which provides students the opportunity to analyze various perspectives, assess information, and reach well-supported conclusions;

– the principle of teamwork, since problem-oriented tasks are generally designed to be tackled in groups, enabling students to improve their collaborative skills by developing effective communication;

– the principle of practical application of knowledge, based on the fact that problem tasks are modelled in such a way that pupils can apply real or close to reality knowledge in practice.

The main methods and technologies of problem-oriented learning in chemistry are considered to be those outlined in Figure 2.

The main methods and technologies are considered to be: case study method; project method; role-playing games and simulations; discussions and debates and electronic resources.

Testing of learning achievements in chemistry for secondary school students should take place in several stages:

– testing at the stage of learning new material

– testing at the stage of consolidation of knowledge and skills

– testing at the stage of applying knowledge and skills

– testing at the stage of improving and systematising knowledge and skills

– testing at the stage of ability development [19]

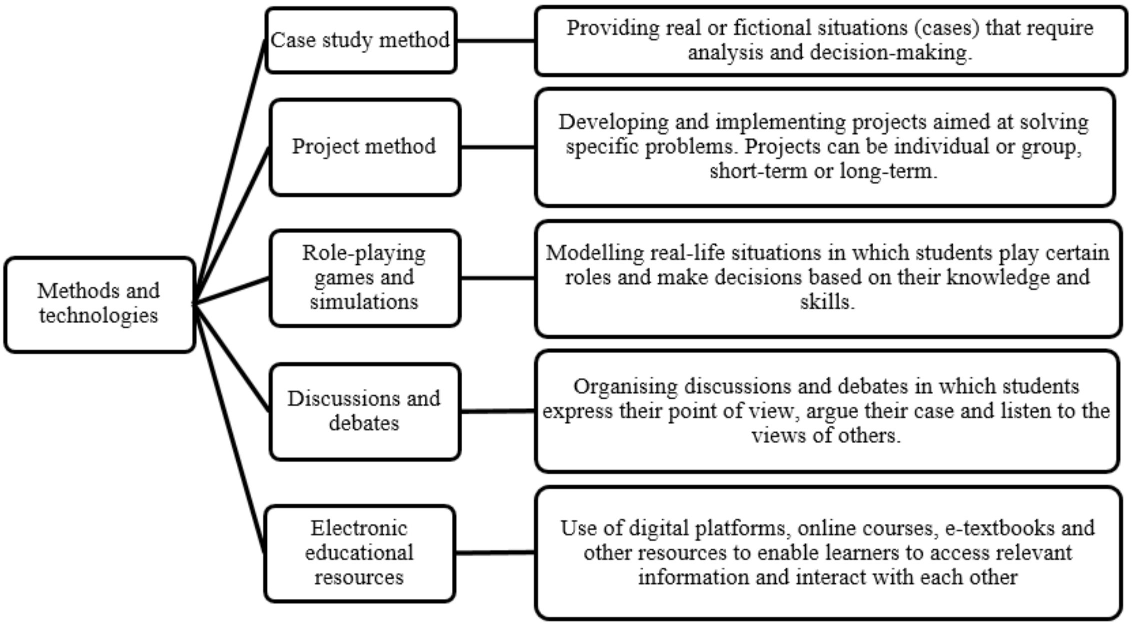

Figure 2 – Basic methods and technologies
of problem-oriented learning in chemistry at school [18]

In the control group testing at the stage of consolidation of knowledge and skills is used.

In the experimental group testing at the stage of ability development.

The results for the first theme (the theme ‘atom structure’: the task to establish the structure of sodium, chlorine and sulphur atoms and others) are reflected in Table 1.

Table 1 – Test results for the first topic

Groups	100-90%	80-60%	50-40%	less than 40%
Control group (CG)	20	19	54	7
Experimental group (EG)	24	25	48	3

Analysis of test results has demonstrated improvement of learning achievements of pupils from the experimental group. Thus, the number of pupils who scored from 100% to 90% points is 4% higher than in the CG. The number of pupils who coped with the test by 80-60% is 6% higher than in the CG. At the same time, the number of those who fulfilled the test by 50-40% is less by 6%, and the number of unsuccessful pupils (less than 40%) is less by 4%.

According to the assessment of learning achievements on the theme ‘chemical bonding’, pupils had to give an answer about the type of bonding in the listed 12 compounds, about the correspondence of covalent and polar bonding, about the relationship between chemical bonding and chemical formula. The results for the second theme are reflected in Table 2.

Table 2 – Test results for the second topic

Groups	100-90%	80-60%	50-40%	less than 40%
Control group (CG)	18	20	53	9
Experimental group (EG)	22	24	46	8

Analysis of the results has shown that in the experimental group, the share of pupils who completed the test by 100-90% was 22%. At the same time, in the control group this indicator is 4% lower. The number of EG pupils with 80-60% marks is 4% higher as compared to the CG. At the same time, also in comparison, the number of pupils in the EG performing the test less than 50% is 6% less, and the number of those who failed (less than 40%) is 1% less.

For the third topic ‘Classification of inorganic substances’, conducted within two lessons, the pupils were asked to identify the classes of various inorganic compounds listed and marked graphically and schematically. The results for the third topic are reflected in Table 3.

Table 3 – Test results for the third topic

Groups	100-90%	80-60%	50-40%	less than 40%
Control group (CG)	19	21	50	10
Experimental group (EG)	23	26	44	7

The analysis of the results of testing of pupils' learning achievements in the third theme has shown that in the experimental group 23% of pupils completed the test by 100%-90%, which is 4% higher than in the control group. The percentage of students scoring between 60% and 80% was 26%, which is an increase of 5% compared to the control group. The number of pupils who coped with the test by 50%-40% in the EG is 44%, which is 6% lower than in the CG, and the number of pupils who failed to cope with the tasks (7%), which is 3% lower than in the CG.

The obtained data make it possible to conclude that the number of pupils in the experimental group has higher indicators of successful learning achievements, as there is a higher number of pupils who coped with the test both ‘excellent’ (or 100%-90%)

and ‘good’ (or 80%-60%) for all topics. At the same time, the number of pupils having ‘satisfactory’ (or 50%-40%) and ‘unsatisfactory’ (or 30%-0%) grades is somewhat lower.

Summarised indicators of testing results of 8th grade pupils in chemistry for the three studied topics are reflected in the Table 4.

Table 4 – General results of the comparative analysis

Criteria of test tasks	Number of pupils from the total number of CG	Number of pupils from the total number of EG	Percentage change
100%-90% or excellent	19	24	+5
80%-60% or good	20	25	+5
50%-40% or satisfactory	52	46	-6
30%-0% or unsatisfactory	9	6	-3

In general, the results indicate that the EG group has higher learning achievements, as pupils from this group coped better with test tasks compared to the CG group.

Figure 3 presents the summarized indicators for both groups for comparison.

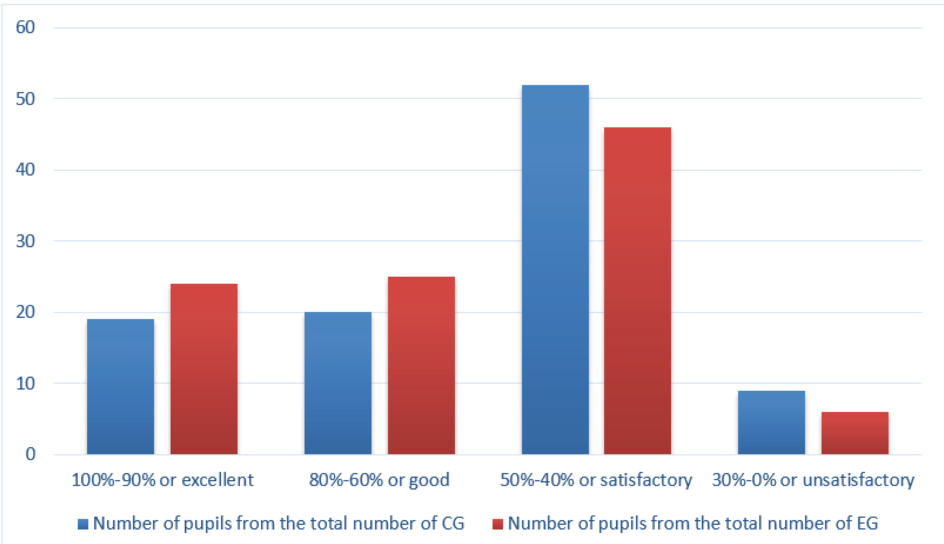

Figure 3 – Generalised indicators of testing results of 8th grade pupils in chemistry

In the experimental group, there is a greater percentage of students receiving 'excellent' grades, indicating superior academic performance among the group's members. Also, there are more pupils with ‘good’ grades, which confirms the tendency to better results in this group. In KG the percentage of satisfactory grades is higher, which indicates that most of pupils cope with tasks at the average level. The percentage of unsatisfactory grades is lower in EG, which should also be considered a positive indicator of learning achievements.

Overall learning achievements reveal that students in the experimental group perform better in the 'excellent' and 'good' categories, indicating a higher level of knowledge across the three topics. Problem areas should be considered the presence of a small number of unsatisfactory marks in both groups, however, their share is lower in EG, which should also be recognised as positive regarding the impact of classes, using technologies of problem-oriented approach.

Results of pupils' survey among pupils of the experimental group:

Like the methodology of problem-oriented learning: 50% of students; 30% – do not like it; 20% – found it difficult to answer

They consider the best elements of the problem-oriented learning methodology to be: most of all – digital technologies (45%), as well as projects and discussions (20%) each, case studies (15%), all of the above (10%), none of the above (10%).

Would like to see the problem-oriented approach used in all chemistry lessons: Yes (30%), partially, for some topics (30%); prefer the traditional format (40%).

Whether more interest to chemistry appeared after introduction of problem-oriented methodology: Yes (40%), remained at the same level (60%).

Elements of the problem-oriented methodology that need improvement: more cases (30%); use more modern digital tools (30%); need to make discussions more interesting and structured (20%); increase the number of projects (20%).

According to students' opinion, the most important factors contributing to the effectiveness of the problem-oriented approach in chemistry lessons in learning achievements are their active involvement in the learning process; practical orientation; individual approach; use of interdisciplinary links; teamwork and regular active assessment of results.

Conclusion

Thus, all the discussed aspects-functions, principles, methods, and technologies-constitute the foundation of problem-oriented chemistry teaching. This approach makes the learning process in schools more engaging, dynamic, and aligned with contemporary educational standards. It facilitates an improvement in students' achievements in chemistry.

The execution of problem-based learning in chemistry lessons is realised under the following conditions: presence of a problem situation in the topic or task; predisposition of a pupil to find a problem solution to the task (situation); probability of solution by ambiguous ways.

Application of software-oriented learning technologies in chemistry lessons allows to organise not only the process of mastering the basic concepts and laws, but also to make such knowledge become a tool to improve performance.

The results of approbation of the elements of the methodology, in which the technologies and tasks based on the problem-oriented approach are included, allow us to conclude that the students of the experimental group obtained a higher level of educational achievements. The obtained data confirm the working hypothesis, according to which the introduction of the problem-oriented approach in the educational process of studying chemistry is able to assist the growth of the level of educational achievements of schoolchildren. Since the use of this approach on the example of three topics shows that pupils have formed academic knowledge, analytical skills, which helped to develop the ability to more easily solve complex problems and apply the acquired chemical knowledge in practice.

The survey revealed that many students appreciated the problem-based learning approach in chemistry, with the most valued aspects of this methodology identified as: digital technology, projects, discussions and case studies to the greatest extent. Some students wanted the problem-oriented approach to be used in all chemistry lessons or partially in some topics. Forty per cent showed more interest in chemistry after the introduction of the problem-oriented methodology. Elements of the problem-oriented approach methodology that require improvement are recognised by all. It is suggested to use more cases, to use more modern digital tools, to make discussions more interesting and structured, to increase the number of chemistry projects.

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Химияны оқытудағы проблемалық-бағдарланған тұғыр және оның оқушылардың оқу жетістіктеріне әсері

Аннотация. Бұл мақалада химияны оқытудағы проблемалық-бағдарланған тәсілдің ерекшеліктері және оның оқушылардың оқу жетістіктеріне әсері талданады. Оқу үлгерімін арттыру мақсатында оқу процесін жетілдіру мәселесі Орта білім берудің басым міндеттерінің бірі болып қала береді. Бұл зерттеудің мақсаты-проблемалық-бағдарланған тәсілдің оқушылардың химия курсындағы академиялық үлгеріміне әсерін зерттеу. Зерттеудің негізгі бағыттары білім беру процесінде проблемалық тәсілді қолданудың қолданыстағы теориялары мен тәжірибелеріне шолу жасауды, мектепте химия сабақтарында осы әдісті енгізуді, сондай-ақ оның тиімділігіне ықпал ететін факторларды анықтауды қамтиды.

Зерттеу нәтижесінде проблемалық тәсілге негізделген технологиялар мен тапсырмаларды қолдануды қамтитын осы әдістеменің тиімділігі анықталды. Эксперименттік топтың оқушылары оқу жетістіктерінің жоғары деңгейін көрсетті. Бұл тәсілді химия бойынша үш тақырыптың мысалында қолдану студенттердің күрделі мәселелерді сәтті шешуге және алған білімдерін практикада қолдануға ықпал ететін академиялық білім мен аналитикалық дағдыларды дамытатынын көрсетті. Химиядағы проблемалық-бағдарланған оқыту оқушылар арасында оң пікірлерге ие. Мақала авторлары көбірек жағдайларды пайдалануды, заманауи цифрлық құралдарды енгізуді, пікірталастарды құрылымдауды және жобаларды көбейтуді ұсынады, бұл химияны оқытудың тиімділігін одан әрі арттыруы мүмкін.

Кілтті сөздер: проблемалық-бағдарланған оқыту, проблемалық-бағдарланған тәсіл, химия, оқу жетістіктері, оқушылар, кейстер, цифрлық технологиялар.

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Проблемно-ориентированный подход в обучении химии и его влияние на учебные достижения школьников

Аннотация. В данной статье анализируются особенности проблемно-ориентированного подхода в обучении химии и его влияние на учебные достижения учащихся. Проблема совершенствования учебного процесса с целью повышения успеваемости остается одной из приоритетных задач среднего образования. Цель данного исследования - изучить влияние проблемно-ориентированного подхода на академическую успеваемость учащихся в курсе химии. Основные направления исследования включают в себя обзор существующих теорий и практик применения проблемного подхода в образовательном процессе, внедрение данной методики на уроках химии в школе, а также выявление факторов, способствующих ее эффективности.

В результате исследования была установлена эффективность данной методики, включающей использование технологий и заданий, основанных на проблемном подходе. Учащиеся экспериментальной группы продемонстрировали более высокий уровень учебных достижений. Применение данного подхода на примере трех тем по химии показало, что у учащихся развиваются академические знания и аналитические навыки, способствующие успешному решению сложных задач и применению полученных знаний на практике. Проблемно-ориентированное обучение в химии имеет положительные отзывы среди учащихся. Авторы статьи рекомендуют использовать больше кейсов, внедрять современные цифровые инструменты, структурировать дискуссии и увеличивать количество проектов, что может еще больше повысить эффективность обучения химии.

Ключевые слова: проблемно-ориентированное обучение, проблемно-ориентированный подход, химия, учебные достижения, ученики, кейсы, цифровые технологии.