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The effectiveness of using interactive computer models when teaching physics in modern school

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Abstract

Relevance. This paper concerns the use of interactive methods and technologies in the distance educational process when studying physics in secondary school.

Purpose. The purpose of the paper is to identify the possibilities of interactive computer models and to develop didactic and practical bases of the methodology of their effective application in teaching physics to secondary school students.

Methodology. The following pedagogical methods of literature analysis and statistical processing of the results are used in the work. Conversation, observation, experience, practical work with the predominance of the heuristic nature of the cognitive activity of students are the main methods of organising work with students.

Results. Special attention is paid to the forms and types of educational activities in information networks, as well as problems that arise during distance learning. The article reveals the need to develop methodological foundations for the use of interactive computer models in teaching a physics course in secondary school. The paper considers the main provisions of the methodology for using interactive computer models in the educational process, methodological and didactic requirements for its organisation. This article discusses the prospects of using interactive methods and technologies in the distance learning process. This paper unlocks the potential of interactive computer models and justifies the expediency of their use in the process of teaching physics in secondary school.

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Conclusions. The article substantiates the importance of the relationship between methodological and technological approaches to the development of interactive educational computer models. The paper shows the effectiveness of interactive computer models in physics for self-training of students to increase their level of practical and applicable skills.

Keywords: physical experiment; distance learning; education; electronic textbook; teaching in secondary school.

Introduction

An information-oriented society facilitates an active modernization of education. The emergence and continuous improvement of forms and sources of obtaining information require education to search for new learning technologies. Today, digital technologies and the Internet are relevant in the process of cultural development of society, since the scale of education has no equal in importance. Educational institutions have switched to online mode due to the access of the whole world to the Internet, as well as social and economic crises caused by the Covid-19 pandemic. The pillar of this research is to conduct and further develop independent work as a methodological guide for the self-education of students using new computer technologies in education. Interactive computer models are new information technologies that allow creating dynamically developing images in various information manifestations by combining statistical visual information (text, graphics, colour) and dynamism (animation) [1; 2]. Interactivity allows the student to be active in working with a computer model, to control the presentation of information within certain limits, to choose an individual course and the pace of the educational material. The harmonious combination of animation, graphics, colour and interactivity provides students with a visual and imaginative perception of the educational material, develops imagination and model thinking, promotes mental activity, increases and stimulates the effectiveness of mastering the materials, cognitive interest in studying subjects. Therefore, computer models have didactic potential and can be used in educational work by various and effective methods [3; 4].

Many studies confirm the increase in the educational and cognitive activity of students using an interactive computer model in the educational process (V. P. Bepalko [5], A. G. Dorrer [6], V. S. Polat [7], I. V. Robert [8], V. A. Starodubtsev [9] et al.). In the Republic of Kazakhstan, certain aspects and types of computer technologies, theoretical and scientific-applied directions of application of information and communication technologies are studied in the work of A. Karaeva [10], E. I. Bidaibekova [11], E. A. Abdykerimova [12], etc. In the works of these authors, the promising direction is proved of using computers as a means of teaching. This allowed considering computer training as one of the most important modern trends in the methodology of teaching physics. Currently, specialists pay attention to the development of various computer-learning models that simulate the environment and various applications for computational experiments. The widespread introduction of computer technologies in all spheres of practical activity and in the educational process raises the issue of textbooks and teaching aids of a new type aimed at the active use of educational programmes, teaching materials, as well as modern computer technologies. This question is especially important for teaching physics since computers open up new opportunities for the educational process, as well as

the study of specific phenomena when this is impossible using traditional methods. Thus, new computer-based learning technologies are an important factor in turning broad information learning into fundamentally intensive learning [5; 6].

Due to the loss of students' interest in the subject, the issue of using physical interactive computer modelling becomes particularly relevant for online learning in modern schools. Having studied the development of the world education system and the prospects for the development of the online learning system, we believe that using electronic textbooks will be the most productive in the future learning process. In the context of intensive computerisation of modern education, new information technologies are being developed and used in secondary schools for teaching physics such as electronic textbooks, multimedia, animation, models, etc. The Internet can also provide access to new sources of knowledge such as interactive computer models that significantly expand and enrich the educational environment. In this regard, the development of methodological theoretical and practical foundations requires constant improvement to use world interactive computer models for physics courses with new textbooks [7; 8; 9].

The purpose of the paper is to identify the possibilities of interactive computer models and to develop didactic and practical bases of the methodology of their effective application in teaching physics to secondary school students. The research work is carried out within the framework of the project of grant financing of scientific and technical projects. The practical significance of the research is to substantiate the importance of the relationship between methodological and technological approaches to the use of physical interactive models in secondary school; to develop scientific and methodological recommendations for the introduction of an interactive computer model as an illustrative material in the physics course and to improve the effectiveness of the educational process; to develop an electronic textbook on the sections of the physics course. The research materials can be used in the work of general education schools, institutes or regional centres for advanced training and retraining of teaching staff. The scientific novelty of the research results is as follows:

- didactic and practical bases of the methodology of using interactive computer models were developed, aimed at a deeper assimilation of physics, activation of cognitive and creative interests of secondary school students;
- the importance of the relationship between methodological and technological approaches to the development of interactive educational computer models was substantiated;
- an electronic textbook was developed and implemented using interactive computer models, and its content and methodological content were determined;

- practical and methodological materials were presented that allowed students to design interactive computer models independently in physics, create electronic textbooks, and carry out project activities;
- when developing a methodology for using interactive materials of an electronic publication, various methodological models can be used, depending on the composition of students in the class, the school's availability of computer equipment and the methodological tasks facing it.

Materials and Methods

Currently, the rapid development of information and communication technologies has made it necessary to modernise the content and structure of all areas of school education. In recent years, there have been significant changes in the goals, content, methods and technologies of training during the modernisation of the education process, namely, during the transition from teaching “knowledge, skills and abilities” to a competence-based approach. The article pays special attention to the forms and types of educational activities in information networks, as well as problems that arise during distance learning. This article provides some conditions for ensuring the effectiveness of interactive methods and technologies in distance learning [10; 11]. The following pedagogical methods are used in the work:

- theoretical: analysis of pedagogical, methodological and special literature on the problem of research;
- general scientific: pedagogical observation, conversations with schoolchildren, analysis of the results of students' activities, the study of computer software products intended for teaching physics at school, study and analysis of the experience of using information technology tools in teaching schoolchildren;
- statistical: processing the results of pedagogical experience.

When developing a methodology corresponding to the tasks of this study, scientific works and methodological publications were analysed on the use of interactive computer models in the process of teaching physics in secondary school. Conversation, observation, experience, practical work with the predominance of the heuristic nature of the cognitive activity of students are the main methods of organising work with students. These methods provide the development of research skills, skills, teach students to make new decisions independently. The individual work of students on PCs is the most effective form of working with interactive models since students gain knowledge in the process of independent creative work. At the stage of generalisation and systematisation of new material, students are invited to independently conduct a small study using a computer model or a virtual laboratory, and get the necessary results. The necessary methodological aspects are proposed in the work: methodological recommendations for various sections of the course are developed for demonstrating and illustrating new material, showing methods for solving problems, solving experimental problems, conducting laboratory and independent work, organising research activities,

monitoring, self-monitoring, etc. The article considers the main provisions of the methodology of using interactive computer models in the educational process, methodological and didactic requirements for its organisation. Methodological instructions were developed for the teacher to work with an interactive computer model.

To study the problem of using interactive computer models in the process of online physics education in secondary school, it was found that a survey of high school students in some schools in Atyrau resulted in great difficulties for students in online learning at an unexpected time, their lost interest in the subject, which did not allow reaching potential [12; 13]. When mastering new knowledge in traditional ways online such shortcomings result from the following:

- a body of information transmitted through traditional education for a limited time, and little time is spent on increasing the creative potential of students;
- the lack of electronic methodological manuals to demonstrate necessary experiments when developing new knowledge;
- formal execution of physical experimental tasks on paper without practical verification of the results;
- it is not possible to perform traditional laboratory tasks online.

Results

Based on the analysis of scientific, pedagogical, methodological and special literature on the problem under study, the types of interactive computer models were determined taking into account the content specifics of the physics course in educational institutions and were recommended for practical and laboratory classes of secondary school students. The didactic and practical methodological base was developed for using interactive computer models in teaching physics to secondary school students. It was found out that interactive computer models opened new doors for the educational process: they significantly increased and stimulated cognitive interest in the subject; created a unique methodological and didactic potential in teaching; developed imagination and model vision; promoted mental activity; individualized learning; developed independence, etc. [14]. The ability to demonstrate visually a lightweight theoretical model is a special feature of interactive computer models that allows you to find physical laws of natural phenomena quickly and efficiently, which can practically not be implemented in a real physical experiment. In addition, students can simultaneously monitor the creation of appropriate graphical dependencies during the experiment. The graphical method of displaying the simulation results facilitates the assimilation of a large amount of information received by students. Because of the research, electronic textbooks were prepared on the sections "Vibrations and Waves", "Conservation Laws", "Atom Structure. Atomic Phenomena. To check the effectiveness of the research on the topic under consideration, the following plan was executed:

1. Methodological support following the curriculum of the 9th grade “Conservation Laws” and “Vibrations and Waves” by developing lesson plans and electronic textbooks using interactive computer models.

2. Improving the quality of education through executing lesson plans and electronic textbooks for the 9th grade in physics, developed using interactive computer models, into the educational process.

The research results were approved during experimental searches in general education schools when studying physics. A pedagogical experiment was conducted in five schools of Atyrau and Atyrau region of the Republic of Kazakhstan to test the effectiveness of interactive electronic models. The weakest parallel classes were selected for an experimental group in each school, while the strongest classes respectively made up a control one. To validate the proposed method, identification and

control tests were conducted using interactive computer models [15]. At the ascertaining stage, tests were conducted in the control and experimental classes. Based on the results, it is possible to draw conclusions about the level of knowledge of students in the subject. The results of the knowledge assessment are shown in Figures 1 and 2. It can be seen from the diagrams that a small part of the students know and understand physics above the "satisfactory" grade. Based on the number of correct answers, the level of knowledge assimilation was determined (calculated on a four-point scale). 20 questions were asked, less than 10 tasks unsatisfactory; 11-14 tasks satisfactory; 14-18 tasks good; 18-20 tasks excellent.

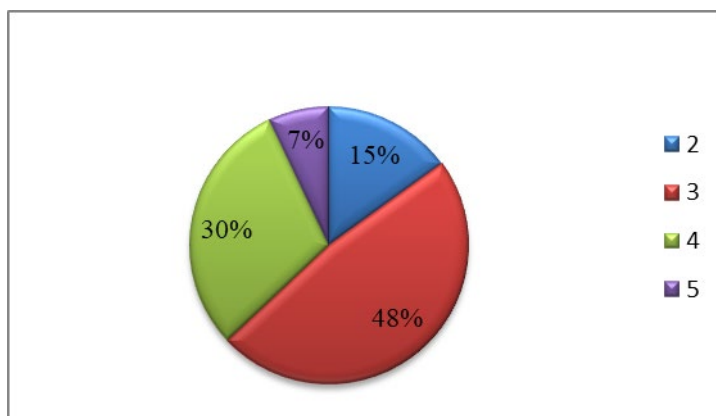


Figure 1. Levels of knowledge assimilation in the experimental classes

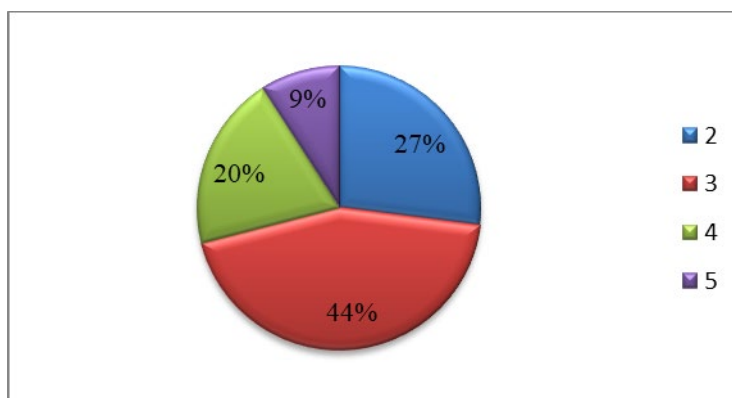


Figure 2. Levels of knowledge assimilation in the control classes

During the formative experiment, students of the 9th grade learned the topics "Conservation Laws", "Momentum", "Momentum Conservation", "Jet Motion", "Mechanical Work and Energy", "Energy Conservation and Transformation Laws". At this stage, physics lessons [10] were conducted in the experimental group using the lesson plans and an electronic textbook prepared using interactive computer models of physical phenomena. Traditional lessons were conducted without computer models in the control class. To check the fulfilment of the purpose, the authors conducted demonstration computer experiments with students of the experimental class when explaining a new topic at the

beginning of the lesson, repeating the material in the middle of the lesson, consolidating knowledge at the end of the lesson. In addition, the lesson considered experiments with students in virtual laboratories. The practical verification of the developed methodology was carried out at the stage of a control experiment. At this stage, a control test was conducted with the experimental and control classes for the topic "Conservation Laws" to confirm the research hypothesis. This was the final test given to the students of the experimental class to determine whether the computer models contributed to improving the quality of learning. The pie charts present the results in Figures 3 and 4.

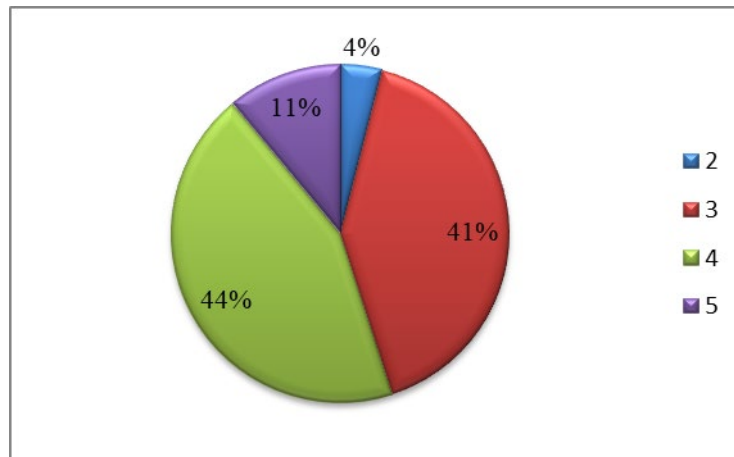


Figure 3. Levels of knowledge assimilation in the experimental classes

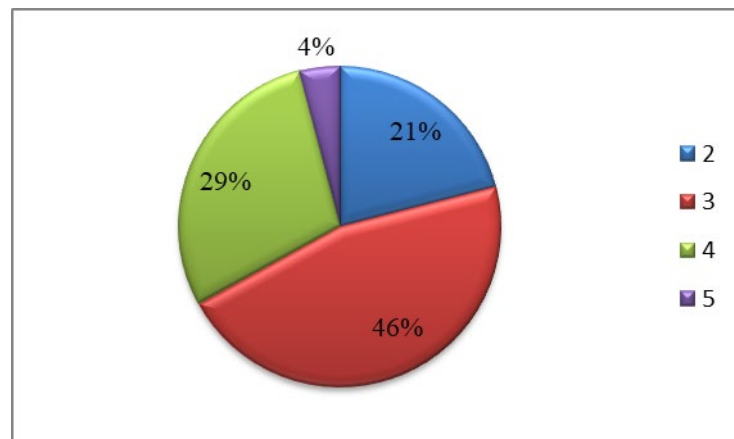


Figure 4. Levels of knowledge assimilation in the control classes

The obtained results confirm the correctness of the proposed study hypothesis, that is, comparing the results of students in the control and experimental classes on ascertaining and control tests, the authors were convinced that using interactive computer models positively affected their academic performance and level of knowledge assimilation. In the experimental classes, the quality of training increased by 1.5 times. Thus, three stages of the experimental search were implemented.

Discussion

Over the past decade and a half, interactive computer models have entered the system of physical education as one of the teaching tools. Teaching physics at school implies constant accompaniment of the course with demonstration experiments. With the advent of computer technology, it became possible to supplement the experimental part of the physics course and significantly increase the effectiveness of lessons [2; 12]. The use of computers in physics lessons turns them into a real creative process, allows using the principles of developmental learning. There is an opportunity to select the necessary material, present it vividly, clearly and accessible. In addition, a much larger number of experiments can be carried out using computers. This type of experiment is implemented using a computer model of a particular law, phenomenon, process, etc. Working with models opens up huge cognitive opportunities for students, making them not only observers, but also active participants in ongoing experiments. In secondary school, the course of physics

includes sections, the study and understanding of which requires a developed imaginative thinking, the ability to analyse and compare. In the conditions of school physical rooms, many phenomena cannot be demonstrated. For example, these are phenomena of the microcosm, or fast-flowing processes, or experiments with devices that are not present in the room. First, we are talking about such topics as "Molecular Physics", some chapters of "Electrodynamics", "Nuclear Physics", "Optics", etc. Strictly speaking, you can find chapters that are difficult to understand in any section of the physics course. As a result, students have trouble in studying them, since they are not able to visualise them.

In such situations, modern technical means of teaching come to the rescue such as computers and multimedia training programmes in physics. Using modern technologies should contribute to solving this problem in the study of physics. Using an interactive computer model as an illustrative material is one of the most popular in school, since it does not require a computer-equipped classroom and can be carried out based on a single workplace with a multimedia projector [14; 16]. Interactivity opens up huge cognitive opportunities for students, making them not only observers but also active participants in ongoing experiments. Since interactive learning is the most modern training, therefore, a hypothesis is put forward: the motivation of schoolchildren to study physics should increase using modern computer technologies. After all, the level of motivation is an important indicator of the effectiveness of the educational

process. Interactive modules make it possible to use the training time more effectively since a real frontal experiment takes more time both to prepare and to conduct. During the development of interactive computer models, teachers must find a reasonable didactically justified correspondence between computer logic and the logic of living human activity. It is important to provide special measures to stimulate educational activities, maintain positive motivation for learning, and create a favourable work regime. Interactive computer modelling makes it possible to obtain visual dynamic illustrations of physical experiments and phenomena, to reproduce their subtle details, which often escape when observing real phenomena and experiments.

It was realised that didactic materials helped students to master the management of a computer model, acquire skills to work with it, contributed to the assimilation of educational material, awareness of the need to acquire knowledge on the methodology of using interactive computer models, created a wide field of creativity in preparation for teaching physics in secondary school. The intensive development of personal computers, information technologies, and powerful supercomputers has made computer modelling one of the most effective methods for studying physical, technical, biological, economic and other systems. Computer models allow exploring easily and simply, as well as carrying out computational experiments. In this regard, we present the requirements that satisfy the model of the system under study [2]:

1. The completeness of the model, i.e. the ability to calculate all the characteristics of the system with strict accuracy and reliability.

2. The flexibility of the model, which allows reproducing various situations and processes, changing the structure, algorithms, and parameters of the system under study.

3. The duration of preparation and implementation, which characterises the time spent on creating the model.

4. A block structure that allows adding, deleting and replacing some parts (blocks) of the model.

In addition, the information support of the model, software and technical means should ensure the exchange of information with the corresponding database and convenient user operation. Using the models and flash animations in the educational process ensures the active reception of new educational materials, as well as increases the interest of students in learning. In addition, this technology increases the visibility of the perception of concepts and makes it possible to assimilate deeply theoretical knowledge, organise new, non-traditional types of educational activities for teachers, and widely use activation methods. For any stage of a lesson, you can create Flash textbooks that can be used at the stage of interpreting and consolidating new knowledge. With the help of such textbooks, it is possible to control the level of assimilation of educational material by students [17]. The programme also makes it possible to develop logical training games that can be used at the stage of consolidating knowledge. At the same time, the use of learning tools based on interactive Flash creates conditions for students to get practice-oriented knowledge. Modern technical and software tools allow creating and using models that bring objects and processes as close to reality

as possible. The combination of video and sound effects provides simultaneous effects on both organs of vision and hearing, significantly increases the information content of the educational process and the effectiveness of its perception. Different feelings are ensured during the analysis of students when exposed to the sensory organs with a colour set, sounds, oral intonations, audio-visual means of teaching, in comparison with already known ideas and concepts.

Using interactive models and dynamic Flash presentations is one of the most effective methods of introducing new information technologies in the educational process. Experience shows that students' interest in physics increases when working with a computer, their psychophysical and intellectual resources are used at the highest level, creative potential develops, horizons expand, the relationship between theory and practice is formed. Computer modelling contributes to the development of students' formal-logical and operational forms of thinking and allows them to rethink creatively modern methods of scientific cognition. If classes are held using interactive computer models, students will be able to choose a profession related to physics in the future, as they will have a more complete understanding of this subject and an increased level of understanding of the educational material.

Conclusions

Practice shows that most of the students of the experimental class began to assimilate the educational material better with the help of interactive computer models of physical phenomena, and some of them began to show a special interest in physics. Based on the analysis, it was proved that using interactive computer models increased the quality of knowledge during the lesson due to the novelty (innovation) of the activity. The more colourfully and visually teachers can give a lesson, the better they will be able to improve the students' academic performance. The survey of the students (participants of the experiment) in schools and the survey of experimental teachers showed that the motivation to perform educational tasks among students increases significantly if the educational tasks are presented in an interactive computer form. The experiment showed that the assimilation of the material will be more effective if a complex of interactive computer models is used, united not only by the generality of the topic, by the methodology of its presentation, but also by a common methodological approach to the use of each model and the whole complex.

Thus, it can be concluded that using interactive computer models in teaching physics increases the student's interest in the subject, the quality of educational materials and student academic performance. The necessity was substantiated to develop interactive computer models based on the content of the basic school physics course aimed at the formation of practical skills of students. It was shown that the multifunctional interactive properties of computer models allowed them to be successfully used in various types of work. It was revealed that the greatest advantages and possibilities of their application were revealed in the physical experiment. Having listed the main advantages of using interactive computer models in physics lessons, their use in the lesson,

we conclude: it significantly increases the effectiveness of the lesson, accelerates the process of preparing for the lesson, allows teachers to demonstrate fully their creative abilities and teaching aids. Based on the above, we note that it is possible to achieve most of what is necessary for the informal development of the physics course and the formation of a physical picture of the world with the competent use of interactive computer models of physical phenomena. The effectiveness is proved of using

interactive computer models in teaching physics in secondary school.

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None.

Conflict of Interest

None.

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Ефективність використання інтерактивних комп'ютерних моделей при навчанні фізики в сучасній школі

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Анотація

Актуальність. Дана робота стосується використання інтерактивних методів і технологій в дистанційному освітньому процесі при вивченні фізики в середній школі.

Мета. Метою роботи є виявлення можливостей інтерактивних комп'ютерних моделей і розробка дидактичних і практичних основ методики їх ефективного застосування у навчанні фізики учнів середньої школи.

Метод. У роботі використано такі педагогічні методи аналізу літератури та статистичної обробки результатів. Основними методами організації роботи з учнями є бесіда, спостереження, дослід, практична робота з переважанням евристичного характеру пізнавальної діяльності учнів.

Результати. Особливу увагу приділено формам і видам навчальної діяльності в інформаційних мережах, а також проблемам, які виникають під час дистанційного навчання. Виявлено необхідність розробки методичних основ використання інтерактивних комп'ютерних моделей у навчанні курсу фізики в середній школі. Розглянуто основні положення методики використання інтерактивних комп'ютерних моделей у навчальному процесі, методичні та дидактичні вимоги до його організації. Обговорюються перспективи використання інтерактивних методів і технологій у процесі дистанційного навчання. Розкрито потенціал інтерактивних комп'ютерних моделей та обґрунтовано доцільність їх використання у процесі навчання фізики в середній школі.

Висновки. У статті обґрунтовано важливість взаємозв'язку методологічного та технологічного підходів до розробки інтерактивних навчальних комп'ютерних моделей. Показано ефективність використання інтерактивних комп'ютерних моделей з фізики для самопідготовки учнів з метою підвищення рівня їх практичних і прикладних навичок.

Ключові слова: фізичний експеримент; дистанційне навчання; освіта; електронний підручник; викладання в середній школі.