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PEDAGOGICAL FOUNDATIONS OF USING MODULAR TECHNOLOGY IN THE TEACHING OF INORGANIC CHEMISTRY

Abstract

This article comprehensively examines the pedagogical foundations of applying modular technology in the process of teaching inorganic chemistry in higher education institutions. In modern education, modular technology is considered one of the effective methods that enables students to master learning material step by step, while improving the quality of knowledge through the interconnection of theory and practice.

The purpose of the study is to identify the pedagogical prerequisites for the application of modular technology in teaching the inorganic chemistry course, to determine its features, and to prove its effectiveness on a practical level. For this purpose, research was carried out with an academic group of 12 first-year chemistry students. At the initial stage, students' opinions about modular learning were identified. The survey results showed that 8 out of 12 students had heard this term for the first time, while only 4 students were able to provide a general understanding of its content.

During the study, the course "Theoretical Foundations of Inorganic Chemistry" was divided into 8 modules, and a 15-week lesson plan was developed. Each module included not only

theoretical content but also practical tasks, which encouraged students to engage in independent inquiry, think scientifically, and apply the acquired knowledge in practice.

After the completion of the classes, students' opinions were collected again through a survey. The results demonstrated the effectiveness of modular technology: 84% of students noted that the learning material was clearer when divided into modules, 8% preferred traditional learning, and 81% emphasized the high integration of theory and practice. The overall satisfaction rate was 88%.

The findings of the study prove that the introduction of modular technology in teaching inorganic chemistry contributes to students' active participation in the educational process, systematic mastery of the subject, and the development of professional competencies.

Keywords: inorganic chemistry, modular teaching, pedagogical technology, quality of education, teaching effectiveness.

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БЕЙОРГАНИКАЛЫҚ ХИМИЯНЫ ОҚЫТУДА МОДУЛЬДІК ТЕХНОЛОГИЯНЫ ҚОЛДАНУДЫҢ ПЕДАГОГИКАЛЫҚ НЕГІЗДЕРІ

Аңдатпа

Бұл мақалада жоғары оқу орындарында бейорганикалық химияны оқыту процесінде модульдік технологияны қолданудың педагогикалық негіздері жан-жақты қарастырылады. Модульдік технология қазіргі білім беру жүйесінде студенттердің оқу материалын кезең-кезеңімен меңгеруіне, теория мен практиканы өзара байланыстыра отырып білім сапасын арттыруға мүмкіндік беретін тиімді әдістердің бірі ретінде қарастырылады.

Зерттеудің мақсаты - бейорганикалық химия курсын оқытуда модульдік технологияны қолданудың педагогикалық алғышарттарын анықтау, оның ерекшеліктерін айқындау және тиімділігін тәжірибелік тұрғыдан дәлелдеу болып табылады. Осы мақсатта 1-курс химия мамандығы бойынша білім алатын 12 студенттен тұратын академиялық топпен зерттеу жұмыстары жүргізілді. Алдымен студенттердің модульдік оқыту туралы бастапқы пікірлері анықталды. Сауалнама нәтижесінде 12 студенттің 8-і бұл терминді алғаш рет естігенін айтса, тек 4 студент қана оның мазмұны туралы жалпы түсінік берген.

Зерттеу барысында бейорганикалық химияның теориялық негіздері курсы 8 модульге бөлініп, 15 апталық сабақ жоспары жасалды. Әр модуль теориялық мазмұнды қамтып қана қоймай, практикалық тапсырмалармен толықтырылып, студенттердің өздігінен ізденуіне, ғылыми тұрғыдан ойлануына және алған білімін тәжірибеде қолдануына мүмкіндік берді.

Сабақтар аяқталғаннан кейін студенттердің пікірлері қайтадан сауалнама арқылы жиналды. Оның нәтижелері модульдік технологияның тиімділігін көрсетті: студенттердің 84%-ы оқу материалы модульдерге бөлінгенде түсініктірек болғанын атап өтті, 8%-ы дәстүрлі оқытуды қолайлы санады. Сонымен қатар, 81%-ы теория мен практиканың үйлесімділігі жоғары екенін айтты. Жалпы қанағаттану көрсеткіші 88%-ды құрады.

Зерттеу қорытындылары бейорганикалық химияны оқытуда модульдік технологияны енгізу студенттердің оқу үдерісіне белсенді қатысуына, пәнді жүйелі түрде меңгеруіне және кәсіби құзыреттіліктерін қалыптастыруға ықпал ететінін дәлелдейді.

Түйін сөздер: бейорганикалық химия, модульдік оқыту, педагогикалық технология, білім сапасы, оқытудың тиімділігі.

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ПЕДАГОГИЧЕСКИЕ ОСНОВЫ ПРИМЕНЕНИЯ МОДУЛЬНОЙ ТЕХНОЛОГИИ В ОБУЧЕНИИ НЕОРГАНИЧЕСКОЙ ХИМИИ

Аннотация

В данной статье всесторонне рассматриваются педагогические основы применения модульной технологии в процессе преподавания неорганической химии в высших учебных заведениях. Модульная технология в современной системе образования рассматривается как один из эффективных методов, обеспечивающих поэтапное усвоение учебного материала студентами, повышение качества знаний за счёт взаимосвязи теории и практики.

Цель исследования - определить педагогические предпосылки применения модульной технологии в преподавании курса неорганической химии, выявить её особенности и доказать эффективность на практическом уровне. С этой целью были проведены исследования с академической группой из 12 студентов 1 курса специальности «Химия». Сначала были определены исходные мнения студентов о модульном обучении. По результатам анкетирования 8 из 12 студентов сообщили, что впервые слышат этот термин, а только 4 студента смогли дать общее представление о его содержании.

В ходе исследования курс «Теоретические основы неорганической химии» был разделён на 8 модулей, был составлен 15-недельный план занятий. Каждый модуль включал не только теоретическое содержание, но и практические задания, что способствовало самостоятельному поиску, научному мышлению студентов и применению полученных знаний на практике.

После завершения занятий мнения студентов снова были собраны посредством анкетирования. Результаты показали эффективность модульной технологии: 84% студентов отметили, что учебный материал становится понятнее при разделении на модули, 8% посчитали более удобным традиционное обучение. Кроме того, 81% указали на высокую согласованность теории и практики. Общий показатель удовлетворённости составил 88%.

Итоги исследования доказывают, что внедрение модульной технологии в преподавание неорганической химии способствует активному участию студентов в учебном процессе, системному усвоению предмета и формированию профессиональных компетенций.

Ключевые слова: неорганическая химия, модульное обучение, педагогическая технология, качество образования, эффективность обучения.

Introduction. The current stage of social development is characterized by the advancement of scientific and technological progress, as well as the emergence of various innovative processes that influence all spheres of life, including higher education. With the implementation of the competence-based approach and the corresponding change in educational objectives, higher education institutions must employ innovative educational technologies in the process of training students in order to form their professional competencies while fulfilling the requirements of state educational standards [1, 485].

Inorganic chemistry is one of the fundamental fields of science that ensures the explanation of natural phenomena at the molecular and atomic levels [2, 2006159]. However, the main difficulties in teaching inorganic chemistry in higher education institutions are associated with the high level of theoretical complexity that requires abstract thinking from students, the lack of sufficient practical skills during laboratory work, and the limited integration of theory and practice. In this regard, in order to improve the quality of teaching, it becomes necessary to introduce innovative pedagogical technologies, including modular teaching technology.

Modular teaching is an educational technology aimed at organizing learning content in systematic, structured blocks that take into account the learner's individual abilities, learning pace, and style [3, 911]. This approach enables students to study independently, develop logical thinking, and acquire knowledge more deeply by integrating theory and practice. In addition, modular technology contributes to the effective structuring of subject content, the optimization of the lesson process, and the enhancement of learners' autonomy.

In recent years, numerous studies have proven the effectiveness of the modular teaching system in improving the quality of education in natural science subjects, especially in inorganic chemistry [4, 112]. This technology adapts to the complexity of the learning material, increases students' interest in the subject, and improves learning outcomes. Learners actively participate in the educational process, plan and evaluate their own activities. The purpose of this study is to identify the pedagogical foundations of using modular technology in teaching inorganic chemistry at higher education institutions and to substantiate its effectiveness in practice. Based on this purpose, a survey was conducted among students, and a scientific hypothesis was formulated regarding the effective implementation of modular teaching in higher education.

Materials and methods. The use of modular technology in teaching inorganic chemistry is considered an important direction in the pedagogical modernization of the educational process. Within the framework of this study, the research was aimed at substantiating the theoretical foundations of modular teaching and the mechanisms of its implementation into the practice of chemical education from a scientific and methodological perspective [5, 88].

The methodological basis of the research is formed by the theories of constructivism, learner-centered teaching, and activity-based learning, which make it possible to develop individual learning trajectories for students, structure subject content, and master educational material in a consistent manner. Within the scope of these theories, the main pedagogical task of modular teaching is to enhance students' cognitive activity, develop their ability to work independently, and ensure the effectiveness of the learning process.

The research was conducted with a group of 12 first-year chemistry students at a pedagogical higher education institution in Kazakhstan. During the experimental lessons, the content of the inorganic chemistry course was restructured according to the modular principle, and students' academic achievements, interest in the subject, and self-study skills were monitored.

The research materials included teaching and methodological complexes, electronic courses, textbooks, and scientific articles on teaching inorganic chemistry from both domestic and foreign universities. In addition, sources in Russian, English, and Kazakh describing the practical implementation of modular technology in chemistry lessons were used.

The questionnaire given to students contained the following questions:

Topic: Initial Attitudes toward Modular Teaching

1. Have you ever heard of "modular teaching"?

Yes

No

2. If yes, in your opinion, what does "modular teaching" mean? (Write in your own words)

3. Which method seems more effective to you in the learning process?

Traditional lecture

Practical classes

Group work

Individual work

Other (please specify)

4. What is the most important aspect of the learning process for you?

Deep understanding of the topic

Acquisition of practical skills

Receiving new information

Independent inquiry
Other (please specify)
5. Are you willing to try new teaching methods (for example, modular teaching)?
Yes
No
Not sure
6. What is the main outcome you expect from teaching methods? (Write your personal opinion)

Table 1. *Modular Plan for the Course "Theoretical Foundations of Inorganic Chemistry"*

Module	Weeks	Topics	Brief Content
Module 1. Fundamentals of Chemistry	1–2	1. The object, methods, and development of chemistry 2. Substances and their properties. Chemical elements, simple and complex substances 3. Fundamentals of the theory of the structure of matter	The role of chemistry, basic concepts, types of substances, scientific research methods
Module 2. Atomic Structure and the Periodic Law	3–4	4. Quantum-mechanical model of the atom 5. Electron shells, orbitals 6. D.I. Mendeleev's periodic law and system, periodicity of atomic properties	Atomic theory, periodic regularities and their significance
Module 3. Chemical Bonding and Molecular Structure	5–6	7. Types of chemical bonds (ionic, covalent, metallic, hydrogen) 8. Valence bond theory (VBT), molecular orbital theory (MOT) 9. Molecular geometry and spatial structure	Types of bonds, molecular shape, hybridization
Module 4. Chemical Thermodynamics	7–8	10. System, state, thermodynamic functions 11. Internal energy, enthalpy, entropy, Gibbs energy 12. Energetics of chemical reactions, conditions of spontaneity	Types of energy, heat effects of reactions, free energy
Module 5. Chemical Kinetics and Equilibrium	9–10	13. Reaction rate and factors affecting it 14. Catalysis and its types 15. Chemical equilibrium, Le Chatelier's principle	Reaction rates, catalysts, equilibrium conditions
Module 6. Theory of Solutions	11–12	16. Classification of solutions, solubility 17. Methods of expressing concentration 18. Physicochemical properties of solutions (osmotic pressure, boiling/freezing point)	Composition and properties of solutions
Module 7. Electrolytic Dissociation and Electrochemistry	13–14	19. Theories of electrolytic dissociation (Arrhenius, Brønsted–Lowry, Lewis) 20. pH and buffer solutions 21. Redox reactions, electrochemical cells	Acid–base concepts, pH, redox reactions, basics of electrochemistry
Module 8. Summarization and Integration	15	22. Review and systematization of general chemical laws 23. Application of inorganic chemistry fundamentals in professional fields	Summarization, demonstration of interdisciplinary connections

The following scientific methods were used in writing this article:

– Literature review and theoretical analysis - studying modern research in pedagogy, chemical education, and teaching technologies (with priority given to sources published after 2020);

– Pedagogical experiment - conducting practical lessons based on modular technology and comparing students' academic achievements [6, 110];

– Observation and survey - identifying students' activity and perception features during the learning process;

– Quantitative analysis - determining the effectiveness of modular teaching through statistical processing of the obtained data.

Thus, the study was aimed at substantiating the effectiveness of modular technology in teaching inorganic chemistry both theoretically and practically.

Results and discussion. During the study, a survey was conducted among 12 first-year chemistry students with the aim of identifying their "understanding and attitudes toward modular teaching prior to its implementation" (Table 1).

According to the collected data, it was observed that the majority of students did not have a clear understanding of the modular teaching method: 8 out of 12 students stated that they had heard the term for the first time, while only 4 students provided a general idea about its content. In their opinion, modular teaching means the division of educational material into sections and its systematic presentation, or simply a new method different from the traditional one.

With regard to lesson formats, most students considered practical classes (5 students) and group work (3 students) to be effective. Meanwhile, 2 students preferred traditional lectures, and another 2 chose individual work. These findings highlight that students are inclined toward active engagement during lessons.

As for the expected outcomes of the learning process, the acquisition of practical skills (5 students), deep understanding of the topic (4 students), and the development of independent inquiry (1 student) were most frequently mentioned. Additionally, some students emphasized the importance of obtaining new information (2 students).

The majority of students (9) indicated their readiness to try new teaching methods, including modular teaching. Only 1 student expressed a negative opinion about this approach, while 2 students reported being undecided.

The main results students expected from teaching methods were: lessons that are simple and understandable (4 students), more practical assignments (3 students), learning how to conduct independent inquiry (2 students), and increased interest in classes (2 students). Thus, the survey demonstrates that students do not yet have a full understanding of modular teaching, but at the same time, their interest in innovative teaching technologies is quite high.

Based on this survey, new modules for teaching general and inorganic chemistry were proposed. Organizing the content of general and inorganic chemistry courses according to the modular system is aimed at ensuring that students master the material systematically and step by step. The logic of dividing the modules was determined in accordance with the internal content structure of the subject and the developmental patterns of chemistry, ranging from theoretical foundations to practical applications.

The first module - "Fundamentals of Chemistry" is designed to introduce students to the general scientific context of chemistry. It covers the object of chemistry, its main methods, and development, as well as the basic types and properties of substances. At this stage, students acquire the initial conceptual framework necessary for the learning process, while also understanding the role and importance of chemistry in society. The content of the module, based on the principles of scientific rigor and accessibility, helps to foster students' initial interest in the subject.

The second module - "Atomic Structure and the Periodic Law" forms the fundamental part of the course. Mastering the quantum-mechanical model of the atom, the organization of electron shells, and the significance of D.I. Mendeleev's periodic law develops students' ability to understand the properties of chemical elements. In this module, the connection between atomic theory and periodicity is revealed, creating the theoretical foundation for subsequent topics.

The third module - "Chemical Bonding and Molecular Structure" serves as a continuation of the previous module, providing a transition from the atomic to the molecular level. It analyzes types of chemical bonds, the spatial structure of molecules, and the theory of hybridization. This knowledge provides students with a universal tool for explaining the physicochemical properties of substances. The content of the module develops students' analytical thinking and trains them to analyze chemical processes from a structural perspective.

The fourth module - "Chemical Thermodynamics" and the fifth module - "Chemical Kinetics and Equilibrium" are closely interconnected. The first deals with the energetic characteristics of

chemical systems, introducing such concepts as internal energy, enthalpy, entropy, and Gibbs energy. The second focuses on the rate of reactions and equilibrium conditions. Considering these two modules together allows students to gain a deeper understanding of the nature of chemical processes and their practical significance.

The sixth module - "Theory of Solutions" introduces students to the classification of solutions, methods of expressing concentration, and the physicochemical properties of solutions. Important phenomena such as osmotic pressure, boiling, and freezing points are explained, along with their applied significance.

The seventh module - "Electrolytic Dissociation and Electrochemistry" is one of the most important sections of inorganic chemistry. It considers acid–base concepts from different theoretical perspectives, explains the pH scale, buffer systems, and redox processes. Electrochemical cells are also studied, with emphasis on their practical applications. This module helps students develop skills needed in their future professional activities, particularly in analytical chemistry, biochemistry, and technological processes.

The eighth module - "Summarization and Integration" is aimed at systematizing and generalizing the knowledge acquired in previous modules, as well as demonstrating ways of applying it in an interdisciplinary context. At this stage, students consolidate the general laws of chemistry and relate them to professional fields. This concluding module ensures the logical completion of the course and develops students' ability to apply their knowledge comprehensively.

After completing the general and inorganic chemistry course through modular teaching, a survey was conducted to determine students' opinions. The results for each question were analyzed and presented in percentage terms (Table 2).

Table 2. *Survey Results on Modular Learning*

Survey Question	**Agree (%)**	**Disagree (%)**	**Neutral (%)**
The learning material became clearer when divided into modules	84	8	8
Modular learning increased my interest in the subject	76	12	12
This system motivated me to study independently	68	14	18
Modular assignments helped develop logical thinking	74	10	16
In the modular system, theory and practice are well balanced	81	7	12
Interactive elements were useful	82	6	12
The assessment methods were clear and fair	79	11	10
I believe modular learning is also applicable to other subjects	77	13	10
Support from the instructor during lessons was sufficient	85	5	10
Overall, I was satisfied	88	4	8

The results of the survey demonstrated that the modular learning approach had a clear positive impact on students' learning process. First of all, dividing the learning material into modules (84% agreement) enabled students to absorb complex information step by step, distribute the learning load more effectively, and master knowledge systematically. This indicator proves that the modular structure increases the clarity and accessibility of educational content.

The increase in students' interest in the subject (76%) highlights the motivational potential of modular learning. This result demonstrates that students became more engaged during classes and perceived the subject as important not only from a theoretical perspective but also in terms of its practical significance. In addition, the majority of students (68%) noted that the modular system encouraged them to study independently. This fact indicates that modular learning contributes to strengthening students' self-directed inquiry and developing their functional literacy.

The effectiveness of modular assignments in developing logical thinking (74%) and the balance between theory and practice (81%) created opportunities for students to form higher-order cognitive

skills. In this regard, modular learning goes beyond merely delivering information, functioning instead as a method that enhances analytical and critical thinking abilities.

The effectiveness of interactive elements (82%) once again confirmed the importance of integrating modern educational technologies. Interactive methods fostered students' active participation in classes and improved the quality of material retention. The fairness and clarity of the assessment system (79%) enabled students to approach their academic achievements with greater confidence, thereby increasing their motivation.

The proportion of students who confirmed the applicability of modular learning to other subjects (77%) demonstrates the universality of this technology and its potential for broader implementation in higher education. Furthermore, the sufficiency of instructor support (85%) provides evidence of the effectiveness of pedagogical interaction between students and teachers.

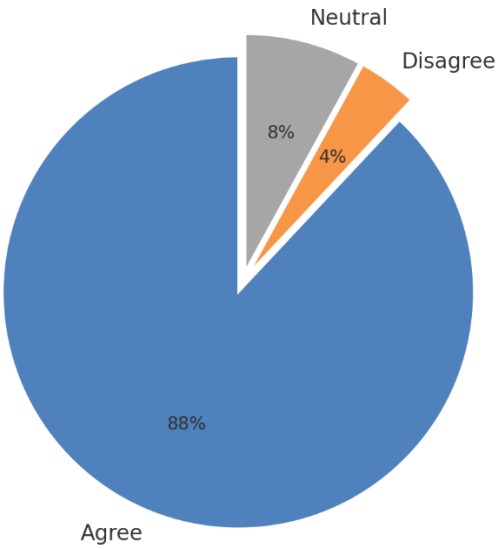

Figure 1 – Students' satisfaction rate with modular learning

The overall satisfaction rate (88%) proves that the modular learning system met students' expectations and made the educational process effective both in terms of content and methodology. These findings indicate that the modular learning approach has significant potential to enhance the quality of education in higher institutions.

The research results showed that the use of modular technology in teaching inorganic chemistry increases the effectiveness of the learning process.

First, modular learning allows for structuring and systematizing the content of education [7, 67]. Since the objectives and tasks of each module are clearly defined, students know in advance what knowledge, skills, and outcomes they are expected to acquire during the course. This approach ensures the transparency of the learning process and strengthens students' motivation.

Second, modular technology integrates theoretical knowledge with practical skills, thereby enabling a holistic understanding of the subject matter in chemistry [8, 187]. For example, complex topics in inorganic chemistry are complemented by laboratory assignments, which contribute to the development of students' practical competencies.

Third, modular learning enhances students' independence in the learning process. Since each module includes individual tasks, control questions, and reflection elements, students are given opportunities to test and improve their knowledge. This contributes to the development of self-management, planning, and critical thinking skills in the learning process.

Fourth, modular technology fosters the development of students' functional literacy. Chemical knowledge is acquired not only theoretically but also through practical tasks applied to real-life situations. Such tasks are aimed at building professional competencies.

Conclusion. The conducted research has demonstrated the pedagogical effectiveness of applying modular technology in teaching inorganic chemistry. During the study, students' initial understanding of modular learning was identified, and based on these findings, the course content was adapted into modules. As a result, it was shown that the modular approach contributes to the systematization of knowledge, the integration of theory and practice, the development of students' independent learning skills, and the enhancement of learning motivation.

The main advantages of modular learning are the structuring of the educational process, the clarity of learning objectives, the improvement of students' functional literacy, and the development of professional competence. This method is particularly relevant for subjects such as inorganic chemistry, which are theoretically complex and require the acquisition of practical skills.

The research findings highlight the necessity of introducing modular programs into the inorganic chemistry course at higher education institutions and emphasize the importance of enhancing teachers' methodological competence. Furthermore, it is considered essential to conduct additional studies aimed at adapting modular technology to other areas of chemistry and integrating it with digital educational resources in the future.

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ОРГАНИКАЛЫҚ ХИМИЯ БОЙЫНША БІЛІМ АЛУШЫЛАРДЫҢ ӨЗІНДІК ЖҰМЫСЫНА АРНАЛҒАН КРИТЕРИАЛДЫ БАҒАЛАУ ПАРАҚТАРЫНЫҢ ТИІМДІЛІГІ

Аңдатпа

Бұл зерттеуде органикалық химия курсы бойынша Білім алушының өзіндік жұмысын (БӨЖ) критериалды бағалау парақтары арқылы бағалаудың тиімділігі теориялық және тәжірибелік тұрғыда талданды. Зерттеудің мақсаты - презентация, постер және интеллект-карта форматындағы оқу өнімдерін бағалауға арналған критерийлердің оқу нәтижелеріне әсерін анықтау. Критериалды бағалау парақтары Блум-Андерсон таксономиясының деңгейлеріне сәйкестендіріліп, білімді білу, түсіну, қолдану, талдау, бағалау және жаңа өнім жасау әрекеттерін кешенді түрде өлшеуге бағытталды. Зерттеу 2025-2026 оқу жылының күзгі семестрінде химия мамандығының 18 студентімен (9+9) жүргізілді, барлық қатысушылар эксперименттік топ ретінде қарастырылды. Студенттер «Алкандар» тақырыбы бойынша үш визуалды форматтағы өнім дайындады, бағалау рубрикалары алдын ала ұсынылды, дескрипторлар нақты дағдыларды өлшеуге бағытталды.