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PEDAGOGICAL AND METHODOLOGICAL CONDITIONS FOR DEVELOPING NATURAL SCIENCE LITERACY IN PHYSICS EDUCATION

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Abstract

This article examines the pedagogical and methodological conditions for developing natural science literacy in physics education within the context of modern teacher training. Natural science literacy is considered not only as the acquisition of theoretical knowledge, but also as the ability to explain physical phenomena, apply scientific concepts in real-life situations, interpret experimental data, and make evidence-based conclusions. The study emphasizes that physics education should be organized through problem-based learning, experimental activities, interdisciplinary integration, digital technologies, and competency-oriented assessment. Particular attention is given to the role of the teacher in creating a learning environment that develops students’ analytical thinking, scientific reasoning, observation skills, and practical problem-solving abilities. The article also highlights the importance of connecting physics content with everyday life, environmental processes, technological development, and social needs. It is argued that the effective development of natural science literacy requires a systematic combination of didactic principles, methodological tools, laboratory practice, and reflective learning strategies. The findings may be useful for improving physics teaching methodology in pedagogical higher education institutions and for preparing future physics teachers to organize modern, practice-oriented and scientifically grounded lessons.

Keywords: Physics education, natural science literacy, methodological conditions, pedagogical approach, scientific thinking, experimental activity, competency-based learning.

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Introduction

FIZIKA TA'LIMIDA TABIIY-ILMIY SAVODXONLIKNI RIVOJLANTIRISHNING PEDAGOGIK-METODIK SHART-SHAROITLARI

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Annotatsiya

Ushbu maqolada fizika ta'limida tabiiy-ilmiy savodxonlikni rivojlantirishning pedagogik va metodik shart-sharoitlari zamonaviy pedagog kadrlar tayyorlash jarayoni nuqtayi nazaridan tahlil qilinadi. Tabiiy-ilmiy savodxonlik faqat nazariy bilimlarni egallash emas, balki fizik hodisalarni tushuntirish, ilmiy tushunchalarni hayotiy vaziyatlarda qo'llash, tajriba natijalarini talqin qilish va dalillarga asoslangan xulosalar chiqarish qobiliyati sifatida qaraladi. Tadqiqotda fizika ta'limini muammoli ta'lim, tajriba faoliyati, fanlararo integratsiya, raqamli texnologiyalar va kompetensiyaviy baholash asosida tashkil etish zarurligi asoslanadi. O'qituvchining o'quvchilarda tahliliy tafakkur, ilmiy mushohada, kuzatuvchanlik va amaliy muammolarni hal qilish ko'nikmalarini shakllantiruvchi ta'lim muhitini yaratishdagi o'rni alohida yoritiladi. Maqolada fizika mazmunini kundalik hayot, ekologik jarayonlar, texnologik taraqqiyot va ijtimoiy ehtiyojlar bilan bog'lash muhimligi ham ta'kidlanadi. Tabiiy-ilmiy savodxonlikni samarali rivojlantirish didaktik tamoyillar, metodik vositalar, laboratoriya amaliyoti va refleksiv ta'lim strategiyalarining tizimli uyg'unligini talab etadi. Tadqiqot natijalari pedagogik oliy ta'lim muassasalarida fizika o'qitish metodikasini takomillashtirish hamda bo'lajak fizika o'qituvchilarini zamonaviy, amaliy yo'naltirilgan va ilmiy asoslangan darslarni tashkil etishga tayyorlashda muhim ahamiyatga ega.

Kalit so'zlar: fizika ta'limi, tabiiy-ilmiy savodxonlik, metodik shart-sharoitlar, pedagogik yondashuv, ilmiy tafakkur, tajriba faoliyati, kompetensiyaviy ta'lim.

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Introduction

The development of natural science literacy has become one of the central tasks of modern physics education, because contemporary society requires individuals who are able not only to memorize scientific facts, but also to understand natural phenomena, interpret evidence, and apply scientific knowledge in practical situations. In the system of pedagogical higher education, this issue has particular importance, since future physics teachers must be prepared to organize lessons that form students' scientific worldview, analytical thinking, experimental culture, and ability to make reasoned decisions based on scientific information. Physics, as a fundamental natural science, has great methodological potential for developing such qualities, because it studies the general laws of nature, explains the interaction between matter and energy, and connects abstract theoretical concepts with real technological, ecological, and everyday processes.

Natural science literacy in physics education includes several interrelated components. First, it involves understanding basic physical concepts, laws, models, and principles. Second, it requires the ability to observe physical phenomena, formulate questions, propose hypotheses, conduct experiments, analyze results, and justify scientific explanations. Third, it implies the capacity to use physics knowledge in daily life, professional activity, environmental awareness, and technological problem solving. Therefore, the teaching of physics should not be limited to the transmission of ready-made formulas and definitions. It should be directed toward the formation of students' active cognitive position, research-oriented thinking, and practical competence.

In the educational context of Uzbekistan, the modernization of science education is closely connected with improving the quality of teacher training, introducing competency-based approaches, strengthening the practical orientation of lessons, and applying digital technologies in the learning process. These priorities require a reconsideration of the pedagogical and methodological conditions under which physics education is organized. A future physics teacher should know not only the content of the subject, but also the methods of transforming this content into meaningful learning activities. This means that physics lessons must be constructed through problem situations, laboratory work, modeling, project-based tasks, interdisciplinary integration, and assessment methods that reveal not only what students know, but also how they use their knowledge.

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The relevance of the topic is also determined by the fact that many students perceive physics as a difficult and abstract subject. This difficulty often arises when theoretical material is separated from life experience, experiments are used only formally, and students are not involved in independent reasoning. In such conditions, knowledge remains fragmentary and does not turn into functional scientific literacy. For this reason, physics education needs methodological renewal based on visualization, experimentation, contextual learning, discussion, and reflection. When students understand the connection between physical laws and real phenomena such as motion, heat transfer, electricity, light, sound, environmental processes, and modern technologies, their motivation and cognitive activity increase.

Thus, the study of pedagogical and methodological conditions for developing natural science literacy in physics education is significant for improving the professional training of future teachers. It allows identifying effective teaching strategies, clarifying the role of laboratory and digital resources, and determining the didactic mechanisms that help students master physics as a practical and intellectually meaningful science.

Methods

The methodological basis of this study is formed by a pedagogical analysis of the conditions that support the development of natural science literacy in physics education. The research approach is directed toward identifying how theoretical knowledge, experimental activity, digital tools, interdisciplinary integration, and competency-based assessment can be combined in the preparation of future physics teachers. Since the topic is connected with both physics content and teaching methodology, the study relies on a qualitative pedagogical design, in which educational concepts, didactic principles, classroom practices, and methodological requirements are examined as interconnected components of one learning system.

The first methodological direction is the analysis of scientific and pedagogical literature related to physics education, natural science literacy, competency-based learning, and experimental teaching. In this process, attention is paid to the interpretation of natural science literacy as a functional ability that enables learners to explain phenomena, understand scientific evidence, apply knowledge in new contexts, and evaluate information from a scientific point of view. This

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theoretical analysis makes it possible to define the main components of literacy in physics: conceptual understanding, experimental competence, analytical reasoning, practical application, and reflective thinking.

The second direction is the study of the pedagogical conditions necessary for organizing effective physics lessons. These conditions include the creation of a problem-based learning environment, the use of practical tasks connected with real-life situations, the integration of laboratory activities, and the development of students' independent cognitive activity. In this regard, the teacher's role is considered not as the only source of information, but as the organizer of inquiry, observation, discussion, and scientific explanation. Such an approach allows students to participate actively in the learning process and to understand physics as a means of interpreting natural and technological processes.

The third direction is connected with the methodological organization of experimental work. Laboratory tasks, demonstrations, measurements, and simple research projects are viewed as important tools for developing natural science literacy. During experimental activities, students learn to observe phenomena, identify variables, compare results, explain errors, and connect empirical data with theoretical laws. In physics education, this is especially important because many concepts become clear only when learners can see, measure, model, or test them in practice. Therefore, experimental work should be systematic, purposeful, and closely related to the topic being studied.

The fourth direction involves the use of digital educational technologies. Simulations, virtual laboratories, video demonstrations, interactive models, and data processing tools can strengthen students' understanding of complex physical processes. Digital resources are especially useful when real laboratory equipment is limited or when a phenomenon is difficult to observe directly. However, digital tools should not replace real experimentation completely; rather, they should complement traditional laboratory work and support visualization, comparison, and independent analysis.

The fifth methodological direction is the use of competency-based assessment. Assessment should determine not only whether students remember definitions and formulas, but also whether they can apply them, interpret graphs, solve practical problems, explain physical situations, and justify their reasoning. For this purpose, diagnostic tasks, situational problems, project assignments, laboratory reports, oral explanations, and reflective written tasks may be used.

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This type of assessment helps future physics teachers understand the real level of students' natural science literacy and select appropriate teaching strategies for further development.

Results

The results of the pedagogical and methodological analysis show that the development of natural science literacy in physics education depends on the systematic organization of learning activities that connect scientific theory with observation, experiment, reasoning, and practical application. When physics is taught only through definitions, formulas, and mechanical problem solving, students may acquire separate pieces of knowledge, but they often experience difficulties in explaining real phenomena or using scientific concepts in unfamiliar situations. Therefore, the main result of the study is the identification of a set of educational conditions that transform physics learning from passive reception of information into active scientific cognition.

One important result is that problem-based learning creates a strong foundation for the formation of natural science literacy. When students are faced with questions related to everyday life, technological processes, environmental changes, or natural phenomena, they begin to perceive physics as a meaningful tool for understanding the world. For example, topics such as motion, pressure, heat exchange, electricity, light, and energy become more accessible when they are connected with transport, household appliances, weather processes, medical devices, construction, and modern communication technologies. In such cases, students do not simply memorize physical laws, but learn to use them for explanation, prediction, and decision-making.

Another significant result is the positive role of experimental activity. Laboratory work, demonstrations, measurements, and independent practical tasks help students understand the empirical nature of physics. Through experiments, learners develop the ability to observe accurately, compare data, recognize cause-and-effect relations, and justify conclusions. Experimental activity also forms responsibility, precision, patience, and critical attitude toward obtained results. In the preparation of future physics teachers, this aspect is especially important, because they must be able to organize laboratory work not as a formal requirement, but as a meaningful method of developing scientific thinking.

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The study also shows that interdisciplinary integration increases the effectiveness of physics education. Natural science literacy cannot be formed within the limits of one subject only, because real-life problems usually require knowledge from several fields. The connection of physics with mathematics strengthens quantitative reasoning and graph interpretation. Its connection with chemistry helps explain molecular processes, heat phenomena, and energy transformations. Its connection with biology makes it possible to understand vision, hearing, body temperature regulation, and biomechanical movement. Its connection with geography and ecology supports the analysis of climate, atmospheric pressure, renewable energy, and environmental safety. Such integration helps students develop a holistic scientific worldview.

The use of digital technologies is another effective condition. Simulations, virtual laboratories, interactive models, video analysis, and digital measuring tools make it possible to visualize complex phenomena and organize independent learning. These tools are useful for explaining processes that are too fast, too slow, too large, too small, or too dangerous to observe directly. At the same time, the results indicate that digital technologies are most effective when they are combined with real experiments, teacher explanation, discussion, and reflective tasks.

The analysis further shows that competency-based assessment has a direct influence on the quality of natural science literacy. Traditional tests that focus only on memorization do not fully reveal students' ability to think scientifically. More effective results are achieved when assessment includes practical problems, interpretation of graphs and tables, explanation of experimental results, project work, and situational tasks. Such assessment allows future physics teachers to identify not only the level of knowledge, but also the degree of students' readiness to apply physics concepts in real educational and life contexts.

Discussion

The development of natural science literacy in physics education should be understood as a complex pedagogical process that requires the purposeful unity of content, methods, learning environment, and assessment. Physics has a special place in the system of natural sciences because it explains the fundamental laws of nature and provides a scientific basis for understanding technological progress, environmental processes, energy systems, and many everyday phenomena. However, the educational potential of physics is fully realized only when the teaching process is organized not around mechanical memorization, but around meaningful scientific inquiry. For this reason, the methodological organization of physics lessons must encourage students to ask questions, observe, compare, measure, analyze, and independently justify their ideas.

One of the most important issues in this process is the transformation of abstract physical concepts into understandable and practically significant knowledge. Many students experience difficulties in physics because they perceive formulas as isolated mathematical expressions rather than as models that describe real processes. To overcome this problem, the teacher should consistently demonstrate the connection between a physical law and the phenomenon it explains. For example, Newton’s laws should be connected with motion in transport, sports, and daily activities; the laws of electricity should be connected with household devices, safety rules, and energy consumption; optics should be connected with vision, lenses, cameras, and modern information technologies. Such contextualization helps learners understand that physics is not separated from life, but is deeply integrated into human activity and social development.

The role of the teacher is especially significant in creating pedagogical conditions for scientific thinking. In traditional lessons, the teacher often presents ready-made information, while students reproduce it during assessment. This approach may provide short-term knowledge, but it does not form stable natural science literacy. A modern physics teacher should act as a facilitator of cognitive activity, guiding students toward independent reasoning and evidence-based explanation. This requires the use of problem situations, open questions, discussions, laboratory investigations, project assignments, and reflection. Through these methods, students learn to defend their ideas, compare different explanations, correct mistakes, and understand the logic of scientific knowledge.

Experimental activity also deserves special attention. In physics education, experiment is not merely an illustrative addition to theory; it is one of the main ways of forming scientific culture. When students conduct experiments, they understand that scientific knowledge is based on evidence, accuracy, verification, and interpretation. Even simple laboratory work can develop essential intellectual skills if it is organized correctly. Students should not only follow instructions, but also predict results, identify variables, explain deviations, and connect observations with theoretical laws. This approach increases responsibility and strengthens the relationship between empirical and conceptual knowledge.

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Digital technologies create additional opportunities for improving physics education, especially in pedagogical universities where future teachers must master modern teaching tools. Virtual laboratories, simulations, multimedia demonstrations, and digital sensors help visualize invisible or complex processes and support differentiated learning. At the same time, the use of digital resources should be pedagogically justified. Technology itself does not guarantee scientific literacy; it becomes effective only when it supports inquiry, analysis, comparison, and independent interpretation.

Thus, the discussion of pedagogical and methodological conditions shows that natural science literacy in physics education is formed through active, practice-oriented, interdisciplinary, and reflective learning. The future physics teacher must be prepared to combine scientific accuracy with methodological flexibility, because only such an approach can develop students' ability to understand nature, apply knowledge, and think scientifically.

Conclusion

The development of natural science literacy in physics education is one of the essential directions for improving the quality of modern pedagogical training. Physics is not only a subject that explains the laws of motion, energy, matter, electricity, heat, light, and other natural phenomena, but also a methodological basis for forming scientific thinking, analytical reasoning, evidence-based decision-making, and practical problem-solving skills. Therefore, the teaching of physics in pedagogical higher education should be organized in such a way that future teachers learn to transform theoretical knowledge into meaningful educational activity. This requires a purposeful combination of pedagogical conditions, methodological tools, experimental practice, interdisciplinary links, digital resources, and competency-based assessment.

The analysis shows that natural science literacy cannot be developed effectively through traditional explanation and reproduction of information alone. Students need to participate actively in the learning process, observe phenomena, ask questions, formulate assumptions, conduct experiments, interpret data, compare results, and justify conclusions. In this regard, problem-based learning, contextual tasks, laboratory work, project activity, and reflective discussion play an important role. These methods help students understand physics as a living

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science that is closely connected with everyday life, technology, environmental processes, health, production, and social development.

A key pedagogical condition is the creation of a learning environment that encourages independent thinking and scientific inquiry. In such an environment, the teacher does not simply transmit information, but organizes cognitive activity, directs students toward evidence-based explanation, and supports their ability to connect theoretical concepts with practical situations. This is especially important for future physics teachers, because their professional competence depends not only on subject knowledge, but also on their ability to select appropriate teaching methods, design experiments, use digital tools, assess learning outcomes, and motivate students to study natural sciences.

Experimental activity remains one of the strongest methodological means for developing natural science literacy. Laboratory work, demonstrations, measurements, and research-oriented assignments allow learners to understand the empirical nature of physics and the logic of scientific knowledge. At the same time, digital technologies expand the possibilities of physics education by making complex, invisible, dangerous, or large-scale phenomena more accessible for observation and analysis. However, digital resources should be used not as a replacement for real experimentation, but as a complementary tool that strengthens visualization, modeling, comparison, and independent learning.

Interdisciplinary integration also has great importance. The connection of physics with mathematics, chemistry, biology, geography, ecology, engineering, and information technologies helps students develop a holistic understanding of natural processes. Such integration prepares learners to solve real problems that cannot be explained within the framework of one subject only. It also increases motivation, because students begin to see the practical value of physics in different areas of life and professional activity.

Thus, the effective development of natural science literacy in physics education requires a systematic, practice-oriented, and competency-based approach. For pedagogical universities, this means preparing future physics teachers who are able to organize lessons based on inquiry, experiment, digital modeling, interdisciplinary thinking, and reflective assessment. Such preparation contributes to the formation of scientifically literate learners who can understand natural phenomena, use knowledge in real situations, evaluate information critically, and participate responsibly in the technological and social development of society.

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