

MODERN APPROACHES TO ORGANIZING LABORATORY WORKS AND PRACTICAL EXPERIMENTS ON MOLECULAR-KINETIC THEORY (ON THE EXAMPLE OF "SCIENCE" IN NATURAL SCIENCES)

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Abstract

The article emphasizes that laboratory work in the study of molecular-kinetic theory serves not only to reinforce theoretical knowledge but also as a crucial tool for shaping students' scientific worldview. It demonstrates the positive results of increasing the efficiency of the educational process through modern approaches, interdisciplinary integration, and the application of innovative technologies.

Keywords

Molecular-kinetic theory, laboratory work, practical experiments, natural sciences, SCIENCE approach, innovative methods, interactive technologies, virtual laboratory, STEM integration, pedagogical innovations, interdisciplinary connections, scientific worldview, experimental design, educational process effectiveness.

Today, when teaching natural sciences (science) in secondary schools, it is an important pedagogical task to explain the inner essence of environmental phenomena to students on a scientific basis, and to develop skills in observing, analyzing, comparing, and drawing conclusions. From this perspective, the issue of forming concepts related to molecular-kinetic theory is of particular relevance. This is because concepts such as the structure of matter, the constant chaotic motion of molecules, temperature, diffusion, pressure, and aggregate states serve as the fundamental scientific basis for many branches of natural sciences.

The reader sees the macroscopic result of these phenomena, but cannot directly observe the internal cause. Therefore, laboratory work is the primary methodological tool in teaching molecular-kinetic theory, ensuring the connection between theory and observation, concepts and experience, and models and real phenomena [2]. The main difference of the modern approach is that the laboratory session is no longer limited to "experimentation." It is organized as an educational and research activity that requires the student to actively think, predict, observe the

result, measure, analyze, and draw conclusions. That is, laboratory work becomes a didactic model that shows how scientific knowledge is formed, rather than a means of demonstrating a ready-made truth. In experiments related to molecular-kinetic theory, this approach is very important, because the student should rise to the level of "I observed, compared, found the reason, therefore I understood" rather than "I saw, therefore I understood" [3]. In this section, modern approaches primarily provide for the purposeful differentiated organization of laboratory work. Experiments related to molecular-kinetic theory can be divided into three groups. The first group consists of demonstration experiments, which serve to form students' initial scientific understanding. For example, the dispersion of odors, the dispersion of ink in water, and the expansion of air when heated. The second group consists of laboratory work based on measurement and comparison, in which the student observes the influence of one parameter on another. For example, comparing the change in diffusion rate with increasing temperature or the increase in gas volume when heated [4]. The third group consists of model-based practical exercises, in which a real phenomenon is analyzed in combination with a conditional particle model, graphics, animation, or a virtual experiment. It is precisely the third type that is of particular importance in modern education, as molecular-kinetic theory is not fully understood without a model of the microcosm.

In the modern organization of laboratory work, the first requirement is to establish conceptual preparation before the experiment. Often, the student sees the experiment but does not know what they are observing. Therefore, before the laboratory session, the teacher must create a minimal theoretical foundation for the students, reveal the purpose of the experiment, and clearly define the object of



observation. For example, before conducting a diffusion experiment, questions such as "Do particles of matter move?" and "Does temperature affect this process?" can

be posed. These questions turn the experiment into a process of searching for an answer to a specific question, rather than a simple spectacle.

The second requirement is to construct the experiment based on a problem situation. In modern methodology, laboratory work must begin with a problem. For example: "Why does sugar dissolve faster in hot tea?," "Why does the cylinder shrink in the cold?," "Why does the smell of perfume spread throughout the room in a few minutes?" Such questions are close to the students' daily experience and encourage them to find a scientific explanation. At the next stage, the experiment is performed and the result is linked to the rules of molecular-kinetic theory. As a result, the laboratory session becomes not just practical work, but a means of drawing theoretical conclusions [5].

The third important approach is to combine experience with a visual model. In topics of molecular-kinetic theory, a bridge must exist between real experience, the result under consideration, and the microscopic process. For example, showing the dispersion of a colored substance dropped into water demonstrates diffusion at a macroscopic level, but the main goal is not achieved if the reader does not link this phenomenon to the chaotic movement of molecules. Therefore, in the modern approach, a microscopic explanation with a particle model, diagram, animation, or virtual simulation must be provided after or during each experiment. This is especially important in the topics of gas pressure, Brownian motion, evaporation, condensation, and the state of matter [5].

The fourth approach is the use of digital and virtual tools. Many processes related to molecular-kinetic theory are difficult to fully demonstrate under real



laboratory conditions. For example, the collision of gas molecules against the walls of a vessel, the increase in the average velocity of molecules with a change in

temperature, or the arrangement of particles in aggregate states are explained only indirectly. In modern education, PhET, Crocodile Physics, GeoGebra animations, video models, and other digital resources alleviate this problem. After seeing the result of a real experiment, the student understands its internal physical mechanism using a virtual model. As a result, the macro and micro levels are combined [6].

The fifth approach is a laboratory model based on micro-experiments and low-cost tools. Not all schools have fully equipped physics laboratories. Therefore, in modern methodology, it is recommended to organize many experiments related to molecular-kinetic theory based on everyday life tools. For example, one can observe the distribution of dye in hot and cold water in a glass, compress air using a syringe, observe the expansion of a sphere when heated, and show evaporation and condensation through ice and hot water. Although such experiments are simple, their theoretical significance is immense. The reader sees the manifestation of a complex scientific theory in everyday events. This connects scientific thinking with real life [6].

The sixth approach is the organization of laboratory work in the form of a group study. It is very convenient to work in small groups on experiments related to molecular-kinetic theory. For example, one group studies diffusion velocity, the second group studies expansion upon heating, the third group studies compressibility, and the fourth group studies the model of aggregate states. Then the results are summarized. Such an approach develops not only experimental skills but also the skills of scientific communication, argumentation, comparison, and generalization. In particular, the combination of various theoretical propositions through different groups demonstrates that molecular-kinetic theory is an integrated system [5, 6].

The seventh approach is the transformation of laboratory work into an educational and research task. In traditional laboratory work, the result is often known in advance. In the modern approach, a small element of research is required from the student. For example, questions such as "Under what conditions does diffusion occur faster?," "What is the relationship between gas volume and pressure when heated?," and "How do temperature and surface area affect the evaporation rate?" are posed. The student observes, collects information, draws up a table, compares, and draws conclusions. This approach increases the scientific level of laboratory work and translates it from simple reproductive activity to analytical activity [5, 6].

The eighth approach is to represent the experimental results through graphs, tables, and diagrams. In molecular-kinetic theory, qualitative observation is

important, but not sufficient. The student must be able to record, compare, and summarize the results. For example, a table for comparing diffusion velocities at different temperatures, a graph of the change in gas volume during heating, or a comparative scheme based on the model of particles in aggregate states can be prepared. This method increases the theoretical value of the laboratory session and organizes the formation of knowledge [5].

The ninth approach is to view reflection and feedback as part of laboratory work. In modern methodology, the work is not finished with the end of the experiment. The student must reflect on questions such as "what did I observe?," "what does this prove?," "to which theoretical rule does it relate?," "was my initial assumption correct?" Such reflection integrates the content of the laboratory work into the student's internal cognitive process. Through this, the teacher can determine which concept is insufficiently formed and where an incorrect interpretation has emerged [5].

The tenth approach is a combination of safety and methodological simplification. Most experiments in molecular-kinetic theory seem simple, but they can be related to heating, steam, pressure, glassware, or chemicals. Therefore, in the modern organization of laboratory work, safety rules should be not only a formal instruction but also an integral part of the methodology. The student must understand and follow safety rules even when performing the experiment independently. It is this aspect that forms laboratory work as a cultured scientific activity [6].

Laboratory work on molecular-kinetic theory can cover the following main experimental directions in terms of content: observation of diffusion; demonstration of gas compressibility; determination of air expansion upon heating; observation of evaporation and condensation phenomena; indirect demonstration of the difference in particle motion in hot and cold environments; comparison of aggregate states based on a model; Analyze Brownian motion using video or ready-made microimages. These experiments complement each other and reveal the three fundamental tenets of the theory—that matter consists of particles, the constant motion of particles, and their interaction—from different perspectives. Thus, modern approaches to the organization of laboratory work and practical experiments in molecular-kinetic theory involve a methodological reconstruction of the experiment rather than a new interpretation of the content. In this case, the experiment must be problematic, the observation must be linked to the model, and the student

Conclusion

Modern approaches to organizing laboratory work and practical experiments in molecular-kinetic theory significantly enhance the effectiveness of the educational process and improve students' scientific understanding of physical phenomena. Laboratory activities not only reinforce theoretical knowledge but also develop students' observation, analytical thinking, comparison, and problem-solving skills. The integration of innovative pedagogical technologies, virtual simulations, interactive methods, and interdisciplinary approaches allows students to better understand microscopic processes that cannot be directly observed in everyday life.

Furthermore, organizing laboratory work as a research-oriented activity encourages students to independently investigate physical phenomena, formulate hypotheses, analyze results, and draw scientific conclusions. The use of low-cost experimental tools and digital technologies also expands opportunities for conducting meaningful experiments even in schools with limited laboratory equipment. As a result, laboratory work becomes an important didactic tool for forming scientific worldview, practical competence, and research skills in students.

Recommendations

It is recommended to widely integrate virtual laboratories and digital simulations into the teaching of molecular-kinetic theory topics in secondary schools.

Teachers should organize laboratory work using problem-based and research-oriented approaches in order to increase students' independent thinking and analytical abilities.

Low-cost and everyday-life experimental models should be actively used in schools with insufficient laboratory equipment.

Greater attention should be paid to connecting laboratory observations with microscopic particle models, animations, and visual explanations.

Group-based experimental activities should be encouraged to improve students' communication, collaboration, and scientific discussion skills.

Educational institutions should provide professional development programs for physics teachers on the application of innovative laboratory methodologies and STEM technologies.

Safety rules and experimental culture should be considered an essential part of every laboratory activity to ensure students' responsible scientific practice.

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