

RESEARCH ARTICLE

Development Of The Interactive Method "Micro-Macro Interpretation Cycle" (MMIC)

Sanabarkhon Siddikova Mahammadaliyevna

Andijan State University Academic Lyceum, Uzbekistan

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Abstract

This article presents the development and theoretical justification of an interactive physics teaching method—the "Micro-Macro Interpretive Cycle" (MMIC)—aimed at developing students' conscious understanding of molecular-kinetic and thermodynamic concepts. The relevance of this study stems from persistent difficulties in mastering the fields of molecular physics and thermodynamics, due to their highly abstract nature and the probabilistic nature of the processes being studied.

The proposed method is based on a step-by-step organization of learning activities, ensuring a cyclical transition from macroscopic observation of physics phenomena to their microscopic explanation and subsequent statistical generalization, leading to the application of the acquired knowledge in new situations. The article describes the structure of the method, defines its didactic functions, and demonstrates the potential for integrating phenomenological and statistical approaches in physics teaching. The results of theoretical analysis and pedagogical modeling indicate that the use of the MMIC method reduces the need for formal memorization of educational material, develops students' analytical and statistical thinking, and fosters a holistic scientific worldview. The method can be recommended for use in teaching molecular physics and thermodynamics in academic lyceums and technical educational institutions.

KEYWORDS

Interactive learning, molecular physics, thermodynamics, statistical thinking, macro- and micro-approaches, physics teaching methods, active learning methods.

INTRODUCTION

Modern developments in science and technology require a qualitative update to teaching methods in fundamental disciplines, particularly physics. Molecular physics and thermodynamics pose particular challenges for students, as the phenomena studied are not directly observable and require reliance on abstract models and statistical representations. Teaching experience shows that traditional explanatory and illustrative methods often lead to the formal assimilation of formulas and definitions without a deep understanding of the physics essence of the processes [1-3].

Research in the field of Physics Education Research points to the need for active student engagement in the process of constructing physics models and interpreting phenomena at different levels of description—from macroscopic to microscopic and statistical. However, most existing methods either focus primarily on macroscopic description or introduce statistical elements fragmentarily, without a well-defined logic for the transition between levels of physics knowledge.

In this regard, the development of an interactive teaching

method that ensures a systematic and conscious transition between different levels of interpretation of physics phenomena is relevant. The purpose of this article is to develop and theoretically substantiate the interactive method "Micro-Macro Interpretive Cycle" (MMIC), aimed at developing students' holistic understanding of molecular-kinetic and thermodynamic concepts.

METHODS

The study of molecular physics and thermodynamics occupies a special place in physics courses, as these sections rely on abstract models, probabilistic concepts, and processes inaccessible to direct observation. Therefore, traditional explanatory and illustrative teaching methods are often insufficient to foster a deep understanding of the physics nature of thermal phenomena in students. Interactive teaching methods in this area are of system-forming rather than auxiliary importance [4; 5].

The key role of interactive methods is to ensure students' active involvement in the process of interpreting physics phenomena. Unlike the repetitive assimilation of ready-made formulas and definitions, interactive learning is focused on collaborative discussion, modeling, and analysis, during which students independently construct cause-and-effect relationships between macroscopic observations and microscopic processes. This is especially important for developing molecular-kinetic concepts, which underlie an understanding of thermodynamic principles. Interactive methods allow for a step-by-step transition between different levels of physics knowledge—macroscopic, microscopic, and statistical. Working with qualitative problems, models, problem situations, and educational research fosters an understanding of the probabilistic nature of thermal processes and the development of elements of statistical thinking [6]. As a result, students begin to perceive thermodynamic laws not as formal mathematical relationships, but as generalizations of the behavior of a large number of interacting particles.

An important function of interactive methods is to reduce cognitive load when learning abstract concepts such as temperature, internal energy, and entropy. Collaborative discussion, visualization, and step-by-step modeling enable complex educational material to be adapted to students' cognitive abilities without oversimplifying its scientific content. This creates conditions for the conscious acquisition of fundamental concepts and prevents formal memorization [7].

Furthermore, interactive methods promote the development of meta-subject skills, including analytical thinking, argumentation, and the transfer of knowledge to new contexts. Through collective analysis of thermal phenomena, students learn to explain physics processes, justify their conclusions, and apply their acquired knowledge to practical and interdisciplinary problems [8; 9]. Thus, interactive learning contributes to the development of a holistic scientific worldview. Thus, in the fields of molecular physics and thermodynamics, interactive teaching methods not only serve a motivational and developmental function but are also an effective tool for developing fundamental physics concepts. Their use creates the methodological prerequisites for the transition from the formal assimilation of educational material to a conscious understanding of the nature of thermal phenomena and the laws of the microworld [10-13].

RESULTS

An analysis of modern approaches to teaching molecular physics and thermodynamics, as well as the identified difficulties in developing students' molecular-kinetic and thermodynamic concepts, allowed us to refine the directions of the methodological research within this study. The need to overcome the abstract nature of the concepts being studied, ensure a conscious transition between the macroscopic and microscopic levels of physics knowledge, and develop elements of statistical thinking led to the development of specialized interactive tools. The study established that a key condition for improving learning effectiveness is the organization of learning activities focused on students' active interpretation of physics phenomena. This premise served as the basis for the creation of the interactive method "Micro-Macro Interpretive Cycle," which is considered in this paper not only as a teaching tool but also as one of the significant results of the study. Below is a description of the structure and didactic capabilities of this method, reflecting the author's contribution to the modernization of teaching methods in molecular physics and thermodynamics. We will then attempt to uncover the essence and scientific idea behind the method:

The "Micro-Macro Interpretive Cycle" method is an interactive method for teaching molecular physics and thermodynamics based on a step-by-step transition of students from observing macroscopic thermal phenomena to explaining them through microscopic (molecular-kinetic) models and subsequent generalization at the level of physics laws. The scientific idea behind the method is that

understanding thermal phenomena is formed not through memorization of formulas, but through a cyclical interpretation: phenomenon → model → law → new phenomenon.

The method is aimed at developing elements of statistical thinking in students, which is especially important when studying the section "Molecular Physics and Thermodynamics."

The purpose of the method is to develop conscious molecular-kinetic and thermodynamic concepts in academic lyceum students through active modeling and interpretation of thermal processes.

Structure of the MMIC Interactive Method

The method is implemented in four sequentially repeating stages, forming a closed learning cycle (Figure 1).

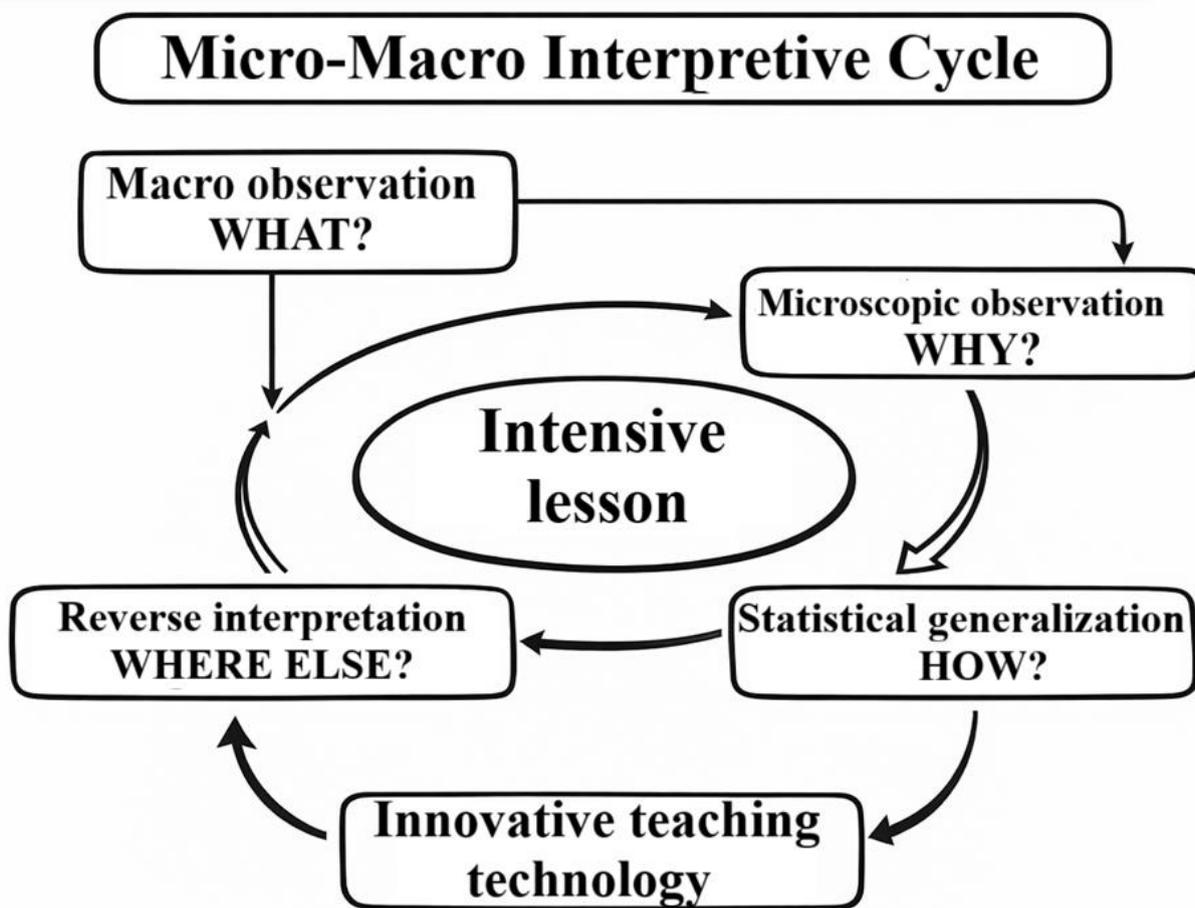


Figure 1. The structure of the interactive method of MMIC

Stage 1. Macroscopic Observation (WHAT?)

Students are presented with an observable thermal phenomenon or experimental situation:

- heating of a gas in a vessel;
- expansion of solids upon heating;
- evaporation of a liquid;
- pressure change at constant volume.

Interactive Stage:

- discussion in small groups;

- formulating hypotheses;
- qualitative questions without formulas.

Result: Students record the fact of the phenomenon, but do not yet know its cause.

Stage 2. Microscopic Reconstruction (WHY?)

Students move on to explaining the phenomenon in terms of particle motion and interaction:

- the nature of the thermal motion of molecules;
- change in average kinetic energy;

- the role of random motion.

The following are used:

- diagrams;
- simple models;
- thought experiments.

Result: a molecular-kinetic explanation of the phenomenon is formed.

Stage 3. Statistical Generalization (HOW?)

Based on a microscopic model, students are introduced to physics laws and relationships:

- the fundamental equation of the MKT for gases;
- the relationship between temperature and kinetic energy;
- thermodynamic quantities.

Formulas are introduced as the result of reasoning, not as a starting point.

Result: a conscious understanding of physics laws and quantities.

Stage 4. Reverse Interpretation and Transfer (WHERE ELSE?)

Students apply their acquired knowledge to:

- new physics situations;
- non-standard problems;
- applied examples (technology, nature).

The cycle is closed and a transition to a new phenomenon occurs.

Result: the ability to transfer knowledge is developed.

Table-1

Key points	Description
Interactive forms of method implementation	<ul style="list-style-type: none"> - small group work; - physicist-explainer discussion; - collective model building; - mini-research; - qualitative problems with alternative answers.
The role of the teacher in the MMIC method	<p>The teacher serves as:</p> <ul style="list-style-type: none"> - moderator of the cognitive process; - discussion coordinator; - research consultant; - organizer of reflection. <p>The teacher does not provide ready-made explanations, but guides students in constructing them independently.</p>
Expected pedagogical effects	<p>The implementation of the MMIC method ensures:</p> <ul style="list-style-type: none"> - a deep understanding of thermal phenomena; - the development of elements of statistical thinking; - a reduction in the formal memorization of formulas; - the development of analytical and logical skills; - a sustained cognitive interest in physics.

The key element of the procedural block of the methodological model is the interactive "Micro-Macro Interpretive Cycle"

method, which provides a step-by-step transition from macroscopic observation of thermal phenomena to their

microscopic and statistical explanation. This method integrates phenomenological and molecular-kinetic approaches, promotes the development of statistical thinking, and ensures conscious assimilation of the "Molecular Physics and Thermodynamics" section.

CONCLUSION

As a result of the study, an interactive "Micro-Macro Interpretive Cycle" method was developed, aimed at gradually developing students' conscious understanding of thermal phenomena. The method is based on a cyclical organization of learning activities, ensuring the transition from macroscopic observation of physical processes to their microscopic explanation and statistical generalization, followed by the transfer of knowledge to new contexts.

Theoretical analysis showed that the proposed method integrates phenomenological and statistical approaches in physics teaching, reduces the level of abstractness in the educational material, and promotes the development of students' analytical and statistical thinking. Unlike traditional linear learning models, the MMIC method focuses on students' active interpretive work and the development of a holistic scientific worldview. The results obtained suggest that the "Micro-Macro Interpretive Cycle" method is an effective tool for modernizing teaching methods in molecular physics and thermodynamics. Prospects for further research include experimental testing of the method's effectiveness and its adaptation to the conditions of a digital and inclusive educational environment.

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