

Modernization Of The Methodology Of Teaching The Section "Molecular Physics And Thermodynamics" Of The Physics Course

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Abstract: This article examines the modernization of teaching methods for the "Molecular Physics and Thermodynamics" section of the physics course at academic lyceums. The relevance of the study stems from the need to update the content and methods of teaching physics in the context of the transition to a competency-based education model and a stronger practice-oriented focus of the educational process. It is noted that traditional approaches to teaching this section are often focused primarily on the formal assimilation of theoretical material and do not sufficiently contribute to the development of a holistic understanding of physical processes occurring in the microworld and thermodynamic systems in students. The paper substantiates the feasibility of implementing modern pedagogical approaches, including active and research-based learning methods, the use of visual modeling, digital educational resources, and interdisciplinary connections. The paper presents the main areas of modernization of teaching methods aimed at increasing students' cognitive activity, developing their analytical thinking, and fostering sustainable subject and meta-subject competencies. It was concluded that the updated methodology contributes to improved learning and the development of a scientific worldview among students at academic lyceums.

Keywords: Physics, academic lyceum, molecular physics, thermodynamics, teaching methods, education modernization, competency-based approach, active learning methods.

Introduction: Modern developments in science and technology place increased demands on the level of training of academic lyceum graduates, particularly in the natural sciences. Physics, as a fundamental science, plays a key role in shaping students' scientific thinking and serves as the foundation for mastering technical and engineering fields of study. Therefore, improving the teaching methods of individual sections of the school physics curriculum, including "Molecular Physics and Thermodynamics," is particularly important. The "Molecular Physics and Thermodynamics" section is characterized by a high degree of abstraction, relying on probabilistic concepts and complex physical models [1]. Experience shows that students experience difficulty mastering microscopic concepts such as the chaotic motion of molecules, internal energy, entropy, and thermodynamic processes. This is largely due to

the prevalence of traditional reproductive teaching methods and the insufficient use of experimental and modeling approaches.

With the modernization of the education system and the transition to a competency-based paradigm, the need to update the teaching methods of this section is increasing. Modern pedagogical approaches involve students actively in the learning process, developing their skills in analyzing physical phenomena, applying knowledge in practice, and establishing interdisciplinary connections. Therefore, a pressing task is the development and substantiation of areas for modernizing the teaching methods of molecular physics and thermodynamics in academic lyceums [2].

METHODS

Molecular physics, as a section of the physics curriculum, examines the physical properties of

substances related to their microscopic structure, the nature of interactions between elementary particles—molecules, atoms, and ions—as well as the characteristics of their thermal motion. This section analyzes both the mechanical and thermal characteristics of bodies, determined by the structure of matter and particle dynamics. A significant place in molecular physics is occupied by the study of the aggregate states of matter and phase transition processes, including melting and crystallization, evaporation, and condensation. Furthermore, physical phenomena arising at the interfaces between media in different phase states are considered. Thus, the content of this section encompasses the study of the properties of gases, liquids, and solids, as well as the patterns of their mutual transformations and interphase processes [3; 4].

Molecular physics is organically linked to thermodynamics and statistical physics, as the development of these fields occurred through the solution of common fundamental problems. The development of the molecular-kinetic theory of heat served as the foundation for the development of statistical physics, the primary goal of which is to study the behavior of macroscopic systems consisting of a large number of interacting particles whose properties are assumed to be known. Over the course of the development of physics, two complementary approaches to studying the properties of physical systems have emerged.

The first, the phenomenological approach, is based on the description of observable macroscopic characteristics without reference to the internal structure of matter.

The second, the statistical approach, relies on the analysis of the microscopic structure of bodies and the mechanisms of the processes occurring within them.

The kinetic theory of heat occupies a central place in the structure of statistical physics and serves as its theoretical foundation. In the educational process, it is advisable to rely on both the phenomenological and statistical approaches to the study of physical phenomena, as their combination allows students to develop a holistic understanding of the nature of physical processes. Students can be introduced to these methods using examples of the simplest

phenomena and processes covered by the school physics curriculum [5; 6; 8].

Elements of statistical thinking can be consistently developed in deriving the fundamental equation of the kinetic theory of gases, as well as in examining issues related to the chaotic motion of molecules, Brownian motion, and fluctuations of physical quantities such as the density of matter and pressure. This is not a matter of expanding the course content by introducing new topics, but rather of raising the scientific level of interpretation of traditional educational material. The transition from the study of mechanics to molecular physics represents an important stage in students' cognitive development and plays a significant role in shaping their scientific worldview. Even at the initial stage of studying molecular physics, it is necessary to demonstrate the explanatory potential of physics as a science capable of investigating phenomena inaccessible to direct observation. It should be emphasized that, without being able to see molecules, physics was able to determine their parameters and establish a connection between the microscopic characteristics of particles and the macroscopic properties of matter, which subsequently made it possible to create materials with predetermined properties [7; 9; 10]. In studying molecular physics, students are introduced to a new form of matter motion—thermal motion—that introduces the physical quantity temperature, absent from classical mechanics. The unique nature of thermal phenomena, compared to mechanical processes, stems from the discrete structure of matter and the existence of a vast number of interacting particles that make up a physical system. Molecular physics examines the properties of substances whose mass can vary widely—from fractions of a gram-mole to significant quantities containing approximately 10^{20} particles or more. The continuous relative motion of molecules and the complex nature of their interactions give rise to fundamentally new patterns, distinct from those studied in mechanics.

RESULTS

During the study, a modernized teaching methodology for the "Molecular Physics and Thermodynamics" section of the physics course at academic lyceums was developed and tested [11]. This methodology combines phenomenological and statistical approaches to

studying thermal phenomena. Implementation of this methodology allowed students to gain a deeper understanding of the relationship between the microscopic structure of matter and its macroscopic properties.

Table-1
Methodology of teaching

Methodology stage	The goal of the stage	Content of the activity	Teaching methods and techniques	Expected results
Introductory and orientational	Formation of motivation and cognitive interest; preparation for the perception of thermal phenomena	Transition from mechanics to molecular physics; discussion of the microscopic structure of matter; introduction of the concept of thermal motion	Problem-solving presentation, heuristic discussion, demonstration experiments, visual models	To enhance students' understanding of the specifics of thermal phenomena; to develop interest in the section being studied
Content-activity-based	Formation of concepts and ideas of molecular kinetic theory and thermodynamics	Study of the properties of gases, liquids, and solids; derivation of the fundamental equation of the kinetic theory of gases; analysis of Brownian motion and fluctuations	Partial search method, solving qualitative and computational problems, modeling, educational research	Deep understanding of the relationship between microscopic and macroscopic characteristics of matter; development of analytical thinking
Practice-oriented (as part of the main stage)	Consolidation and application of knowledge	Solving applied problems; analysis of real physical situations; interdisciplinary connections (physics–chemistry–mathematics)	Practical assignments, mini-projects, group work	Ability to apply knowledge in non-standard situations; development of argumentation skills
Generalizing-reflexive	Systematization and comprehension of the studied material	Comparison of mechanical and thermal forms of motion; generalization of concepts; discussion of practical significance	Summary discussion, reflection, complex tasks	Formation of a holistic physical worldview; conscious assimilation of the material

The study utilized a combination of complementary methods to ensure the scientific validity and reliability of the results. The choice of research methods was

determined by the purpose and objectives of the study, as well as the specific content of the "Molecular Physics and Thermodynamics" section of the physics course

offered at academic lyceums.

Theoretical research methods included the analysis and synthesis of scientific, methodological, psychological, pedagogical, and educational literature on physics teaching, the study of current curricula and textbooks for academic lyceums, and the modeling of the content and structure of the educational material, taking into account modern requirements for science education. The theoretical analysis allowed us to identify the didactic potential of molecular physics and thermodynamics for shaping students' scientific worldviews and identify areas for modernizing their teaching methods [12-14].

Empirical research methods included pedagogical observation of students' learning activities, questionnaires and discussions with teachers and students, analysis of test and independent assignment results, and the study of students' learning outcomes. These methods were used to identify common difficulties in studying thermal phenomena and evaluate the effectiveness of the implemented teaching methods.

The pedagogical experiment was conducted in a real-life academic setting at academic lyceums and included ascertaining, formative, and control stages. During the formative stage, the developed teaching method for the section "Molecular Physics and Thermodynamics" was introduced. It was based on a combination of phenomenological and statistical approaches. The effectiveness of the method was assessed by comparing the learning outcomes of students in the experimental and control groups.

Data processing and analysis methods included qualitative and quantitative analysis of learning outcomes, a comparison of academic achievement trends, and elements of mathematical statistics used to substantiate the validity of the findings. The use of these combined methods ensured the comprehensive nature of the study and allowed for the collection of objective data on the effectiveness of the modernized teaching method for molecular physics and thermodynamics at academic lyceums. The developed teaching methodology for the "Molecular Physics and Thermodynamics" section was implemented into the educational process at academic lyceums during the formative stage of a pedagogical experiment. The main

goal of the experimental work was to test the effectiveness of the proposed methodological approaches and their impact on student learning.

The introductory and orientation phase of the methodology contributed to the development of students' sustained learning motivation and a conscious attitude toward the study of thermal phenomena. The transition from mechanics to molecular physics, accompanied by problem-based presentation and visual modeling, reduced the level of formal perception of new material and prepared students for the assimilation of abstract concepts at the microscopic level.

The content-based and activity-based phase of the methodology had the greatest impact on learning outcomes. The combination of phenomenological and statistical approaches in studying the fundamental principles of molecular kinetic theory and thermodynamics provided a deeper understanding of the relationship between the microscopic motion of particles and the macroscopic properties of matter. Students in the experimental groups demonstrated a higher level of meaningful application of physical concepts and laws compared to students in the control groups. Practice-oriented assignments and elements of educational research contributed to the development of analytical skills, reasoning skills, and independent solution-seeking abilities. An analysis of tests and independent assignments revealed a reduction in the number of typical errors associated with rote memorization of formulas and an increase in the proportion of detailed explanations of physical processes. The generalizing and reflective stage of the methodology allowed students to systematize their acquired knowledge and develop a holistic understanding of the thermal form of matter motion. The final results of the experiment confirmed the positive impact of the modernized methodology on the level of assimilation of the "Molecular Physics and Thermodynamics" section and the development of students' scientific worldview.

An analysis of the learning outcomes revealed an increased level of conscious understanding of key molecular physics concepts, such as thermal motion, internal energy, temperature, and pressure. Students demonstrated more robust skills in interpreting physical processes from a molecular-kinetic

perspective, as well as the ability to apply this knowledge to solving qualitative and computational problems. The introduction of statistical thinking elements into the study of the fundamental equation of the kinetic theory of gases, Brownian motion, and fluctuations of physical quantities contributed to the development of analytical thinking and the formation of students' understanding of the probabilistic nature of thermal processes. Increased student interest in studying physics was noted through the use of visual modeling, problem-solving situations, and interdisciplinary connections.

The results of pedagogical observations and analysis of assessments indicate a decrease in the number of typical errors associated with the formal memorization of definitions and formulas, and an increase in the proportion of meaningful explanations of physical phenomena. Students became more confident in using physics terminology and arguing their reasoning based on the laws of molecular physics and thermodynamics. Thus, the study confirmed the effectiveness of the modernized teaching methodology aimed at enhancing the scientific level of presentation of educational material and developing a holistic physics worldview in students at academic lyceums. The results obtained allow us to recommend the proposed methodology for implementation in educational practice when studying the relevant section of the physics course.

CONCLUSION

The analysis showed that modernizing the teaching methods for the "Molecular Physics and Thermodynamics" section of the physics course at academic lyceums is essential for improving the quality of natural science education. Updating the teaching tools helps overcome the formal nature of knowledge acquisition and fosters students' holistic understanding of the physical processes occurring in the microcosm and macroscopic systems.

The use of active, problem-based, and research-based teaching methods, as well as elements of digital modeling and visualization, enhances students' cognitive activity and promotes the development of their analytical and critical thinking. The modernized teaching methods provide a deeper understanding of fundamental physical laws and their practical significance.

Thus, the implementation of the proposed approaches to modernizing the teaching methods of molecular physics and thermodynamics creates the conditions for improving the effectiveness of the educational process at academic lyceums and meets the modern requirements of the education system's development.

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