

INNOVATIVE STRATEGIES FOR MULTI-LEVEL NATURAL SCIENCE EDUCATION OF TEACHERS IN THE CONTEXT OF A CONTINUOUS EDUCATIONAL PROCESS

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Summary

Current socio-cultural challenges and rapid digitalization necessitate a paradigm shift in pedagogical education. Modern teacher training adopts a dual approach: cultivating a visionary intellectual and a highly qualified specialist. Within this framework, multi-level natural science training serves as a foundational vector, evolving from academic fundamentals to integrated environmental, research, and digital competencies.

The purpose of this article is to analyze innovative strategies for the multi-level natural science education of future teachers within a continuous professional development system. The study highlights how these strategies synthesize professional competence with advanced pedagogical mastery. The analysis confirms that Ukraine's educational paradigm is transforming from a static «knowledge-based» model into a dynamic competence ecosystem.

Special emphasis is placed on the natural science teacher as a key respondent to global technological and environmental crises. Integrating a fundamental scientific base with flexible STEM methodologies, AI-driven practices (such as the «AI-Micro-Educator» concept), and digital tools forms a new type of educator – a facilitator of scientific inquiry. This transformation is reinforced by the unique experience of Ukrainian education under martial law, which fosters critical thinking and psychological resilience.

Prospects for further exploration include developing individualized training trajectories, transdisciplinary approaches, and ecological competence vital for post-war restoration. This developmental vector ensures an adaptive environment capable of nurturing resilient, intellectually mature personalities – the architects of Ukraine's innovative future.

Key words: innovative strategies, multi-level education, natural science teachers, continuous educational process, STEM methodologies, professional competence, digital transformation, pedagogical innovation.

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1. Introduction

The current stage of civilization development, which scientists describe as the era of the «Fourth Industrial Revolution» in the context of global environmental challenges, puts forward fundamentally new requirements for natural science education, which is undergoing tectonic shifts under the influence of both global and local crisis phenomena. The COVID-19 pandemic, which became the first shock test for educational systems, and the full-scale Russian invasion of Ukraine have transformed the issue of teacher adaptability from a theoretical plane into an existential one, as blended and distance learning forms have transformed from a temporary measure into a new pedagogical reality. This reality requires a natural science teacher to have

fundamentally new competencies – from organizing a virtual experiment in the absence of access to laboratories to providing initial psychological support to students in the face of security threats. In this complex context, the pedagogical education system has found itself faced with the need for a radical rethinking of approaches to professional training, where the multi-stage training of a natural science teacher is viewed not as a linear process of accumulating a body of knowledge, but as a continuous, flexible trajectory of professional development, covering levels from undergraduate to postgraduate education and self-improvement throughout life (Life Long Learning).

Analysis of recent research and publications. In modern socio-cultural conditions, professional and pedagogical training is designed to solve two complexes of interrelated tasks: first, to promote the social development of the future teacher's personality, his general educational, cultural, and ideological training; second, to ensure professional development in the chosen field of pedagogical activity (Kovalenko, 2020: 154-156). The development of the teacher's personality, the acquisition of relevant knowledge and abilities that allow him to make well-founded conclusions about the state and course of the pedagogical process and to act effectively, is the goal, basis, and condition of effective professional activity.

Of particular importance is the multi-level natural science training of future teachers, which involves the gradual formation of competencies: from basic knowledge in the field of natural sciences to the integration of environmental, interdisciplinary, and research skills (Baibak, 2025: 232-233). Modern approaches emphasize competency-based, practice-oriented, and integrative learning, which combines a fundamental theoretical basis with innovative methods, digital technologies, and environmental values. Such a system provides not only professional readiness but also the ability of the teacher to act as an agent of change in the community, to form the environmental consciousness of students, and to promote sustainable development.

Leading scientists who study the issue of improving the content of professional education (V. Bondar, S. Goncharenko, N. Hrytsay, N. Guz, I. Zyazyun, V. Kremen, V. Kuz, V. Lugovyi, O. Moroz, N. Nychkalo, V. Radul, O. Savchenko, S. Sysoeva, L. Khomych, etc.) quite rightly believe that in modern conditions the traditional image of professional and pedagogical culture no longer ensures a teacher's career success, his competitiveness, a high level of professionalism, and pedagogical skills. That is why multi-level natural science training using modern educational approaches becomes a key factor in updating the system of continuous education (Hramatyk, 2023: 23-36).

The purpose of the article is to identify and analyze modern approaches to multi-level natural science education of future teachers in the system of continuous educational process, as well as to reveal its role in the formation of professional competence and pedagogical skills.

2. Presentation of the main material of the study

Modern education requires from the training of future natural science teachers not only deep professional knowledge, but also the ability to flexibly respond to the challenges of the time, integrating innovative approaches, ecological thinking, and interdisciplinarity into their own pedagogical practice. In the modern educational space, which is rapidly transforming, the principle of fundamentalization – as interpreted by Academician S. Honcharenko – is considered not as a mechanical accumulation of theoretical material, but as the formation of a deep methodological culture, which provides the future natural science teacher with the ability to holistic scientific thinking, interdisciplinary integration and innovative pedagogical action

(*Honcharenko, 2008: 13-21*). This allows the future teacher to see a single scientific picture of the world based on individual facts and to integrate disparate knowledge of physics, chemistry, and biology into a holistic system. The fundamentalization of the content of natural science education at the present stage acquires a distinct axiological and activity dimension, where scientific knowledge is considered not as an end in itself, but as a tool for preserving life, the environment, and ensuring the sustainable development of society. This idea is consistently developed in her works by A. Stepaniuk, who substantiated the methodological principles of forming the integrity of knowledge about living nature as the basis for the integration of natural sciences, proving that the future teacher must have the ability for interdisciplinary synthesis, and not only narrowly professional erudition (*Stepaniuk, 1999: 135-136*).

The specifics of professional training of teachers of the natural science cycle in Ukraine are differentiated depending on the dominant subject specialization, each of which has its own unique vectors of development, analyzed in detail in the fundamental dissertation studies of leading Ukrainian scientists of the last decade. In particular, in the field of biology teaching methods, a significant contribution was made by N. Hrytsai, who, in her dissertation research, developed the concept of a methodological system for teaching biology based on an activity approach (*Hrytsai, 2014: 154-158*). The scientist emphasizes that the methodological training of future teachers should be inextricably linked with the formation of their research competence, which allows realizing the tasks of the New Ukrainian School by involving students in real scientific research, and not just reproductive assimilation of the material (*Sharko, 2021: 223-225*).

In parallel with this, S. Rudyshyn, in his works, substantiates the ecological-evolutionary approach to the training of biology teachers. The scientist emphasizes that understanding evolutionary processes is the key to the formation of a scientific worldview, and the ecological component should permeate all disciplines of the natural cycle, forming in the future, teacher responsibility for the state of the biosphere (*Rudyshyn, 2009: 227-254*). This is especially relevant in the context of modern environmental crises, when the teacher becomes the main conductor of environmental consciousness for the younger generation. In the same context, I. Koreneva investigated the problem of forming methodological competence of future biology teachers in the process of pedagogical practice, proving that it is a practical activity at school that is the integrative environment where theoretical knowledge is transformed into stable professional skills, and methodological competence becomes a tool for adapting to the changing conditions of the educational process (*Koreneva, 2020: 645*).

No less significant changes are taking place in the training of physics and chemistry teachers. The priority here is methodological mastery and digitalization of the educational process, which is thoroughly analyzed in the works of V. Sharko (*Sharko, 2021: 312*). The researcher proves the necessity of the transition of the physics teacher from the role of translator of physical laws to the role of organizer of research, search, and STEM projects. This idea is developed in her study by I. Salnyk, revealing the potential of computer-oriented tools and emphasizing that modern training of physics teachers is impossible without mastering the skills of working with digital measuring complexes and virtual environments (*Salnyk, 2015: 480*). At the same time, the study by N. Chaichenko focuses on the formation of chemical competence through practical experiments, which brings learning closer to the real life of students (*Chaichenko, 2018: 65-72*).

Analysis of educational and professional programs of leading pedagogical universities of Ukraine indicates the efforts of higher education institutions to adapt the content of training to the requirements of transdisciplinarity and the challenges of the time. An important step on this path was the introduction of the specialty 014.15 «Secondary Education (Natural Sciences)»/

A4 Secondary Education as a subject specialty A4.15 Secondary Education (Natural Sciences) of the field of knowledge A Education, which aims to train a new type of teacher.

The globalization of the educational space requires the harmonization of Ukrainian standards for teacher training with European ones, which actualizes the need for a deep comparative analysis of domestic and foreign models (*Hrynova, 2015: 284*). The experience of Finland, where entry into the teaching profession is possible only with a master's degree, demonstrates the effectiveness of the research-oriented model (Research-Based Teacher Education). Finnish researchers J. Lavonen and K. Juuti emphasize that a teacher must have developed skills of «pedagogical thinking», which allow them to independently diagnose students' problems, analyze data, and choose optimal methods (*Lavonen & Juuti, 2022: 345-358*). This model forms in the teacher the ability to reflect scientifically and to construct new didactic approaches independently, which has become the key to the phenomenal stability of the Finnish education system during the COVID-19 crisis.

In contrast, the Polish training model is particularly relevant to Ukraine in the context of implementing integrated courses in basic school (the subject «Nature» – Przyroda). As researchers V. Kuzmenko and M. Martyniuk note, the Polish system is characterized by flexibility and clear profiling at higher levels of education (*Kuzmenko, 2019; Martyniuk, 2017*). Polish universities offer master's programs that allow bachelors in biology to quickly master the methodology of teaching chemistry, physics, or geography through an extensive system of postgraduate education and micro-qualifications. Comparative analysis allows us to state that the Ukrainian system is gradually evolving from the rigid subject specialization characteristic of the German model (where a teacher is trained in a fixed combination of two subjects, for example, biology and sports), to greater flexibility and integration characteristic of the Anglo-Saxon and Scandinavian systems (*Kocherha, 2021: 21*).

The content of multi-stage training of a teacher of natural sciences should be updated systematically along several strategic vectors, among which the key one is the methodological transformation towards learning through research (Inquiry-Based Learning). This implies that the future teacher should not only master scientific facts, but also master the methodology of organizing students' research activities (15). A striking example of such work is the introduction of «citizen science» projects into teacher training, where students learn to organize monitoring of the state of the environment, water, or air quality using available tools, turning learning into a socially significant activity. An integral part of modern training is becoming digitally competent, which goes beyond basic literacy and involves mastering immersive technologies, such as virtual laboratories Labster or PhET (*Rothland, 2020: 315-330*). In war conditions, when access to real school laboratories is often limited or impossible, a teacher must be able to organize a full-fledged virtual workshop that allows students to develop research skills in a digital environment.

The further logic of modernization of teacher education requires going beyond formal academic training and focusing on the context of lifelong learning, since a bachelor's or master's degree is no longer sufficient for a teacher's professional longevity in a turbulent world. The system of lifelong learning for science teachers is transforming from the traditional model of periodic professional development (once every five years) into a dynamic ecosystem of professional development based on the principles of andragogy and heutagogy (self-determined learning). In the context of rapid obsolescence of scientific knowledge and technological innovation, a teacher is forced to constantly update their professional tools, moving from the status of a «consumer» of new knowledge to the status of a «co-creator» of educational content.

The implementation of the principle of lifelong learning in science teacher training involves a transition from discrete education to a holistic multi-level architectonics, where each stage has its own unique mission and tools:

First level (Bachelor's degree): Fundamentalization and worldview base. This stage is the foundation of professional development, where yesterday's schoolchild is transformed into a future specialist. The key task of the bachelor's degree is the formation of a scientific worldview and subject competence.

- Content: Students study classical fundamental disciplines (general physics, inorganic and organic chemistry, botany, zoology, anatomy), which form «hard skills».

- Innovative aspect: The response to the challenges of modernity was the introduction of integrated courses, such as «Biophysics», «Physical and Colloidal Chemistry», «Biogeography», and «Chemical Ecology». This allows us to destroy artificial inter-subject barriers even at the stage of knowledge acquisition, forming in the student an understanding of the unity of natural processes.

- Psychological and pedagogical component: In parallel, there is an immersion in the world of childhood through courses in age psychology and pedagogy, which lay the foundations of the humanistic worldview of the future teacher.

Second level (Master's degree): methodologization, research, and professional identity. A master's degree is the stage where the «subject expert» turns into a «master teacher». The focus shifts from «what to teach» to «how to teach» and «how to research».

- Methodological mastery: Students master complex technologies: STEM/STEAM education, distance and blended learning methods, and critical thinking technologies. It is here that the readiness to work in inclusion and create a barrier-free educational environment is formed.

- Differentiation: There is a clear profile: preparation for teaching individual subjects at an advanced level in a specialized high school (lyceum) or teaching an integrated course «Natural Sciences» in a basic school and colleges.

- Research component: The master's student acts as a researcher, performing scientific work, which often has the character of «Action Research» – analysis of real pedagogical situations during practice and finding ways to solve them.

Third level (PhD – Doctor of Philosophy): innovations and strategic leadership. Training of Doctors of Philosophy in specialties 011 «Educational, Pedagogical Sciences» or 014 «Secondary Education» goes beyond the school classroom. This is the level of training of the elite of the educational industry – leaders of change.

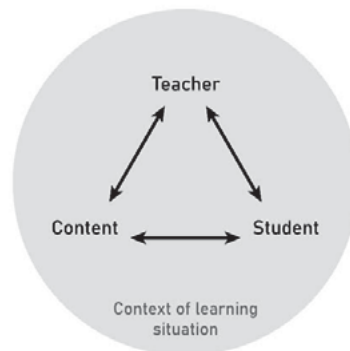
- Mission: Training developers of new methodologies, authors of textbooks and digital content, and teachers of higher education institutions.

- Activity content: postgraduate students explore global trends (digitalization, neuropedagogy, educational management), develop and experimentally test innovative learning models. They become a bridge between academic science and school practice, transferring new knowledge into the education system.

Fourth level (Postgraduate education): adaptation, development, and informal education. This is the most dynamic and flexible link that accompanies a teacher throughout his or her professional life.

- Reactivity: In conditions of war, reforms, or pandemics, it is this link that allows a teacher to survive professionally. Through the system of micro-credentials, a teacher can master critically needed skills in a few weeks: «Digital assessment tools», «Psychological support in stress conditions», «Mine safety», «Artificial intelligence in education».

- Formats: Moving away from formal courses every 5 years to continuous development through:
 - Informal education: online courses (Prometheus, EdEra, Coursera), webinars.
 - Horizontal connections: participation in (non) conferences, EdCamp, professional communities in social networks, where peer-to-peer experience is exchanged.
 - Certification: independent assessment of professional competencies, which stimulates self-development.



**Fig. 1. Model of didactic interaction in the system of continuing education.
Translation of elements (signatures)***

- * The Teacher-Content Relationship
- The Student-Content Relationship
- The Teacher-Student Relationship
- The Context of Learning Situation

Such architectonics ensures the continuity of the teacher's professional growth, allowing him to remain relevant, competent, and motivated at every stage of his career (Tirri, 2024: 450-456).

For example, a biology teacher can, in a short time, master the basics of tactical medicine, mine safety methodology, or artificial intelligence tools for generating educational tasks, which cannot be quickly integrated into bulky university programs. Such flexibility is critically necessary to ensure the resilience of the education system in the conditions of martial law and post-war reconstruction (Rothland, 2020: 315-330).

In addition, continuing education acquires the features of horizontal interaction, where experienced teacher practitioners act as mentors for young colleagues, creating professional network communities. This allows overcoming professional isolation, exchanging best practices in implementing integrated courses, and jointly developing methodological cases for working with students who have educational losses or psychological trauma. A science teacher in the continuing education system becomes a researcher of his own practice, constantly reflecting on the effectiveness of his methods and adapting them to the needs of a particular class, which is the highest manifestation of pedagogical skill and the key to the formation of an environmentally conscious nation.

3. Conclusions and prospects for further exploration of the direction

Summarizing the analysis of multi-level training, it can be argued that the modern paradigm of pedagogical education in Ukraine is experiencing a phase of deep systemic transformation, gradually moving away from the traditional knowledge model in favor of a dynamic competency ecosystem. Of particular importance in this process is the specificity of training a natural science teacher, who becomes a key figure in responding to global technological and environmental challenges. It is the integration of the fundamental scientific base with flexible STEM methodologies, experimental practices, and digital tools that forms a new type of natural science teacher: this is no longer just a translator of facts, but a facilitator of scientific research, a researcher and innovator, capable of transforming the educational process into an exciting knowledge of the world. The harmonization of national standards with leading European models, reinforced by the unique experience of the functioning of Ukrainian education under martial law, contributes to the crystallization of an original school of training teachers of physics, chemistry, biology, and geography. This school is based on the development of critical thinking, psychological resilience, and the ability to quickly adapt. Prospects for further scientific exploration are seen in the development of individualized training models, the implementation of transdisciplinary approaches, and the deepening of environmental competence, which is critically important for post-war environmental restoration. Such a development vector will ensure the creation of an adaptive educational environment capable of educating an intellectually mature, environmentally conscious, and resilient personality – the creator of the innovative future of Ukraine.

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