

Technology of Using Computer Models in Teaching Physics Course in Secondary School

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Abstract

One of the main directions of education in modern times is the application of information and communication technologies (ICT) in the teaching process. In teaching physics, these technologies, especially computer models, virtual laboratories, make the learning process more interesting, visual and interactive for both the teacher and the student.

The article examines the essence and methodological possibilities of using computer models in order to increase the efficiency of the teaching process in the physics course of secondary school. In the context of the rapid growth of information, the role of interactive models, virtual demonstrations and experiments (simulations) in the development of students' scientific and cognitive skills is emphasized. The visual presentation of physical phenomena and processes through computer models allows students to be involved in independent research activities.

Since natural sciences, especially physics, are based on experiments and observations, the use of computer models and virtual laboratories in teaching its subjects is of great importance.

In teaching the VII-IX grade physics course, the use of computer models is very effective in helping students to deeply understand the essence of physical phenomena, learn their practical application, and form independent research skills. Computer models play an important role in explaining physical phenomena and processes. In addition to replacing real demonstrations and experiments, they create the following opportunities for students:

- Conducting demonstrations and experiments safely and repeatedly;
- Observing the results of events and experiments by changing parameters;
- Analyzing the results in the form of graphs, tables, and animations.

The mentioned features make the teaching of physics interactive and interesting. In teaching physics, it can be difficult or expensive to demonstrate many events and processes in real conditions. In this regard, computer models are considered indispensable.

Keywords: physics, computer, model, demonstration, virtual experience, practical work, technology.

Introduction

In modern education systems, the integration of information and communication technologies (ICT) has significantly enhanced the quality of the teaching and learning process. One of the primary tasks emerging from scientific and technological progress is the effective use of ICT in education.

Educational reforms implemented in the Republic of Azerbaijan continue systematically and strategically. These reforms create a foundation for enriching and modernizing the educational environment both in terms of content and material–technical infrastructure (Ministry of Education of the Republic of Azerbaijan [MoE], 2022).

In physics education, the use of modern ICT tools enables students to acquire knowledge and develop skills more effectively. Teaching physics today is not limited to knowledge transmission; it also aims to enhance students' cognitive activity and develop critical and creative thinking skills. Therefore, interactive teaching methods and digital technologies are particularly important.

Aim of the Study

Teacher professionalism and pedagogical competence play a decisive role in optimizing physics instruction. Teachers possessing both pedagogical and technological knowledge significantly improve instructional effectiveness and promote deeper student understanding.

The integration of modern technologies in physics teaching strengthens practical orientation and enhances student engagement (Hestenes, 2010). Thus, examining the theoretical and methodological foundations of technology integration in physics education is an important pedagogical direction.

Significance

Virtual laboratories, simulations, interactive whiteboards, and digital platforms enhance instructional content and facilitate understanding of abstract physical phenomena through visual models (Hestenes, 2010).

However, challenges remain, including:

- Insufficient technological infrastructure in some schools,
- Limited ICT competencies among teachers,
- Unequal distribution of digital educational resources.
- Addressing these issues requires continuous professional development programs, adaptation of digital tools to the national educational context, and development of localized digital resources.

Theoretical Framework

Computer models - provide a demonstration of physical processes or phenomena using computer programs. These models are used to conduct experimental demonstrations and experiments and to understand complex phenomena (Hestenes. 2010, Mammadov. 2021, Aghayev. 2015).

These models help students understand complex concepts and learn physical concepts and quantities safely instead of real experiments.

In the process of teaching physics in secondary school, computer models are used for the following purposes:

1. To clarify abstract concepts;

For example, concepts such as “Electric charge” and “Interaction of charges – Coulomb's law” can be explained with visual animations and graphics (Physics animation/Simulation. 2025.

<https://www.vascak.cz/physicsanimations.php?l=ru>).

2. To perform dangerous and costly demonstrations and experiments;

It is possible to safely simulate dangerous demonstrations such as electrical circuits, chemical and nuclear reactions, etc. on a computer.

3. To repeat experiments in laboratory work;

In virtual laboratory work, students can check individual parameters and compare results.

4. To simplify complex processes;

For example, topics such as “Laws of motion”, “Wave motion”, etc. can be presented in different scenarios (Physics animation/Simulation 2025. <https://www.vascak.cz/physicsanimations.php?l=ru>).

Literature Review

Literature has been published in various languages on the use of modern technologies in teaching physics. Since these literatures are written in different languages, students and pupils have difficulty using them. For example, the work “Teaching Informatics and the Application of ICT” (Huseynov, 2006) provides a general methodological approach to information technologies in teaching physics. The work “Innovative Technologies in Teaching Physics” (Aghayev, 2015) presents local examples of the application of computer simulations and virtual laboratories in physics lessons (Mammadov, 2021).

However, there are very few materials on the technology of using computer models in teaching physics in general secondary and high schools. For this purpose, I have published articles on the technology of using computer models in teaching physics (Hajiyev, 2024; Hajiyev, Ismayilbeyli, 2024). This article is also devoted to the technology of using virtual demonstrations and experiments in teaching physics in secondary schools.

Methodology

In the 7th grade physics course of secondary school, students are introduced to electric circuits and circuit elements using the virtual laboratory simulation “Constant Current” in the teaching of the topics of the section “Electrical Circuits and Circuit Elements”.

Through this simulation, an electric circuit is assembled by connecting a current source, a lamp, and a switch through wires (PhET Interactive Simulations. 2025, <https://phet.colorado.edu/az/simulations/circuit-construction-kit-dc-virtual-lab>). Students visually observe how current is generated in the circuit and learn the conditions for the generation of current.

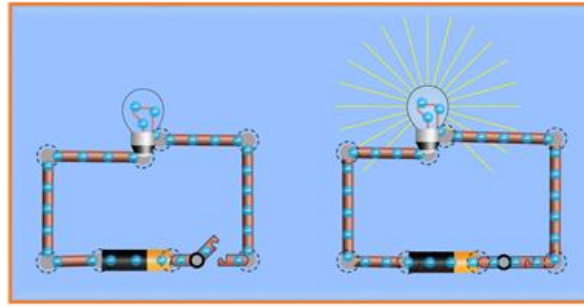


Figure 1

Figure 2

When the switch is open, no current flows through the circuit, and in this case the lamp does not light up. However, when the switch is closed, current flows through the circuit, and in this case the lamp lights up (Figure 1; 2). Based on this visual demonstration, students determine the following conclusions:

- In metal wires, electric current is created by free electrons moving in a regular manner.
- For current to exist in a circuit, there must be a current source and free charge carriers (in metals – electrons, in electrolytes – positive and negative ions, etc.).
- In metal wires, the direction of electric current is considered to be the opposite of the direction of movement of electrons.

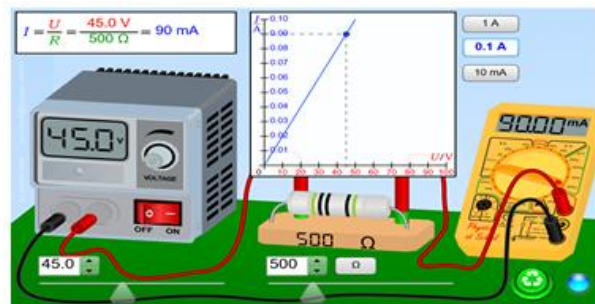
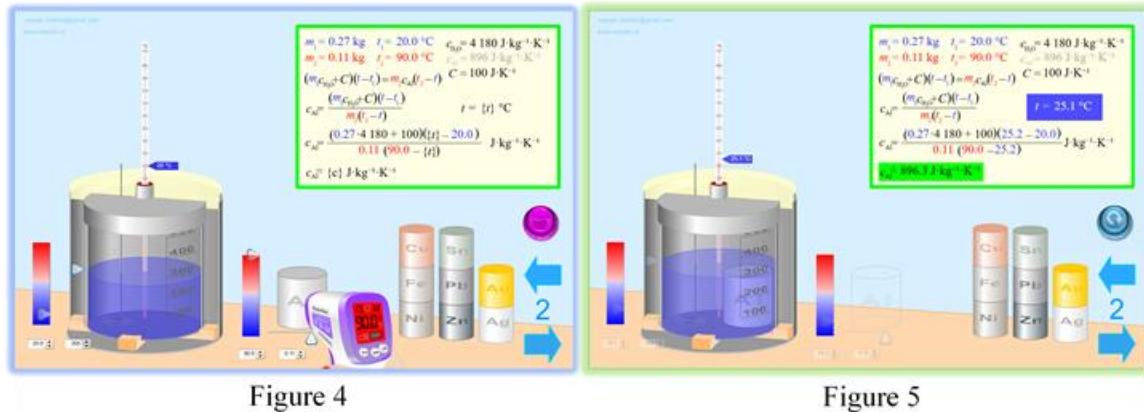


Figure 3

In teaching the topic of “Ohm’s law”, a circuit consisting of a current source, a resistor (lamp), a switch, an ammeter and a voltmeter is assembled using the simulation of the same name (Physics animation/Simulation2025. <https://www.vascak.cz/data/android/physicsatschool/templateimg.php?s=eleohm&l=ru>). Students observe that as the voltage at the ends of the circuit (lamp) increases, the value of the current also increases by the same amount. According to Ohm’s law, the ratio of the voltage at the ends of the circuit to the current intensity is constant (Figure 3). This ratio is called electrical resistance and its value does not change:

$$R = \frac{U}{I} = \text{const}$$

In the 8th grade physics course of secondary school, it is advisable to use a virtual simulation called “Calorimeter” to carry out the practical work “Determination of the specific heat capacity of a solid” (Figure 4;5). (Hajiyev, 2024. Physics animation/Simulation 2025, https://www.vascak.cz/data/android/physicsatschool/templateimg.php?s=mf_kalorimetr&l=ru).



Students safely determine the specific heat capacity of a cylindrical solid made of various materials (for example, aluminum) through this simulation.

$$c_{Al} = \frac{c_{H_2O}m_{H_2O}(t - t_1) + c_{cal}m_{cal}(t - t_1)}{m_{Al}(t_2 - t)}$$

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Where c_{H_2O} –specific heat capacity of water, m_{H_2O} –mass of water in the calorimeter, C_{cal} –calorimeter heat capacity, t_1 –initial temperature of water and calorimeter, t_2 –initial temperature of cylinder, t –steady temperature of the system.

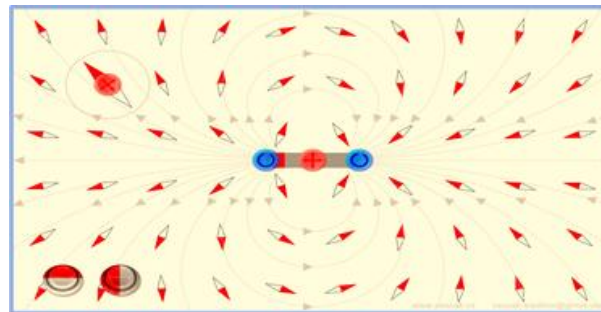


Figure 6

Using this virtual simulation, the specific heat capacities of other cylinders made of different materials can also be determined.

In the 9th grade physics course, the connection between electric and magnetic phenomena is explained in the process of teaching the topics of the chapter “Magnetic Field”. To demonstrate the appearance of a magnetic field, the teacher can use the animation “Magnet” (Figure 6), and to demonstrate the magnetic field of a rectilinear current, the animation “Magnetic Field of a Current-Carrying Wire” (Hajiyev, Ismayilbeyli, 2024; <https://www.vascak.cz/data/android/physicsatschool/templateimg.php?s=magnet&l=ru>).

By demonstrating the virtual experiments “Magnetic Field of a Current-Carrying Wire”, the teacher draws the attention of students to the formation of a permanent magnetic field around a current-carrying wire and explains that the formation of this field is associated with the movement of electric charges. Students see that the magnetic field lines around a straight current are arranged in concentric circles (Figure7;8) (Physics animation/Simulation. 2025, <https://www.vascak.cz/data/android/physicsatschool/templa-teimg.php?s=magvodic&l=ru>).

By demonstrating a virtual experiment, it is determined that there is a relationship between the direction of the current in the wire and the direction of the magnetic field lines. It is noted that when several magnetic needles are placed around a current-carrying wire, the north direction of the magnetic needles is directed in the direction of the magnetic induction vector. Students are explained how the direction of the lines of force changes based on the change in the direction of the magnetic needles by changing the direction of the current flowing through the

conductor. That is, it is determined experimentally that the direction of the lines of force of the magnetic field is related to the direction of the current flowing through the conductor. Students are explained how to determine the direction of the lines of force using the right-hand rule and the right-hand rule.

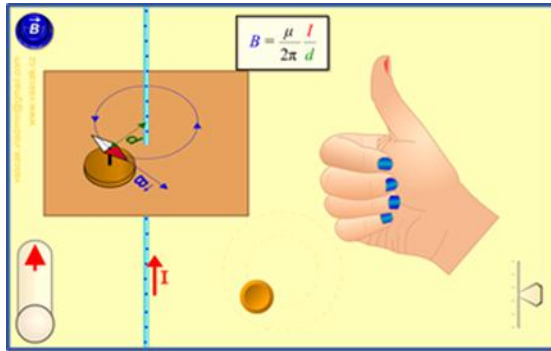


Figure 7

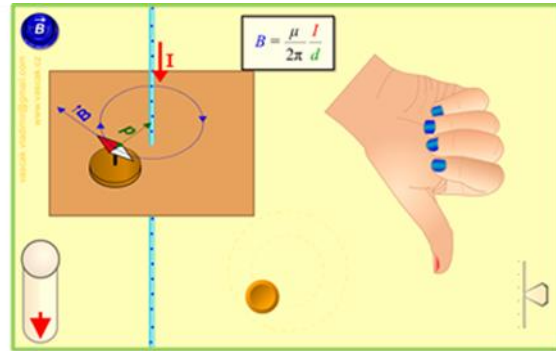


Figure 8

In 1820, the French physicist A. Ampère, based on his experiments, determined that there are magnetic interactions between parallel current-carrying conductors. The interaction between parallel current-carrying conductors can be demonstrated using an animation called “Ampere’s law” (Physics animation/ Simulation 2025. [https://www.vascak.cz/data/android/physicsatschool/templateimg.php?s=ele amper &l=ru](https://www.vascak.cz/data/android/physicsatschool/templateimg.php?s=ele+amper+&l=ru)).

Based on the demonstration, it is determined that when the currents flowing through parallel conductors are in the same direction, they attract each other, since opposite poles of magnetic fields are created between them (Figure 9).

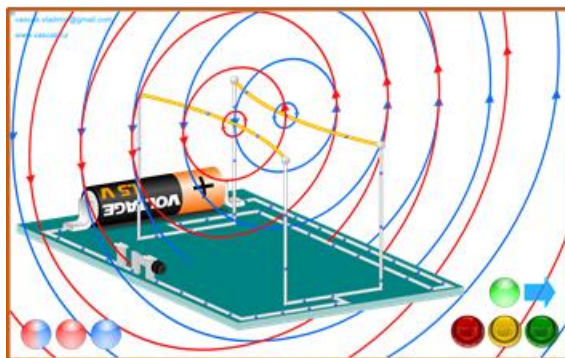


Figure 9



Figure 10

When the currents flowing through parallel conductors are in opposite directions, they repel each other because the same poles of the magnetic field are created between them (Figure 10).

The value of the magnetic interaction force between parallel conductors with current depends on the current intensity in the conductors, the length of the conductors, and the distance between them.

$$F = \frac{\mu}{2\pi} \frac{I_1 \cdot I_2}{d} \cdot \Delta l$$

Here F –modulus of magnetic interaction force between parallel conductors with current, μ –magnetic permeability of the substance, I_1 and I_2 –current intensity in parallel conductors, Δl –length of conductors, d –distance between them. The unit of current intensity in the BS–ampere (A) was determined based on the magnetic interaction force between parallel conductors with current.

Findings and Discussion

After the students master the computer models, they can be offered to perform some experiments at home.

The use of computer models in teaching high school physics provides teachers and students with the following opportunities.

- Advantages of computer models:

- Helps students understand difficult concepts more easily;
- Visual presentation of results facilitates learning.
- Allows experimentation with variable parameters;
- Permits unlimited repetition of experiments.

Although practical work using computer models cannot replace real laboratory work, it develops the skills of students. Therefore, it is appropriate to use virtual laboratory experiments to carry out practical work in teaching physics in secondary schools.

The use of virtual demonstrations and experiments in the process of teaching physics in secondary schools provides teachers and students with the following opportunities:

For teachers:

- more time for individual support to weak students;
- rapid diagnostics of students' practical work results.

For students:

- ability to perform independent practical work using computer models;
- analyzing and interpreting physical phenomena and laws through individual practice;
- opportunity to conduct practical work that cannot be performed during lessons;
- opportunity to carry out virtual experiments outside class hours;
- skills to use a computer as a learning tool;
- ability to work with electronic resources.

Conclusion:

The role of technology in the modern education system is increasing. Especially in the teaching of physics, computer models and virtual laboratories serve to better understand physical phenomena, develop experimental skills and increase activity in the teaching process. Computer models open up new opportunities for both teachers and students and ensure safe, cost-effective and efficient implementation of experiments.

Virtual laboratories and simulations are powerful tools for understanding physical phenomena and complex laws.

The application of computer models in teaching physics is one of the most effective directions of modern pedagogical technology.

Based on the findings of the study, the integration of computer models into physics teaching offers substantial pedagogical benefits. First and foremost, computer-based simulations contribute to the development of students' scientific worldview by allowing them to observe, analyze, and interpret physical phenomena in a structured and interactive environment. Through repeated experimentation and manipulation of variables, students gradually strengthen their experimental and research skills, gaining experience that mirrors authentic scientific inquiry.

Moreover, the visual representation of abstract physical concepts significantly enhances conceptual understanding and increases students' motivation to learn. When learners are able to see dynamic models of otherwise invisible processes, misconceptions become easier to identify and correct. In addition, computer models provide a safe environment for conducting experiments that would otherwise be dangerous, costly, or technically complex in real laboratory settings. This combination of safety, flexibility, and interactivity ultimately improves the overall quality of learning and promotes deeper cognitive engagement.

To maximize these benefits, systematic steps should be taken at the institutional level. Professional development programs should be organized to support physics teachers in developing the competencies necessary to design and effectively implement computer-based models in their lessons. At the same time, secondary school physics classrooms need to be equipped with modern technological infrastructure to ensure equal access to digital learning tools. Furthermore, curriculum-aligned lesson plans that integrate virtual laboratories should be developed to provide methodological guidance for teachers. Finally, digital teaching resources - such as Physics Animations, PhET simulations, Yenka, and Algodoo – should be incorporated into the curriculum in a structured and sustainable manner to ensure their consistent pedagogical application.

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