

Methodology of Using Natural Sciences Integration in Teaching Students the Technology of Producing Nitrogen-Containing Organic Compounds in The Chemical Industry

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Abstract: This scientific-methodological paper presents a methodology for teaching students about nitrogen-containing organic compounds produced in chemical industry enterprises, utilizing an integrative approach based on natural sciences. The approach aims to reveal the practical relevance of the topic by harmonizing chemistry, biology, ecology, medicine, and industrial sciences. The applied significance of major Uzbek chemical enterprises such as "Navoiyazot" and "Farg'onaazot," as well as the use of laboratory experiments and project-based learning, are highlighted as tools for developing interdisciplinary thinking, practical skills, and professional interest among students. Furthermore, the content and analyses of this article are fully aligned with Uzbekistan's "New Uzbekistan" Development Strategy for 2022–2026 and the concept of ensuring close linkage between science, production, and education.

Keywords: Nitrogen-containing organic compounds, industrial integration, educational innovations, STEAM approach.

Introduction: In the 21st century, the rapid development of science and technology demands that the education system prepare specialists with practical, interdisciplinary knowledge, capable of independent thinking and effective problem-solving. In particular, deep and systematic instruction in the natural sciences—especially in chemistry—is a pressing task, enabling students to act independently in situations linked to real industrial contexts.

Nitrogen-containing organic compounds occupy a critically important place in chemistry. They are not only of theoretical interest but also widely used in practical fields such as medicine, agriculture, the food industry, ecology, and pharmaceuticals. Knowledge about their structure, properties, synthesis, and applications plays a key role in developing students' chemical thinking. Therefore, using interdisciplinary approaches and integrating methods involving industrial enterprises significantly strengthens and

deepens knowledge while demonstrating its practical relevance.

In Uzbekistan, major chemical plants such as "Navoiyazot" JSC, "Maxam-Chirchiq" LLC, and "Farg'onaazot" JSC serve as practical schools for the synthesis and application of nitrogen compounds. Establishing integrated collaboration with these enterprises in the educational process enhances not only theoretical knowledge but also prepares students for practical application.

Moreover, international educational standards (such as those by OECD PISA, UNESCO, and Bloom's Taxonomy) emphasize the importance of applying knowledge in interdisciplinary contexts to assess students' deep understanding of science. Therefore, teaching nitrogen-containing compounds in conjunction with biology, ecology, technology, and informatics aligns with these standards and supports the development of students' intellectual potential.

This article analyzes, on a scientific basis, the content, methodology, and practical results of a modern interdisciplinary approach to teaching nitrogen-containing organic compounds in integration with Uzbekistan's industrial enterprises. The proposed approach is aimed at the harmonious development of students' theoretical knowledge and practical skills, as well as fostering their interest in scientific research.

Nitrogen-containing organic compounds are hydrocarbons that include nitrogen (N) atoms and are key components in vital biological processes and industrial chemistry. These compounds are distinguished by their chemical properties, reactivity, and biological significance.

The main classes of nitrogen-containing organic compounds include:

1. Amines ($R-NH_2$, R_2NH , R_3N):

These are derivatives of ammonia and can be classified as primary, secondary, or tertiary.

Example: Methylamine (CH_3NH_2), Dimethylamine ($(CH_3)_2NH$)

2. Amides ($R-CO-NH_2$):

Formed by condensation between carboxylic acids and amines.

Example: Acetamide (CH_3CONH_2)

3. Nitro Compounds ($R-NO_2$):

Compounds where the nitrogen atom is bonded to a carbon via a nitro group.

Example: Nitrobenzene ($C_6H_5NO_2$)

4. Nitrogen-containing heterocycles:

Ring structures containing nitrogen atoms.

Examples: Pyridine, Imidazole, Purine

5. Amino acids and proteins:

Biologically active compounds that serve as the building blocks of living organisms.

Examples: Glycine (NH_2CH_2COOH), Alanine, Lysine

Many nitrogen-containing compounds are water-soluble and capable of forming hydrogen bonds. Amines exhibit basic properties and form salts with acids. Nitro compounds are highly polar and may possess explosive properties.

Chemical reactions and synthesis pathways:

- Amines synthesis: Reaction of haloalkanes with ammonia

- Amides synthesis: Carboxylic acids + amines \rightarrow amides + water

- Nitro compounds synthesis: Aromatic hydrocarbons + concentrated $HNO_3/H_2SO_4 \rightarrow$ nitroaromatic compounds (nitration reaction)

Biological and industrial significance:

- Amino acids and proteins are fundamental components of living cells.
- Nitrogen fertilizers (urea, ammonium nitrate) are widely used in agriculture.
- Nitro compounds are used in the production of explosives (TNT), pharmaceuticals (paracetamol), dyes, and plastics.

Problems of Application in Education

Students often face difficulties in understanding abstract concepts (such as intermolecular bonds, hydrophilic/lipophilic properties). A lack of practical experience leads to an inability to connect theoretical knowledge with real-life situations. Additionally, the fact that educational materials sometimes do not reflect modern industrial realities lowers student motivation.

Advantages of Interdisciplinary Approach in Education

The modern education system aims to teach students to think critically, solve problems, and adapt to practical tasks by revealing the interconnections between disciplines rather than studying them separately. This principle is emphasized in international educational standards, such as the OECD PISA, the UNESCO Global Education Monitoring Report, and the 21st Century Skills framework.

Essence of the Interdisciplinary Approach

The interdisciplinary approach is a teaching method that establishes connections between several disciplines (e.g., chemistry, biology, physics, computer science, technology) and teaches them in an integrated manner. Through this method:

Students learn to apply abstract knowledge in real-life contexts.

The subject matter is explored from the perspectives of different disciplines, which ensures a deeper and more systematic understanding.

The integration of theory and practice is strengthened.

For example, in the study of nitrogen-containing organic compounds, the following interdisciplinary integration can be implemented:

Subject	Integration Path
Biology	Nitrogen bases in proteins, amino acids, DNA, and RNA.

Ecology	Nitrogen cycle, soil pollution through fertilizers.
Technology	Production of nitrogen fertilizers, synthesis methods.
Informatics	Construction of 3D molecular models, simulation of reactions.
Physics	Energy of chemical bonds, basics of spectroscopy.

Advantages of the interdisciplinary approach:

High-level knowledge is formed based on Bloom's taxonomy: analyzing, evaluating, creating. It corresponds to constructivist pedagogy: shaping the student as an active participant rather than a passive recipient.

It supports the STEM approach: teaching in the harmony of science, technology, engineering, and mathematics. It develops creativity and innovative thinking.

It increases motivation — the student sees the practical value of their knowledge in real life.

Experience and practical evidence:

In the Finnish education model, teaching based on interdisciplinary projects has become a national standard. In Uzbekistan, some higher education institutions (for example, TATU, Tashkent Chemical-Technological Institute) have established interdisciplinary laboratory works. In an experiment conducted in 2022 among students of the chemistry-biology specialty in Tashkent, groups using the interdisciplinary approach achieved on average 17%

higher results.

The necessity of teaching nitrogen organic compounds integrated with industry: Modern chemical education requires not only theoretical knowledge but also a practice-oriented approach connected with real industrial conditions. Especially for widely spread substances like nitrogen organic compounds, which are of strategic importance for industry, this integration is urgent.

The essence and purpose of integration: An industry-integrated methodology for teaching nitrogen compounds includes the following:

- Using real industrial technologies, production processes, and technical equipment in the educational process;
- Developing students' readiness for production, understanding, and evaluating technological processes;
- Developing creative thinking through studying innovative approaches in production.

The importance of nitrogen compounds in Uzbekistan's industry

Sectors:	Applications of nitrogen compounds:	Examples of local industry
Chemical industry	Fertilizers (urea, ammonium nitrate)	Navoiyazot Joint Stock Company
Pharmaceuticals	Antibiotics, analgesics, sulfanilamides	Fargonaazot
Textile and dyes	Nitro dyes, azo dyes	Jurabek Laboratories
Explosive materials	TNT, nitroglycerin, ammonium nitrate	Nobel Pharmaceutical Industry

Nitrogen Compounds constitute an important part of Uzbekistan's export potential. According to reports from 2023, the export of urea fertilizers alone exceeded 170 million USD.

Results Achieved Through Integration with Industry:

1. Students learn to apply theoretical knowledge in practical situations.
2. Career readiness improves: students

observe real professional activities during internships.

3. Innovative thinking develops: technological innovations from the industry are introduced into education.

4. A bridge is established between science and production: continuous communication arises between universities, factories, and research institutions.

International Experience:

In Germany, the "Dual Education" system allows students to spend part of the week at an enterprise and part at the university.

In South Korea, STEM fields are integrated with industrial laboratories; companies like Samsung and LG directly provide grants to universities.

In Russia, the "University – Factory – Technopark" model organizes laboratories based on production (for example, at Mendeleyev University of Chemical Technology).

Integration Initiatives Being Implemented in Uzbekistan:

The "Integration of Chemical Education and Industry" project has been carried out by the Ministry of Higher Education since 2022.

At the Tashkent Chemical-Technological Institute (TCTI), practical training bases have been organized at enterprises such as Navoiyazot and Maxam-Chirchiq for students in the "Industrial Chemistry" specialization.

For pedagogical fields, professional laboratories and chemistry classrooms have been reconstructed and equipped with modern tools.

The industry-integrated methodology provides students not only with knowledge but also with competencies necessary in real life. Through this approach, students gain deep answers not only about the structure and reactions of nitrogen compounds but also about how they are produced, how they are used, and what problems they solve.

Methodology for Teaching Nitrogen Organic Compounds Based on an Integrated Approach:

Using an integrated approach to teach nitrogen organic compounds develops not only theoretical knowledge but also practical skills used in real industrial conditions. The methods and techniques, which play a significant role in this approach, help develop students' thinking systems.

Role of the Integrated Methodology in the Teaching Process:

The integrated methodology for teaching nitrogen

organic compounds aims at the following main goals:

- Linking theoretical knowledge with practice: students apply their knowledge of chemistry, biology, ecology, and technology to real industrial processes. Learning nitrogen organic compounds occurs not only in the laboratory classroom but is also connected to real industrial conditions.
- Applying innovative approaches: students are prepared for modern production by introducing new technologies and innovations used in scientific research and industry.
- Developing creative thinking: students gain the ability to propose new approaches and innovative solutions for solving industrial problems. This develops their creativity and problem-solving skills.

Methodological Approaches:

- Teaching based on project work and practice: students carry out various laboratory works, observe real production processes, and develop projects based on industrial research. For example, practical training in cooperation with the Navoiyazot enterprise allows students to see the production process of compounds firsthand.
- Use of advanced technologies in the educational process: students analyze the structure and reactions of nitrogen organic compounds using computer simulations and molecular modeling software such as ChemDraw and Gaussian, which enable the creation of 3D molecular models and simulation of their reactions.
- Working in experimental and industrial laboratories: students learn specific real tasks related to the synthesis and analysis of nitrogen organic compounds in industrial laboratories. Knowledge of production processes and technologies becomes practically relevant. An example is the production of nitrogen fertilizers and pharmaceutical compounds in specialized chemical laboratories (e.g., at the Tashkent Chemical-Technological Institute).

Development of Practical Skills in Students:

Integration with industry in teaching nitrogen organic compounds involves educating students about industrial technologies, such as the production processes of the nitrogen industry, pharmaceutical companies, or nitro dyes in the textile industry. This, in turn, provides students with practical skills relevant to industry.

Simulation and Laboratory Work: After studying the theoretical part of nitrogen organic compounds, students must be given the opportunity to work in practice to synthesize, analyze, and understand the

mechanisms of reactions. Laboratory work also helps develop students' abilities to use software, perform statistical analysis, and present technical results.

Advantages of Integrating Methodological Approaches:

- **Rapid and effective learning:** Students quickly absorb knowledge by studying real and practical examples during the learning process and learn to apply the acquired theory in everyday life.
- **Preparedness for real life:** When students start their careers, they are ready to solve real industrial problems and work with industrial technologies.
- **High motivation:** Direct connections with industry foster high motivation in students toward their fields, encouraging them to apply their knowledge in practice.

The integrated approach teaches students not only the theoretical aspects of nitrogen organic compounds but also their practical application. Through this approach, students develop problem-solving skills and become specialists ready for industry.

Educational Materials and Methodologies: Effective Approaches to Teaching Nitrogen Organic Compounds. Choosing effective educational materials and methodologies during the process of teaching nitrogen organic compounds plays an important role in students' knowledge acquisition. This process helps students not only master theoretical knowledge but also develop practical skills. Educational materials and methodologies should be based on innovative approaches so that students can apply an active and interactive approach in learning nitrogen organic compounds.

Educational Materials: Theoretical and Practical Foundations. The following educational materials and resources are essential for studying nitrogen organic compounds:

1. **Textbooks and manuals:** Textbooks provide fundamental knowledge for students. These textbooks include theoretical information about nitrogen organic compounds, their synthesis, reactions, and applications. For example, the textbook "Nitrogen Compounds and Their Reactions" is a primary educational resource for students.
2. **Interactive educational materials:** Using electronic resources and online learning platforms is effective. Simulations, video lessons, and virtual laboratories help apply visual and interactive methods in teaching nitrogen organic compounds. This enables students to create, study, and test nitrogen compounds with the help of a computer.
3. **Scientific and technical articles:** Recent

scientific research and articles can be important sources for students in studying nitrogen organic compounds. Journals such as *Agroinnovation*, *Chemistry and Chemical Technology*, and the "Journal of Natural Sciences" contain information on innovations and new approaches related to nitrogen compounds.

4. **Materials related to industrial technologies:** To teach industrial practices, it is necessary to study production processes, eliminate technological errors, and analyze technical documentation. For instance, technical documents related to the enterprises Navoiyazot and Farg'onaazot help students better understand production processes and technologies.

Methodologies: Encouraging Active Learning in Students

Methodological approaches in teaching nitrogen organic compounds serve to motivate students to be active, encourage scientific inquiry, and develop practical skills. Effective methodologies may include:

1. **Constructivist Approach:** According to the constructivist approach, students create knowledge based on their own experiences. In studying nitrogen organic compounds, this methodology encourages students to think independently, conduct experiments, and analyze the obtained results. For example, when students study the synthesis of urea or ammonia, they may develop these processes themselves.
2. **Project-Based Learning:** During the study of nitrogen compounds, it is necessary to create projects aimed at solving real-life problems for students. For example, students may work on projects related to the production of nitrogen fertilizers or the creation of pharmaceutical nitrogen compounds. This method helps students acquire practical knowledge and apply it to industrial problems.
3. **Laboratory Work and Experiments:** Laboratory work and experimental methods are of great importance for students. Performing real chemical reactions, analyzing results, and evaluating them from a scientific perspective provide valuable experience. During laboratory work, students familiarize themselves with production technologies and industrial processes.

Effective Use of Educational Materials

The effective use of educational materials in teaching nitrogen-containing organic compounds is implemented as follows:

1. **Development of curricula and modular systems:** Educational materials should be divided into several modules, each of which includes both

theoretical and practical knowledge. For example, the first module presents nitrogen compounds and their general concepts, while the second module provides information about their industrial applications.

2. Establishing practical training and industry connections: It is necessary to organize practical training and establish industry connections for students. This allows learners to study real industrial processes firsthand.

Effective educational materials and methodologies in teaching nitrogen-containing organic compounds not only help students acquire knowledge but also provide them with practical skills. These methods develop students' critical thinking, innovative approaches, and readiness for industrial practices.

Innovative Pedagogical Technologies in Teaching Nitrogen-Containing Organic Compounds

In the process of studying nitrogen-containing organic compounds, innovative pedagogical technologies serve to teach students scientific research, practical skills, and creative processes. These technologies not only increase students' motivation but also help develop their scientific and practical activities. Modern pedagogical technologies aim to transform the educational process, organize effective teaching, and facilitate students' learning processes.

Importance of Innovative Pedagogical Technologies

Innovative pedagogical technologies create new forms of learning and encourage students to participate more actively in the learning process. In teaching nitrogen-containing organic compounds, these technologies offer the following advantages:

- Increasing activity: Innovative technologies stimulate students' engagement and independent thinking.
- Interactive teaching: Modern teaching methods, such as simulations and laboratory work, create opportunities for students to exchange ideas and apply knowledge in practice.
- Developing creativity: Innovative technologies encourage students to create and find new approaches.

Methods of Applying Innovative Technologies in Teaching Nitrogen-Containing Organic Compounds

Simulations and virtual laboratories: Simulations and virtual laboratories can be effective tools in studying nitrogen-containing organic compounds. For instance, students can model reactions on computers and test them. Using software like ChemSketch and ChemDraw, students can create molecular structures and simulate them. These technologies help learners visualize

chemical processes and accelerate the learning process.

Online learning platforms: The use of online learning platforms is also important in teaching nitrogen-containing organic compounds. Platforms such as Moodle, Google Classroom, and Edmodo allow students to reinforce their knowledge through lessons, tests, laboratory work, and forums. This enables students to attend classes on time and from any location, thereby increasing the efficiency of education.

Flipped Classroom: Using the flipped classroom technology in teaching nitrogenous organic compounds can be effective. This method involves students studying the lesson materials beforehand and then engaging in group work, discussions, and practical exercises during class based on the acquired knowledge. For example, students learn about the synthesis of nitrogenous compounds on their own and then study their practical application during the lesson. This approach helps activate students and promotes deeper understanding of the material.

Gamification (Use of Game Elements): Gamification is one of the innovative pedagogical technologies that makes the learning process interesting and interactive for students. In teaching nitrogenous organic compounds, students can learn through various games, such as chemical reaction-solving games. This creates motivation through rewards, points, or medals to achieve goals. Gamification encourages students to learn and helps strengthen their knowledge.

Webinars and Distance Learning: Webinars and distance learning are widely used in integrating innovative technologies into education. In teaching nitrogenous organic compounds, webinars provide opportunities for communication with experts and specialists from industry. This enables students to acquire new knowledge, observe practical exercises, and study real industrial examples.

Integration of Innovative Technologies with Industry in Teaching Nitrogenous Organic Compounds

Integrating innovative technologies with industry plays a crucial role in teaching nitrogenous organic compounds. Students are given opportunities to study real industrial production processes and apply the relevant technologies in practice. The following technologies effectively facilitate this process:

- Collaboration Between Industry and Universities:

Through cooperation with industrial enterprises, students can learn the production processes of nitrogenous organic compounds. For example, internships organized at enterprises such as Navoiyazot

and Farg'onaazot encourage students to participate in industrial processes.

- **Real Experience and Research:**

To solve real problems in industry, it is necessary to organize scientific research and laboratory work for students. For instance, students gain close access to industry for conducting practical experiments related to nitrogenous fertilizer production processes.

- **Introduction of Technological Innovations and New Approaches:**

Applying new technologies and innovative approaches in teaching nitrogenous organic compounds is important for students. This process allows learners to apply theoretical knowledge in practice.

Innovative pedagogical technologies make the teaching process of nitrogenous organic compounds efficient and engaging. These technologies activate students, develop practical skills, and encourage scientific research. Their integration with industry creates opportunities for students to gain real experience and improve practical competencies.

The importance of studying nitrogenous organic compounds lies in their chemical structure, properties, and reactions, which have great significance for science and industry. Learning these compounds can be challenging for students due to the complexity of understanding their chemical structure and reactions. However, this knowledge is applied not only in chemistry but also in biotechnology, pharmaceuticals, ecology, and other industrial sectors.

Problems in the Teaching Process

Several problems arise in teaching nitrogenous organic compounds, including poor assimilation of theoretical knowledge, lack of laboratory facilities, insufficient methodological preparation of teachers, and low student motivation. To effectively address these issues, it is necessary to apply modern methods, expand resources, and establish active cooperation with students.

Importance of Interdisciplinary Approach

It is essential to use an interdisciplinary approach in teaching nitrogenous organic compounds. Combining knowledge from chemistry, biology, physics, and mathematics allows students to develop a deeper understanding. This approach also fosters problem-solving and logical thinking skills.

Recommendations

Implementation of Interactive and Innovative Methods:

Applying interactive learning methods such as collaborative learning, online courses, virtual

laboratories, and simulations increases the effectiveness of the educational process. Such methods facilitate easier acquisition of new knowledge and make learning more engaging.

Improvement of Laboratory Conditions:

Expanding resources and equipping laboratories with modern equipment is necessary for laboratory work. Improved lab conditions allow students to observe chemical reactions in real-time and apply their knowledge in practice.

Enhancement of Teacher Qualifications:

Improving teachers' methodological preparation, applying modern pedagogical methods, and introducing new educational materials and technologies are crucial. Additionally, organizing training and seminars for teachers on effective educational management helps in working more effectively with students.

Strengthening the Motivation System:

Developing a motivation system to increase students' interest in studying is important. Rewards, grants, competitive projects, and additional incentives for laboratory work enhance students' motivation.

Strengthening Cooperation with Industry:

Enhancing collaboration with industry helps students gain practical experience. Involving students in integrated projects with industrial enterprises prepares them to solve real-world problems and demonstrates the practical significance of the knowledge acquired.

To effectively solve the problems arising in the teaching process of nitrogenous organic compounds, it is necessary to apply modern pedagogical methods, improve laboratory conditions, enhance teachers' qualifications, and motivate students. These methods, along with strengthening cooperation with industry, help make the educational process more efficient.

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