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Methodology of Teaching Lectures on Molecular Physics

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Abstract: This article analyzes the modern methodological foundations of organizing lectures on molecular physics. The role of innovative approaches, interactive methods, and information and communication technologies in the educational process is highlighted. Also, foreign experience and scientific and methodological recommendations for harmonizing the practice of teaching physics in the higher education system of Uzbekistan are presented. The study developed a model for the effective organization of molecular physics lessons based on methodological, systemic, and didactic approaches.

Keywords: Molecular physics, teaching methodology, interactive method, simulation, digital education, lecture, innovative technologies, STEM education, experiment, methodology.

The issue of increasing the effectiveness of teaching physics in the modern education system is recognized not only as a factor determining the quality indicators of the educational process, but also as a criterion expressing the level of innovative development of the educational process. Physics is the central link in the system of natural sciences, and the level of its teaching directly affects the assimilation of other subjects. Therefore, each section, in particular the course of molecular physics, plays an important role in the formation of students' scientific worldview, logical thinking, and research competencies.

The object of study of molecular physics is the molecular structure of matter, the laws of particle motion and interaction between them. This field embodies the most important laws of the material world and reveals the microscopic essence of energy, heat, pressure, diffusion, and other processes. Therefore, the methodologically correct organization of lectures on molecular physics guides students towards a deep understanding of theoretical concepts, connecting them with practical phenomena, and mastering methods of scientific thinking.

Today, the process of teaching physics is moving away from its traditional form and developing on the basis of innovative and interactive educational technologies. When conducting lectures, the teacher's task is not only to convey information, but also to involve students in the active thinking process, encouraging them to search, analyze, and make independent decisions. From this point of view, the introduction of such methods as problem-based learning, project-based approach, modeling, and simulation technologies in the molecular physics course significantly increases the effectiveness of the educational process.

The main goal of teaching molecular physics is to scientifically explain to students the internal structure of matter, the mechanisms of interaction between atoms and molecules, and the processes of energy

exchange. This serves to form not only their physical knowledge, but also the skills of understanding, observing, analyzing, and drawing conclusions about the essence of natural phenomena at the micro level. Once a student begins to understand molecular processes, they will learn to identify the scientific reasons behind everyday phenomena such as temperature, pressure, or energy exchange. Through this, thinking oriented towards scientific research activity is formed in it.

Also, the teaching of molecular physics is inextricably linked with other disciplines - chemistry, biology, ecology, materials science, and develops interdisciplinary thinking in students. Such an approach is in harmony with the concept of STEM (Science, Technology, Engineering, Mathematics), which is widely used in today's educational paradigm, and ensures the practical orientation of the educational process.

In recent years, the methodology of teaching physics in the world has been developing rapidly. This development is primarily associated with the introduction of digital technologies, simulation models, and interactive teaching methods into the educational process. Instead of traditional lecture forms, a student-centered learning approach is increasingly being used. In this case, the teacher acts not as a source of knowledge, but as a manager and guide of the educational process.

For example, M.P. Allen (2007) in his scientific article "Educational aspects of molecular simulation" analyzed in detail the role and advantages of molecular simulations in education. According to the author, by modeling processes at the molecular level in a virtual environment, it is possible to visually demonstrate complex physical phenomena to students, which will help them gain a deeper understanding of the topic [1]. Also, with the help of such technologies, students develop the ability to perceive abstract concepts in a concrete form, logical analysis, and reasoning based on experience.

In his research, M.P. Allen substantiated the principle of "visual understanding" by integrating molecular simulations into the learning process. According to this principle, the student perceives the phenomenon not only on the basis of textual or verbal explanations, but also through real dynamic models. As a result, the level of mastery of topics such as molecular motion, heat exchange, and the kinetic model of gases increases.

At the same time, in a study by B. Orazov and co-authors (2025) published in the journal Journal Pendidikan IPA Indonesia, the issue of improving the methodological system for teaching molecular physics was highlighted [2]. The model developed by the authors is aimed at developing students' professional competencies, stimulating independent learning, and connecting knowledge with practice in an interactive environment. The study revealed that the use of virtual laboratories, computer simulations, and blended learning methods in the educational process increased the effectiveness of teaching by 28-35%.

In particular, in the methodological system developed by Orazov and his team, three stages of the teacher's activity are distinguished:

Theoretical explanation stage - in which lectures are conducted using modern visualization tools;

Virtual experimental stage - students observe molecular processes through simulation programs and analyze the results;

Reflection and analysis stage - students evaluate their activities, identify mistakes, and draw conclusions.

The research results show that the introduction of digital technologies in teaching students molecular physics increases their motivation, strengthens interdisciplinary integration, and creates the opportunity to transform theoretical knowledge into practical skills. Therefore, in many educational institutions around the world (for example, MIT, ETH Zurich, and Cambridge Universities), molecular physics courses are taught using virtual laboratories and interactive platforms based on simulation [3], [4].

In general, foreign experience shows that for effective teaching of molecular physics, it is necessary to

combine the technological approach with the methodological system. The teacher becomes not only a subject who explains the laws of physics, but also a subject who creates the environment of the educational process. In this way, lectures are moving away from passive listening to active learning and analysis. [2].

Methodological foundations of teaching molecular physics

For the effective organization of lectures on molecular physics, the correct choice of methodological, didactic, and technological foundations of teaching is of great importance. A methodological approach is understood as a systematic combination of content, forms, and means used by the teacher in the lesson process. The peculiarity of molecular physics is that theoretical concepts, mathematical models, and experimental proofs are inextricably linked. Therefore, teaching methods in this area should be aimed at activating students' thinking, developing observation, analysis, and modeling skills.

1. Didactic foundations

The following play an important role as the main didactic principles in teaching molecular physics:

The principle of scientificity - all concepts, laws, and formulas should be explained on a scientific basis, using specific examples. For example, demonstrating the concepts of the kinetic theory of gases or thermal motion based on real experience and simulation.

The principle of visualization - since phenomena at the molecular level are processes that cannot be directly observed, it is effective to use virtual models, animations, and 3D simulations to describe them.

The principle of activity and independence - the student should become an active participant, not a passive participant in the learning process. For this purpose, it is necessary to use interactive methods such as "problem-based learning," "question-answer," "small project."

The unity of theory and practice - it is necessary to reinforce theoretical concepts not only through mathematical formulas, but also through their application in experiments, laboratory classes, and computer models.

Lectures organized based on these principles teach students to deeply analyze physical phenomena and connect them with real processes in nature.

2. Interactive methods

One of the most effective approaches to teaching molecular physics is the use of interactive methods. Interactive methods contribute to the active participation of students in the learning process, the exchange of ideas, discussion, analysis, and the development of a creative approach. Here are some methods that can be used in lectures on molecular physics:

Problem-based learning method. Before explaining a physical phenomenon during a lecture, the teacher poses a problem to the students. For example, the question "Why does gas pressure increase when the temperature increases?" awakens in students the motivation for scientific research.

Project-Based Learning. Students are divided into small groups and prepare a project on a specific topic (for example, "Modeling the Brown Movement"). As a result, they acquire skills in searching, analyzing, and presenting scientific information.

Simulation-based learning. This method allows for the observation of molecular processes through interactive programs (PhET, SimPHY, Virtual Lab). The student visually analyzes microscopic phenomena that cannot be observed in real laboratory conditions.

"Mind Mapping" method. Students describe a specific physical process in a schematic form and determine the relationship between phenomena. This approach increases the systematicity of concepts.

When using these methods, lectures transition from a monologue to a dialogic and interactive format. The student, together with the teacher, becomes an active subject in the process of creating knowledge.

3. Technological approach

Digital technologies are becoming an integral part of molecular physics education. With the help of computer technologies, mobile applications, and distance learning platforms (Moodle, Coursera, Edmodo), it is possible to individualize the educational process and create the possibility of learning at the student's own pace. For example, through the PhET Interactive Simulations platform created by the University of Colorado, processes such as the kinetic theory of gases, energy exchange, and heat capacity are demonstrated in the form of dynamic models. This process forms the sequence "seeing - understanding - analyzing" in the student.

Also, the Blended Learning model - that is, the combination of the traditional lesson form with online platforms - has become widespread in teaching molecular physics in recent years. Students independently review the video lessons, and at the next stage, they discuss their questions during the lecture. This approach activates student activity and makes the lesson more effective at the individual level.

4. Pedagogical model

For the systematic organization of the educational process, it is necessary to develop a methodological model. The following three-step model has been found to be effective in teaching molecular physics:

Preparatory stage: the relevance, purpose, and objectives of the topic are explained, and problematic questions are posed.

Interactive learning stage: simulations, virtual laboratory experiments, video materials are used during the lecture.

Analysis and evaluation stage: student activity is assessed through reflection, conclusions are summarized, and practical examples are analyzed.

Such an approach increases the learning motivation of students, teaches them to independently search, conduct research, and justify their opinion.

5. Possibilities of application in the education system of Uzbekistan

In recent years, digital laboratories, electronic textbooks, and distance learning systems have been introduced in higher educational institutions of Uzbekistan. This process marked the beginning of a new stage in the teaching of molecular physics. In particular, through such initiatives as "Electronic Physics Laboratory," "Simulation Training Module," lectures are acquiring a practical character. At the same time, it is necessary to develop methodological manuals for subject teachers at each university, organize courses to improve the qualifications of teachers and apply foreign experience.

RESEARCH RESULTS AND PRACTICAL RECOMMENDATIONS

1. Purpose and methodology of the research

The main goal of the research is to determine the effectiveness of interactive methods and digital technologies in teaching molecular physics, to assess their influence on the educational process. For this purpose, experimental training was carried out in several higher educational institutions (Tashkent State Pedagogical University, Fergana State University, and Karshi State University) during the 2024-2025 academic year.

The study was conducted in the following stages:

Diagnostic stage - the level of students' knowledge and attitude towards the lesson process are determined;

Experimental stage - lectures on molecular physics are organized based on a new methodology;

The control stage analyzes the indicators of students' mastery, the level of independent thinking, and practical skills.

The research used methods of sociological questionnaires, pedagogical observation, test analysis, and comparison. 120 students participated in the experimental group, and 110 students in the control group.

2. Analysis of the results

According to the results of the conducted experiment, the use of interactive methods (simulation, project-based learning, problem-based approach) in teaching molecular physics gave the following positive results:

The level of students' knowledge acquisition increased by 22%;

Independent thinking and problem situation analysis skills improved by 27%;

The level of preparation for practical activities (analysis of experience, modeling) increased by 19%;

Motivation and active participation in the lesson increased significantly.

In addition, in classes using digital simulations (for example, PhET Interactive Simulations), the level of students' visual perception of such concepts as "molecular motion," "gas pressure," "energy exchange" was higher than in traditional training groups.

These results are consistent with the research conducted by M.P. Allen (2007) and E. Winkelmann (2019). They emphasized that teaching molecular physics through visual modeling allows students to visualize abstract concepts in a clear form [1,2].

3. Analysis and discussion

The obtained results show that three components of the teacher's activity are important for the effective organization of lectures on molecular physics:

Methodological training - the teacher must have a deep knowledge of new technologies, virtual laboratories, and interactive methods;

Motivational component - the teacher should awaken in the student an interest in scientific research, analysis, and experimentation;

Reflexive component - analysis of the educational process, assessment of one's own activity and continuous improvement.

In foreign experience, in particular, in the educational systems of Finland, South Korea, and Canada, the concept of "research-based learning" is widely used in teaching physics. This approach develops in students not only ready-made knowledge in class, but also the skills of searching for it, proving it through experience, and drawing scientific conclusions.

In adapting this model for the education system of Uzbekistan, it is important to improve the methodological qualifications of teachers and introduce virtual laboratories. In this way, it is possible to strengthen the organic connection between theory and practice in the lesson process.

4. Practical recommendations

Based on the research results, the following recommendations can be made:

Implementation of "Virtual Physics Laboratory" modules for conducting lectures on molecular physics in an interactive form in higher educational institutions;

Organization of methodological trainings and seminars for each physics teacher, in which modern teaching technologies are taught;

Integration of free educational programs, such as PhET, SimPHY, Molecular Workbench, into the educational process of state universities;

Implementation of mini-projects on online educational platforms in order to strengthen students' independent work;

Organization of lectures based on a problematic approach, that is, the development of a system of problematic questions on each topic;

Creation of an electronic test database and virtual laboratory tasks in molecular physics.

As a result of the implementation of these recommendations, in the process of teaching molecular physics, students:

firmly acquires theoretical knowledge;

acquire practical skills;

develops the ability to conduct scientific analysis, modeling, and experimentation.

5. Conclusion

The above analysis shows that increasing the effectiveness of teaching molecular physics depends not only on the teacher's skill, but also on the methodological and technological support of the educational process. Interactive methods, digital simulations, and project-based approaches increase students' cognitive activity, form physical thinking, and broaden their scientific worldview.

Therefore, the introduction of pedagogical innovations, strengthening methodological training, and digitalization of education in the teaching of molecular physics in the higher education system of Uzbekistan should be a priority.

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