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Organisation of Independent Cognitive Activity of Students of a Specialised School in a Chemistry Subject Based on the Project Method

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Abstract. The relevance of the study is determined as follows: insufficient attention to the educational and research activities of students in the process of learning various disciplines, in particular, chemistry; weak implementation of the potential of scientific disciplines for the educational and research activities of high school students; the need to develop the technology of creating educational research environment for secondary school students studying STEM subjects. In the conditions of constant development of science and technology, computerisation of society, integration of education and science, the requirements for graduates increase: with sufficient theoretical knowledge, it is necessary to be able to apply them in various life situations, predict possible consequences of decisions made, demonstrate social activity, interest in scientific problems and initiatives. The purpose of the study is to develop, theoretically substantiate, and experimentally test the content and pedagogical conditions of educational activities of high school students in chemistry classes. As a research method, a systematic approach was used when considering the phenomena of current chemistry teaching in the context of modern education, and a method of comparing chemistry teaching in Kazakhstan and other countries. The result of the study was the concept of a project method, which is based on a focus on the result that can be obtained when solving a specific practical or theoretically significant problem. To achieve such a result, it is necessary to teach children or adults to think independently, find and solve problems, acquire knowledge from various fields, be able to predict the results and possible consequences of various decisions, and be able to determine the causes, relationships, and consequences. It was concluded that the use of the project method increases motivation, develops creative abilities, personal qualities, and improves the learning material and knowledge of basic research methods

Keywords: chemical education, project implementation, child's potential, research activity, project method

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INTRODUCTION

One of the basic principles of didactics was and will remain the principle of student activity in the educational process. This principle assumes the quality of activity, characterised by a high level of motivation, a conscious need to acquire knowledge and skills, effectiveness and compliance with social norms [1]. The teacher should turn the learning

process from boring and monotonous to interesting and voluntarily complete [2]. One of the ways to achieve this is through the variety of pedagogical technologies used in the educational process. The main focus is on search, design, and research activities that allow the use of a personality-oriented approach to learning [3]. The founder of

the project methodology, W. Kilpatrick, defined its essence as follows: "This is a method of purposeful activity related to solving a school problem in a real situation" [2]. This method involves the transition from listening and information of passive perception to action and the acquisition of new knowledge through the experience of a learning experiment, from memorisation and simple reproduction of educational material to a critical and creative understanding of the environment, from the teacher's instructions to a conscious and natural organised cognitive search [4]. The main difference of this approach is innovation and non-standard approach to problem solving, close connection with real-life practices and the development of special skills and abilities [5].

E.V. Zelenskaya [6] suggests that the project method offers the teacher the widest opportunities to change conventional approaches, forms, and methods of educational activity, and brings the entire system of teaching chemistry to a qualitatively new level. It helps organise educational activities, observing a reasonable balance between theory and practice, ensures the development of independence and activity, and unites children. P. Guo et al. [7] claim that the activity of the educational project is focused on the study of a completed academic subject or academic course. It is based on the development of cognitive abilities of students, the ability to independently project their knowledge, navigate the information space, the development of logical and creative thinking, and spatial imagination. According to T.-T. Wu and Y.-T. Wu: "The project method is a way to achieve a didactic goal through a detailed development of a problem (technology), which should end with a very real, tangible practical result, formulated in one way or another. The project method is always focused on the independent activity of students – individual, pair or group, which students perform for a certain period of time" [8].

E.V. Tyaglova [9] is convinced that studying chemistry at school contributes to the development of students' worldview and the general scientific world picture, students gradually understand the need for chemical education to solve everyday problems. While chemistry is being taught, the competence of moral behaviour in the environment increases. In the conditions of a sharp reduction in the time allotted for studying chemistry while maintaining the volume of its content, the student's interest in the subject decreases. T. Sasipraba et al. [10] suggest that it is necessary to organise the learning process in such a way that school-children accept chemistry as a necessary and in-demand science in life, as part of world culture, necessary for every educated person.

Thus, design and research methods are a tool that creates prerequisites for a decisive and independent understanding of the new, stimulating natural curiosity and a desire for the unknown. The result of such work is the self-realisation of the child through the development of abilities and the accumulation of individual experience. These methods can be used at any stage of training, in working with students of different age categories, and when

studying materials of varying complexity, they adapt to any academic subject, including chemistry. In this regard, one of the main tasks of the new educational standard of general education is to attract students to design and research.

The theoretical significance of the study is conditioned by the fact that its results expand knowledge about natural science education in the context of "educational activities and research for secondary school students", which reinforces the concept of teaching and learning. The practical significance of the study lies in the fact that its materials, results, and conclusions can be used by teachers to conduct research activities of students in the field of STEM subjects.

The purpose of the study is to develop, theoretically substantiate, and experimentally test the content and pedagogical conditions of educational activities of high school students in chemistry classes. To achieve the goal, it was necessary to solve the following tasks:

- to study the main pedagogical characteristics of the technology of design and research education;
- to investigate the main difficulties preventing the widespread use of the project method in teaching school chemistry;
- to develop a conceptual model of using the project method of teaching to eliminate the differences between the requirement for updated educational content and limited methods of implementing design and research activities in the extracurricular system of chemical education.

MATERIALS AND METHODS

The study was conducted during the 2021 academic year at Lyceum No. 8 for gifted children in the city of Pavlodar. The study involved 94 students of grades 9-11 aged 14 to 16 years. The methodological basis of the study consists of methods of analysis, synthesis, comparison, observation, induction, deduction, and generalisation. A systematic approach was used when considering the phenomena of the current teaching of chemistry in the context of modern education.

Analysis was used to investigate scientific and methodological literature. The synthesis was used to consider the main pedagogical characteristics of the technology of design and research education. The essence of the method of pedagogical observation was the organised perception of the pedagogical process in natural conditions. The observation was direct, indirect, and systematic. The methods of induction and deduction interacted with each other as a dialectical unity of cognition of the general and concrete. The comparison was used in the study of the peculiarities of teaching chemistry in Kazakhstan and other countries. With the help of the generalisation, the advantages of the methodology of setting mini-projects in the study of chemistry in a specialised school were discovered.

RESULTS AND DISCUSSION

In the concept of modernisation of the structure and content of education, the design and research activities of students are considered as advanced technology of practice-oriented and industry-specific training. Education is important content because it helps students express themselves, as well as:

- understand activities from a social, personal, and strategic perspective related to cognitive interests, life, and professional projects;
- learn to set goals to achieve important results;
- master the techniques of self-education and self-organisation;
- develop the ability to aggregate, combine, and consolidate information from various sources;
- consider problems, make assumptions, and demonstrate intellectual abilities;
- make choices and decisions.

The project method is based on the development of the student's cognitive skills, the ability to independently

construct their knowledge and navigate the information space, find and solve problems, attract knowledge of various fields for this purpose, the ability to predict the results and possible consequences of various decisions, the ability to report on the causes and consequences of communication (Fig. 1). It allows solving the tasks of teaching and developing various intellectual abilities, critical and creative thinking. The implementation of the project method and the research method in practice leads to a change in the position of the teacher. From a carrier of ready-made knowledge, the teacher will turn into an organiser of the cognitive activity of students, a teacher as a leader and an instructor.

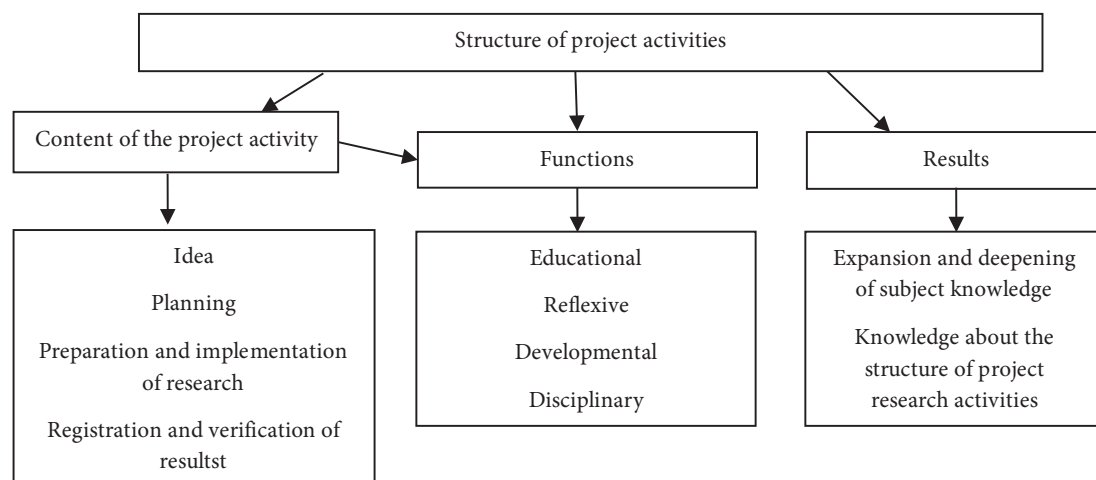


Figure 1. Structure of project activities

Next, the study considers the main pedagogical characteristics of the technology of design and research education and the possibilities of its application in the industry-specific training of high school students. The main purpose of specialised training in design technology:

1) to acquaint students with the subject and interdisciplinary material with socially, scientifically and practically significant problems characteristic of specialised education, vocational training, and professional activity, and ways to solve them;

2) to involve students in dynamic and real activities, in experiencing real events and feelings, allowing students to understand the social and personal significance of this activity and its results, evaluate their preferences, and ability to perform actions with characteristics for a certain profile;

3) stimulate students' interest in solving problems independently:

- for the acquisition of knowledge from various fields that can be used in life, in future professional activity, to continue training in the chosen profile;
- achieve a real result that has social and personal significance;
- creative activity in the development of new objects.

It is possible to establish education at a sufficiently high level only with a very small group of students, since this requires certain capabilities and training. In addition, the

complexity of these works excludes the possibility of simultaneous execution of a large number of them. Therefore, the research is usually conducted as an individual task; it is not necessarily related to the subject of the school chemistry or other individual tasks that are performed in parallel by other students.

Applied topics can be divided into several categories. First of all, these are tasks for the installation of visual aids, exhibits, tests for use in lessons. In some cases, such work may be performed by order. Their creative element is overcoming the difficulties associated with the shortage of some materials, replacing them with others, searching for optimal modes for conducting experiments, etc. For example, it is possible to simulate the catalytic synthesis of sulphuric acid by selecting the presence of a catalyst from the available test material, the optimal gas flow rate, etc.

In preparation for the topic "Dissociation of electrolytes", students will be able to demonstrate that the electrical conductivity of the solution increases with the generation of salts by choosing the optimal size and shape of the substance (acid, base), their concentration, indicator, and instrument during the neutralisation reaction. The second category includes research tasks, the results of which have minimal social significance and cannot be announced in advance. For example, a teacher can ask students to develop

a tool to measure the carbon dioxide content in the atmosphere and monitor the composition of the air in the classroom from one to six hours, or use another tool to systematically measure the oxygen concentration under the ice of a river in winter.

The third category includes tasks whose results may have a practical result. These include work on drawing up soil maps necessary for the proper use of fertilisers in the fields, determining the concentration of pollutants in the environment, analysing water from natural sources, etc. Chemistry is an experimental science, attempts to study the basics of chemistry without laboratory work are doomed to failure. Therefore, purely literary versions of research are much less effective than chemical experiments. Although the literary version of a licensed work is widely distributed, only in rare cases it can be classified as a research work. Most often, when developing projects, these are fragments of more or less successful information from several sites.

When organising research work, it is necessary to consider that, as in a real study, the results may not meet the expectations of the experimenter. The student should be directed to such an opportunity from the very beginning. Next, the study lists the main difficulties that prevent the widespread use of the project method in teaching school chemistry. Firstly, there is a shortage of teachers who are able to effectively implement project science. It is clear that the project manager must be highly qualified, have a good chemical education, which is rare in the teaching environment. The project manager should be enthusiastic, because project activities require a lot of time and energy. A significant part of the time is spent searching for reagents and materials needed for testing and for literature.

The experience of teachers in the practice of implementing group projects, when two or three people participate in the project, shows that it is often difficult to assess the real contribution of each participant. An objective disadvantage is an inequality in the assimilation of educational material in comparison with the classical explanatory and illustrative method of teaching: scientific sections directly related to the topic of the project, and those that are far from the project are usually not affected at all. Another objective problem is a noticeable decrease in the basic training of schoolchildren, and hence students in the future. This is especially true of creative research skills, which are clearly explained by the growing formalisation of school subjects and knowledge testing methods.

How can students be encouraged to implement technological projects in practice? The study suggests that it is advisable to start with the application of competence-oriented tasks. Their solution is possible in the classroom, during the independent work of high school students. They are divided into contextual tasks, situational tasks, and practice-oriented tasks. A large number of definitions are given in the scientific and methodological literature. Here are some of them.

"Contextual (context) task is a motivational task of describing a specific life situation related to the existing socio-cultural experience of students (known data); a

need-based (unresolved) task consisting in analysing, understanding and explaining the situation or actions in it, and the result of solving the problem is an educational task and awareness of its personal significance" [6]. Next, the study considers an example of such a task that can be used in the topic "Monatomic alcohols" in the 10th grade: "Iodine tincture or a 5% alcohol solution of iodine is used to treat the skin around the lesion, such as wound. Calculate how many grams of crystalline iodine and what volume of 100 ml of alcohol with a density of 0.7893 g/ml should be taken to prepare 200 g of solution?" Situational tasks are tasks focused on the step-by-step processing of mental actions in the process of working with scientific material: familiarisation – understanding – application – analysis – synthesis – evaluation. Here is an example of a problem we have constructed that can be applied in the 10th grade in the topic "Haloalkanes": "For the treatment of warehouses, as well as grain, vegetables, and fruits in warehouses and holds, fumigation with vapours of some organochlorine and organobromine compounds, such as dichloroethane and methyl bromide, was previously used. At the same time, dichloroethane was widely used for treating empty warehouses, and methyl bromide was widely used for treating fruits and grains. Explain the benefits of methyl bromide."

Practice-oriented tasks are tasks that develop students' practical skills and form an understanding of where, how, and for what the acquired skills are used in life [11]. Practice-oriented tasks allow combining knowledge, encourage high school students to use additional sources of knowledge, which increases motivation for learning in general and ultimately affects the quality of learning [12]. Here is an example of one of the tasks developed and used by us in the topic "Aldehydes" of the 10th grade: "A gas weapon is a self-defence weapon designed to temporarily neutralise the enemy with the help of a gas or aerosol cloud. Such a cloud has in its composition irritants that cause reactions when they get on the mucous membrane or skin and affect the respiratory tract:

1. Determine the formula of the substance that is part of the gas cloud, if it is known that the mass fractions of hydrogen, oxygen and carbon, respectively, are equal to 6.67%, 53.33%, 40%.
2. Specify the class to which this compound belongs, give a trivial name and its name in accordance with the systematic nomenclature, write its molecular and structural equation.
3. What properties can this substance have? Write down the reaction equations."

The most difficult tasks for the teacher, which they must develop and perform for the student, are problem-creative tasks of an experimental nature, close to mini-projects [13]. Consistently using the above types of tasks in chemistry lessons (applying them as students' mental activity becomes more complicated), leads students first to mini-projects, and then to research projects. After studying the updated content of the chemistry subject in high school, the following projects reflecting the current problems of our time and the regional component are offered:

“Plastic life: Formaldehyde and we” (10th grade, the topic “Aldehydes”), “Koumiss: The secret of a living drink” (10th grade, the topic “Monatomic alcohols”), “Kazy-karta: A delicacy of nomads” (10th grade, topic “Esters. Fats”), “Dietary supplements: Excess or necessity?” (10th grade, topic “Carboxylic acids”), etc. They can be used at the end of the study sections or at the end of the study quarter.

Ultimately, a fairly wide range of reagents is usually required to conduct a chemical experiment within the framework of the project, and the school administration, insuring against possible accidents, does not always participate both in the purchase of reagents and in the experimental work of students. This circumstance is another obstacle to the organisation of student research directly at school. Modern Kazakh education is more focused on the use of project technology in the extracurricular learning system. However, it is possible to use the main form of education – a lesson, but there are very few such serious methodological developments for the implementation of educational projects in chemistry in the Kazakh literature.

According to P.A.S. Moreira and V.E. Lee [14], the use of the project method allows changing priorities from the assimilation of ready-made knowledge to the active and independent cognitive activity of each student. In the process of such work, not only the student, but also the teacher acquires new experience and improves their skills. According to A.A. Gumusay and T.M. Bohne [15], it is very important that children learn to evaluate the results of their actions and bring them to public discussion. The project method always involves solving a problem, which includes, on the one hand, the use of a set of methods and various learning tools, and on the other hand, the need to integrate knowledge and skills from different fields of science, technology, and creative fields. S.G. Shcherbakova [16] suggests that the chemistry course in environmental content projects allows:

1. To reveal the special role of chemical science in the fight against environmental ignorance, which manifests itself in deep-rooted ideas that chemistry is “to blame” for the current environmental situation.
2. To involve students in research work on the study of the state of the natural environment.
3. To instill in students a sense of personal responsibility for its preservation.

E. Polat [17] classifies projects according to their content: intellectual, material, environmental, service, and

complex; I.D. Chechel – by the nature of the dominant activity in the project and by the subject and content industry [18]. C. Macariu et al. [19] argue that the implementation of the project method is possible without destroying the system of lessons. Using simple lessons in which people listen and repeat what they hear, a teacher should try to move the student into an active position: not only to master what is already ready for them, but also to organise educational activities independently or together with the teacher, to receive and analyse information in various decision-making situations. For example, a teacher can declare the purpose of the lesson. Then the students are passive. However, if they explain the reason for looking at the phenomenon under study and do not rush to set a goal, but ask the children to do it, thereby transferring the trainees to an active position, the development of a universal goal-setting skill will begin [20].

CONCLUSIONS

Thus, as evidenced by practice, project activity contributes to the development of a new type of student who has the skills and abilities for independent constructive work, who has collaboration and interaction with purposeful methods of activity, equipped with self-education experience. Most importantly, participation in the project allows the student to get a unique experience that is impossible with other forms of education. Participation in the creation of the project has the greatest impact on those classes where students are overloaded with unstable attention and low interest in the subject. Project activity leads to a diverse and emotional colouring of educational activities, relieves fatigue, develops attention, intelligence, mutual assistance, contributes to the development of the ideological position of students.

A partial approbation of the methodology for setting up mini-projects during chemistry classes at a specialised school has already shown the advantages of this method: the development of techniques for self-extraction of knowledge, the ability to operate with knowledge from different subject areas, the ability to construct small research papers. Thus, using project technologies in modern schools when teaching chemistry, it is possible to significantly develop the key competencies of high school students. The purpose of further study is to find the best ways to organise school projects of various types that develop the educational and research activities of students.

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Організація самостійної пізнавальної діяльності учнів профільної школи під час вивчення хімії на основі методу проєктів

Анотація. Актуальність теми зумовлено низкою нагальних проблем: недостатня увага до навчальної та дослідницької діяльності учнів у процесі вивчення різних дисциплін, зокрема хімії; слабка реалізація потенціалу дисциплін наукового циклу для навчально-дослідницької діяльності старшокласників; необхідність розробки технології створення та розвитку навчально-дослідницького освітнього середовища для учнів середніх шкіл, які вивчають наукові цикли. В умовах постійного розвитку науки та технологій, комп'ютеризації суспільства, інтеграції освіти та науки вимоги до випускників зростають: володіючи достатнім обсягом теоретичних знань,

потрібно вміти застосовувати їх у різних життєвих ситуаціях, прогнозувати можливі наслідки ухвалених рішень, демонструвати соціальну активність, дослідницький інтерес до наукових проблем, ініціативу. Мета дослідження – розробити, теоретично обґрунтувати та експериментально апробувати зміст і педагогічні умови навчально-дослідницької діяльності учнів старших класів освітніх закладів під час вивчення хімії. Як методи дослідження використано системний підхід для розгляду явищ нинішнього викладання хімії в контексті сучасної освіти та метод порівняння щодо викладання хімії в Казахстані та інших країнах. Результатом дослідження стала концепція проектного методу, в основі якого – спрямованість на результат, який можна отримати вирішуючи конкретне практичне або теоретично значуще завдання. Для досягнення такого результату необхідно навчити дітей чи дорослих самостійно мислити, виявляти та розв’язувати проблеми, набувати знань у різних галузях, передбачати результати та можливі наслідки різних рішень, визначати причини, взаємозв’язки та наслідки. Зроблено висновок, що використання проектного методу підвищує мотивацію, розвиває творчі здібності та особисті якості, сприяє кращому засвоєнню навчального матеріалу, допомагає освоїти основні дослідження

Ключові слова: хімічна освіта, реалізація проєктів, потенціал дитини, дослідницька діяльність, проєктний метод