

Research Article



Methodology for Enhancing the Professional Competence of Prospective Physics Teachers through the Development of the Topic “Law of Distribution of Molecular Velocities: Maxwell’s Distribution of Molecular Speeds” Using Digital Educational Tools

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Abstract: This article presents a methodology for teaching the distribution of molecular velocities — the Maxwell–Boltzmann distribution — using contemporary digital educational tools. The primary focus is on developing and enhancing the professional competence of prospective physics teachers. Initially, the theoretical foundations of the topic are discussed, followed by an analysis of the challenges teachers face in mastering the subject and the methodological tools that can be employed to address these challenges. The study highlights the use of interactive simulations, modeling platforms (GeoGebra, Python, PhET, etc.), and graphical analysis tools to improve instructional effectiveness. Finally, the article examines the practical effectiveness of the methodology, analyzes observed changes in teachers’ theoretical and practical knowledge, and provides methodological recommendations.

Keywords: Maxwell–Boltzmann Distribution, Molecular Velocities, Digital Educational Tools, Physics Education, Professional Competence, Interactive Teaching, Visual Modeling, Prospective Teachers, Educational Technologies



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Introduction

At the core of the ongoing reforms in the education sector of our country is the primary goal of training highly qualified specialists who are competitive in the global market, eager for knowledge, and proficient in their respective fields. Special attention is particularly given to the professional development of prospective teachers graduating from higher pedagogical institutions. It is consistently emphasized that the educational process should be organized in a manner that meets contemporary demands while maximizing students’ potential and fostering their professional competencies.

Today, in the teaching of physics, the use of interactive, modeled, and visual tools is becoming increasingly relevant, gradually replacing traditional lecture-based and problem-solving methods. Organizing the educational process for prospective teachers in higher education institutions with the support of digital educational tools, ensuring their acquisition of deep knowledge, skills, and competencies in their specialized subjects, is also of great importance[1].

Materials and Methods

The main objective of this article is to develop and implement a methodology for enhancing teachers’

skills in organizing lessons in a visual, interactive, and comprehensible manner by integrating modern technological approaches alongside theoretical knowledge.

In this study, we examine the teaching of a selected topic from the lecture portion of molecular physics using digital educational tools. Once the lecture-type session is chosen, a total of 15 new topics, allocated over 30 hours for higher pedagogical education, are presented. As an example, we consider the fifth lecture session, titled “Distribution of Molecular Velocities: Maxwell Distribution”[2].

Initially, students are introduced to the theoretical part of the topic. A lecture text, available within the digital educational platform, serves as a supporting resource. After reviewing the theoretical content, students optionally watch a video lesson covering the main aspects of the topic. To reinforce understanding, students are required to reflect on the topic in a designated section, connecting key concepts to real-life applications. The resulting database of reflections must be at least one page in length. This activity fosters students’ comprehension levels and critical thinking skills[3].

Subsequently, students are provided with 10 assessment tests related to the topic. Completion of these tests allows students to proceed to the next topic. Moreover, students have the opportunity to retake these tests until the scheduled study period for the subsequent topic, thereby consolidating their understanding[4].

Taking these considerations into account, a digital educational program was developed in higher pedagogical education institutions with the aim of enhancing the professional competence of prospective physics teachers. This program integrates the complete lecture, practical, and laboratory components of the molecular physics curriculum. As mentioned above, this digital tool represents a highly relevant and significant approach in modern education.

Results

The program contains a wealth of information related to molecular physics and employs various methods across multiple directions to improve teaching effectiveness. Using this digital platform, we examine the teaching of the topic “Law of Distribution of Molecular Velocities: Maxwell Distribution of Molecular Speeds.”[5]

- First, the student logs into the digital platform and selects the corresponding higher education institution.
- Each student accesses the platform using their personal credentials.
- Next, the student selects the Molecular Physics section from the course catalog.
- In the following step, the student chooses the type of lesson.[6]

Next, a set of 15 new lectures, designed for a total of 30 hours, becomes available. The student accesses the lecture corresponding to their assigned topic, in this case, the third lecture. At the beginning of studying the topic, a review of the previously covered material is conducted[7].

The student is required to complete the tasks provided on the platform according to the specified methodology. For this topic, responses must be submitted to questions presented using the “Question Wheel” method. In this activity, a circle containing six numbered segments rotates, and the student must answer the question corresponding to the randomly selected number in the designated input field on the screen.

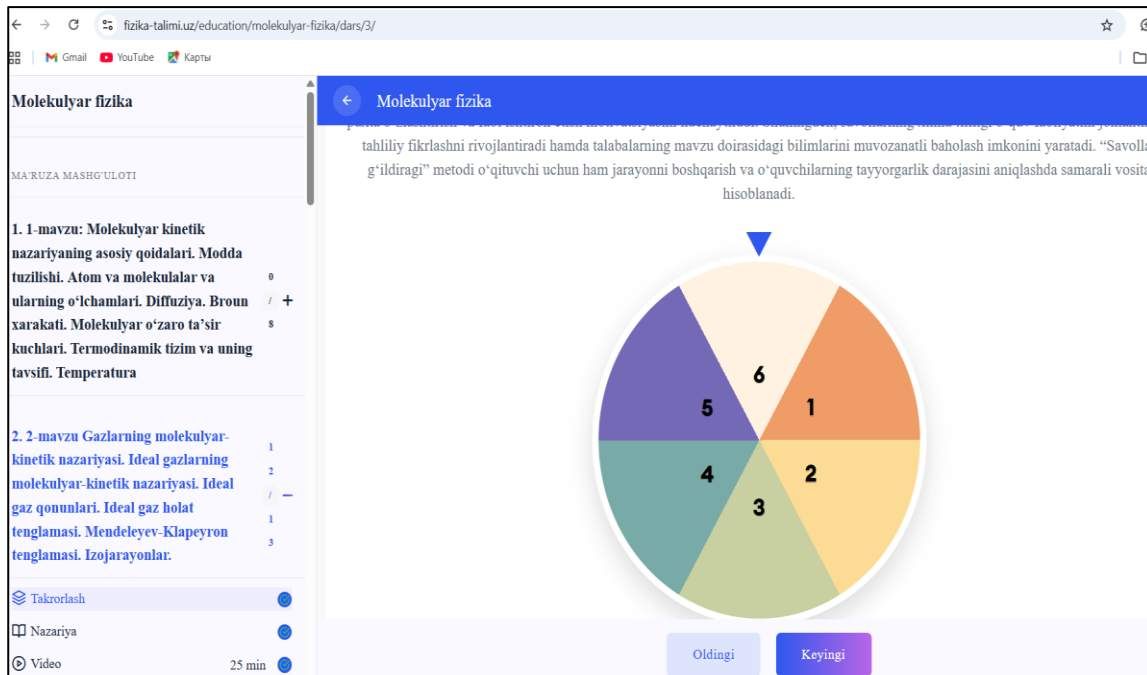


Figure 1. Visualization of the “Question Wheel” Method

All submitted answers are automatically evaluated using artificial intelligence. Completion of all questions is mandatory[8].

In the following section, the exposition of the new topic is presented. The user has the option to download the theoretical components of the topic as a file and study them independently at their own pace.

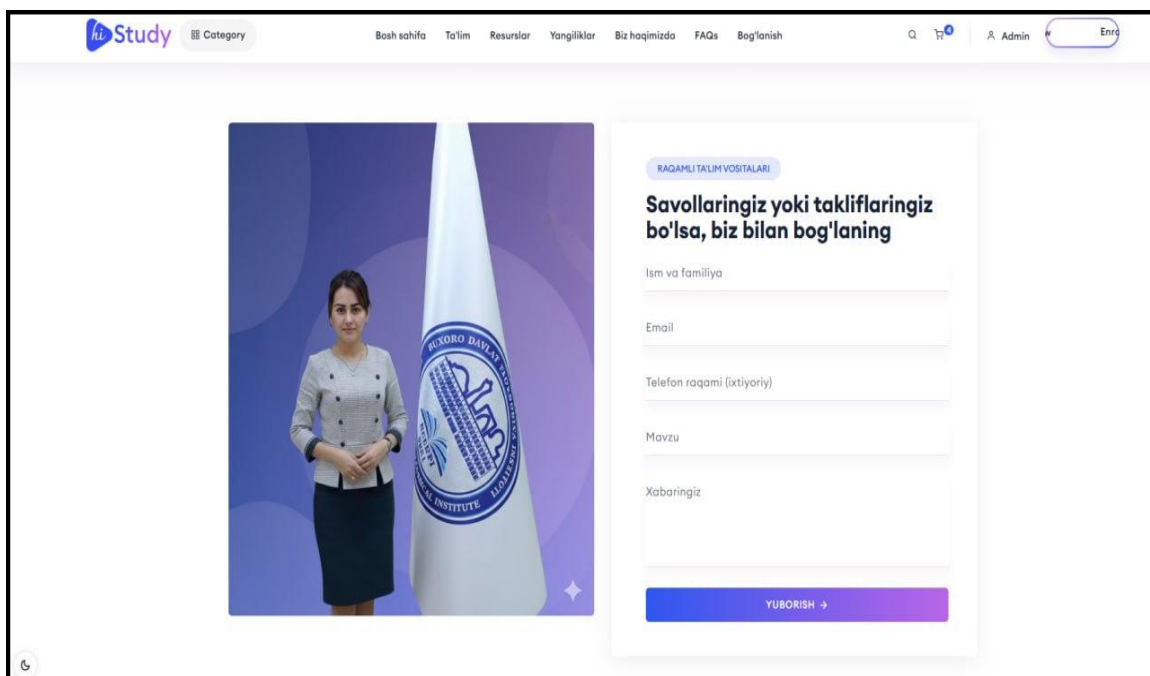


Figure 2. Working interface of the digital platform

During the process of familiarizing themselves with the theoretical part of the topic, if the student encounters unclear information, unfamiliar terms, or complex formulas, supporting video lessons related to the topic are provided to facilitate understanding. Access to these videos is optional, allowing students

to study them at their discretion. This feature enables students to immediately review any material they did not fully comprehend via links provided on the platform, thereby directing their attention to the specific content and enhancing the learning process[9].

After reviewing the exposition of the new topic, the student clicks the “Back” button to proceed to the next step, where they assess their level of understanding of the previously covered material. Subsequently, the student moves on to the next lecture session[10].

Before beginning this topic, students are initially given 10 pre-tests on the previously covered material. Each correct answer is awarded one point. Students who achieve a total score of 60% or higher are allowed to proceed to study the theoretical part of the new topic. Otherwise, they must revisit the previous topic and master it before moving forward. Students who fail to complete topics within the designated time frame will not pass the course.

After mastering the second lecture, the student proceeds to study the exposition of the third lecture. Additionally, by watching the corresponding video lesson, the student can acquire a conceptual understanding and visualization of the main content of the lecture. Once the theoretical knowledge of the topic is acquired, students complete a consolidation test, which also contains 10 questions, of which at least 6 correct answers are required to demonstrate understanding[11].

In this sequential manner, the program enables students to master all 15 new topics, designed for a total of 30 hours, in a structured and progressive way.

In modern physics education, the study of molecular motion and their statistical properties holds significant importance. In particular, the Maxwell–Boltzmann distribution provides the probability of gas molecules moving at various speeds. This distribution serves as a critical theoretical foundation for a deep understanding of physical processes, the phenomena of heat, gas laws, and fundamental concepts in thermodynamics[12].

Discussion

Nevertheless, learning this topic and effectively conveying it to others—especially for prospective physics teachers—is not straightforward. Understanding the physical meaning of the distribution graph, the statistical types of molecular speeds, the effects of parameters such as temperature and mass, and presenting this knowledge to students in a visual and logical manner introduces specific didactic challenges[13].

However, practical experience shows that many future physics teachers do not fully comprehend these tools, fail to utilize them correctly during lessons, or do not sufficiently exploit technological resources. This leads to certain gaps in their professional competence.

Therefore, this article scientifically analyzes the issue of developing the professional competence of prospective physics teachers by improving the teaching methods of the topics “Law of Molecular Speed Distribution” and “Maxwell Distribution” using modern digital educational tools[14].

Conclusion

The use of such a software application provides the opportunity to develop the professional competence of prospective physics teachers in organizing the teaching process. Moreover, in an era of rapidly advancing digital technologies, utilizing such programs contributes to the continuous development of their skills.

An analysis of the existing digital educational tools in the field of physics instruction reveals a clear need for a software-based teaching tool specifically designed for the preparation of future physics educators in higher education. In particular, there is a demand for a tool that facilitates the teaching of Molecular

Physics. In response to this need, such a software educational resource has been developed and is currently being implemented in the educational process[15].

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