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The effectiveness of using interactive computer models as methodological tools in science school education

Bayan Kuanbayeva†, Maxot Rakhmetov‡, Asset Turkmenbayev*, Elmira Abdykerimova* & Anar Tumysheva†

Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan†
L.N. Gumilyov Eurasian National University, Astana, Kazakhstan‡
Yessenov University, Aktau, Kazakhstan*

ABSTRACT: The article deals with the problem of methodological support in school education based on the example of the subject of physics that involves interactive computer models. The authors also draw attention to the direction of further development, when interactive computer models in education could be used as a methodological tool for self-organisation in the self-education of students. Interactive computer models are considered as a didactic, software and hardware system for learning. It includes the surrounding phenomena and objects that complement each other, and it is distinguished by mutual quality, accessibility, clarity, regularity and accuracy. The ways of improving the existing methods of teaching physics, the preparation of electronic textbooks based on interactive computer models and their use in the educational process are determined, and the effectiveness of the proposed methodology in a pedagogical experiment is also verified. The result of the experiment showed that the need for students to master software products, the ability to update and apply current knowledge in new situations is significantly increasing.

INTRODUCTION

The capabilities of information and telecommunication technologies are growing rapidly with the advent of a global network and their intensive integration into all service development [1].

These technologies have also been integrated into the process of education, including on-line accessibility of educational resources and tools, provision of on-line courses, communication and educational networks and platforms. The dynamic technological advances have a significant impact on modern education and culture, as well as on creating conditions for the development of innovative teaching methods.

The main types of computer educational tools include:

1) General purpose service software [2].
2) Software tools to monitor and measure the level of education, business and professional skills of students [2].
3) Information retrieval reference systems [2].
4) Electronic textbooks. General purpose service software can be used to automate day-to-day calculations, design training documentation, process experimental study results, laboratory and practical exercises, and to organise independent and design work of students [3].

Electronic textbooks are considered one of the main electronic learning tools. They should ensure the continuity and completion of the teaching/learning cycle through interactive feedback. One of the main advantages of electronic textbooks over their paper equivalents is - as the name implies - their electronic format that integrates the content with the method/feedback. So, when the content is printed it leads to the loss of special didactic qualities inherent in electronic textbooks [4].

Those actively involved in the development of electronic learning tools (ELTs) should be sufficiently trained to use them in the educational process. The requirements for a teacher in this new environment should include traditional requirements for any teacher and special requirements related to the use of modern information technology and electronic educational resources. The traditional requirements involve [5]:

1) Organisational skills (work planning, student association’s formation, etc) [5].
2) Didactic abilities (specific skills in the selection and preparation of educational material, use of technology, presentation of educational material in an accessible, clear, expressive, convincing and consistent form, stimulation of development of cognitive interests and spiritual needs) [6].
3) Communication skills (interaction with pupils, their parents, colleagues, educational networks, establishment of adequate pedagogical relations with the heads of the institution) [7].

4) Predictability and the ability to factor in the emotional impact of studying on students.
5) Research (ability to know and objectively assess pedagogical situations and processes).
6) Scientific knowledge (the ability to acquire scientific knowledge in the chosen field) [8].
7) Subject (vocational education by subject).

In the case of the creation and use of electronic learning tools, such requirements differ significantly. For example, it is difficult to imagine how predictability and receptivity can be demonstrated when communicating on a resource forum [9].

In practice, in the creation and use of ELTs, some of the traditional pedagogical features may be lost, especially non-verbal means of communication: expressive movements (footsteps, gestures, facial expressions, etc), haptics (handshake, touch, etc), proxemics (direction, distance), prosody and extra linguistics (intonation, volume, timbre, delay, laughter, etc) [10].

In addition, specific requirements for working with ELTs include: didactic skills of a teacher and the ability to use information and telecommunication technologies, knowledge of the principles of interface structuring, ability to create on-line content and use visualisation for on-line-educational resources full familiarity with the methods of determining the quality of such resources, mastery in the techniques of practical design of educational resources within the framework of teaching the given (*own*) subject [11].

Also, the main activity of the teacher - the management of the processes of education, upbringing and development should remain relevant at all times [12].

Based on these requirements, the authors of this article have developed a training system that involves interactive computer models (ICMs) based on the example of training in physics, and they are also developing an Internet portal containing a forum. The uniqueness of this project is that it has the functionalities of general-purpose service software, it includes software tools for monitoring and measuring the level of education, and information and reference resources [13].

There are other works that are aimed at conducting and further developing ICMs as methodological tools for independent work of students [14].

RESEARCH FRAMEWORK

Intensive computerisation of modern education is constantly expanding the space of information and interaction through the introduction of new electronic resources and communication channels into the education system.

It is indisputable that the effectiveness of the introduction of electronic educational content in the educational process, as well as the effectiveness of students' learning at different levels of general education school, often depends on the quality of content development and methodological aspects of all structural components of traditional education combined with digital components. Therefore, the use of electronic textbooks, multimedia, animation, ICMs and the development of methodological theoretical and practical bases for their use to enhance the physics course - which is considered in this article - with new learning tools requires constant improvement.

The ICMs are new information technologies that allow dynamic images to be displayed in different information representations by integrating statistical visual information (text, graphics, colour) and dynamics (animation) [15][16].

They are an element of the suite of e-learning tools. The modelling method is currently one of the leading methods in the cognitive process, and the use of computer models in the educational process provides an opportunity for students to get familiar with this cognitive method, and for the teacher to expand the possibilities of presenting educational information.

Currently, there are many educational programmes that include different types of educational computer models, but despite the diversity of them, their use leads to some difficulties, as the methodological framework is insufficient.

In the broad review literature conducted by the authors of this article, several works have been identified, which indicate the didactic potential of ICMs that can be effectively used in a variety of educational activities.

There are a number of researchers that investigated the possibilities of computers and didactic requirements for software products in increasing the efficiency of the educational process, including V.P. Bespalko, B.S. Gershunsky, A.A. Kuznetsov, I.V. Robert, E.A. Pervushkina and U.K. Sitnikov.

Scientists who gave priority to the use of ICMs in improving the methods of teaching physics are: H. Gould, A.A. Ezov, V.A. Schoozchikov, S.E. Kamenetsky, N.A. Soloduhin, K.A. Kokhanov, R. Razmer, N.E. Rumbeshty.

Scientists who provided a complex description (philosophical, cybernetic, pedagogical) of interactive computer modelling used in the process of training, and also psychological and pedagogical requirements for computer-based models of training include: D.V. Bayandin, M.V. Bogdanova, A.F. Kavtrev, V.V. Levitsky, I.V. Pabolkov, N.B. Rozova, O.G. Revinskaya, O.N. Sharov and others.

Researchers that focused on the theory and algorithms in their studies on distance learning and interactive computer modelling of physical phenomena include: T.A. Belyaev, E.I. Boutikov, I.M. Gorbachenko, A.G. Dorrer, P.M. Zhdanovich, N.P. Emets, G.V. Efeyeva, N.A. Ospennikova, D.A. Savateeva and others.

The distinctiveness of these studies, which determine the methods of computerisation in teaching general physics, is that the theoretical basis of the pedagogical goal is formulated, tools and methodological bases for the use of computer models are created, thus ensuring continuity, The high-quality content and methodological continuity are essential in the study of the physical foundations of physical phenomena in the course of general physics.

Didactic possibilities of computer technologies in the Republic of Kazakhstan were discussed by a numer of authors: Zh.A. Karaev, E.Y. Bidaibekov and N.N. Kerimbayev focused on scientific and theoretical bases of development of informatisation in physics education; S.N. Nurkasimova and A.E. Ashurov on computer-based teaching methods of physics; A.A. Isahovu on mathematical and computer modelling of physical processes; E.A. Abdykerimova on improvement of methods of teaching physics with the help of physical computer models, etc.

Through this literature review that centred on Kazakhstan and the region's studies it has been established that the introduction of information technologies in the educational process, the problems of independent training, organisation of distance learning, creation of various test programmes and the organisation of virtual laboratories have been solved. Also due to the structure of educational programmes, priority is given to research.

In contrast to above-mentioned works, the study presented in this article had a specific focus as it was designed to improve the development of textbooks, and particularly to enhance a new type of handbooks based on the active use of teaching materials, updated curricula and modern computer technologies. That enhancement was undertaken in view of the didactic potential of computer technologies and the opportunities created by the comprehensive use of these technologies in the educational process.

After all, in some modern educational programmes, the technological side of the educational material has priority over the pedagogical component. The creation of an education system based on methodological, didactic, psychological and pedagogical requirements and appropriate methods determines the relevance of the research problem.

USE OF INTERACTIVE COMPUTER MODELS IN PHYSICS EDUCATION - RESULTS

An analysis was undertaken of the work done by students, teachers and methodologists that were involved in the study on ICMs used in physics: research, design, demonstration. Figure 1 and Figure 2 are examples demonstrating the ICMs that were developed in accordance with the required didactic methods of using such models as educational tools.

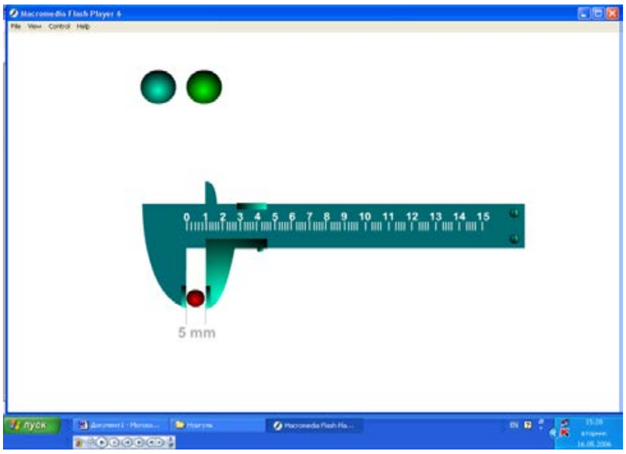

Figure 1: Computer interactive model - measurements.

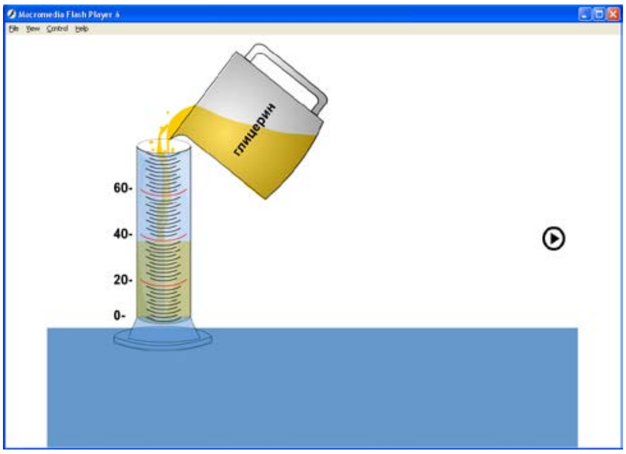

Figure 2: Computer interactive model - the operational principles of a calliper.

There are great opportunities for physical and interactive computer models in the organisation of the educational process, including the possibility of creating a unique picture of changes, demonstrating physics laws or establishing larger-scale models for research work. With the help of such models, it is possible to develop appropriate activities and establish priorities; one could create models to acquire specific measurement values and that reflect individual preferences, necessary for the resolution of educational tasks.

The ICMs involve task simulation, the use of which allows for a better organisation of research and laboratory work. They have an illustrative role, demonstrating a number of functions with the purpose of forming foundations for specific and logical, concrete and abstract knowledge. The specific and logical *moussing* that comes with interpretation increases the relationship between real-life and abstract knowledge.

The research work outlined in this article was prepared by electronics teachers for different heads of the physics subject of 9th grade classes.

In order to ensure the effectiveness of the methodological provision of physics education with the help of ICMs, the following plan was implemented:

1) preparation and methodological provision of educational materials for the physics subject for 9th grade classes on the basis of ICMs.
2) improving the quality of education through the introduction of ICMs into physics education - quality didactic materials and electronic textbooks.

The pedagogical experiment was carried out simultaneously in the process of physics education for 9th grade classes in four schools of the city of Atyrau, Kazakhstan. Each school consisted of two classes, experimental and control classes.

Experience-intensive Work with Construction and Control Stages

At the same time, tests with the control and experimental classes were conducted on the topic of *basic dynamics*.

According to the number of correctly chosen answers, the level of knowledge acquisition was determined and calculated on a four-point scale: 5 - very good; 4 - good; 3 - satisfactory; 2 -] unsatisfactory. Figure 3 and Figure 4 show the results of the *detection* experiment for both the classes.

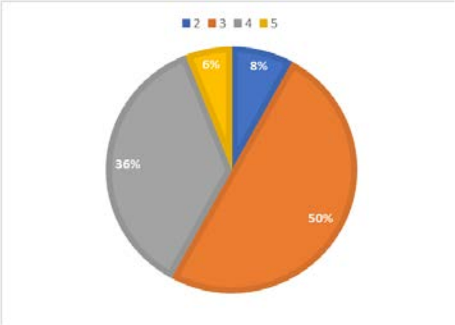

Figure 3: Results of the *detection* experiment (control class).

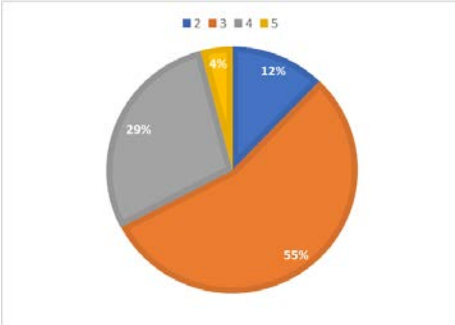

Figure 4: Result of the *detection* experiment (experimental class).

During the experiment, students in the experimental group were taught with ICMs, while the control classes followed the traditional approach. The practical proof of the effectiveness of the proposed method was at the control stage of the experiment. During this stage, a control test on the topic of the *law of conservation* was conducted, which was supposed to confirm/refute the hypothesis of the research.

This was the final test, conducted with interactive computer models in the experimental classes, which improved the quality of training as demonstrated in percentages in Figure 5 and Figure 6.

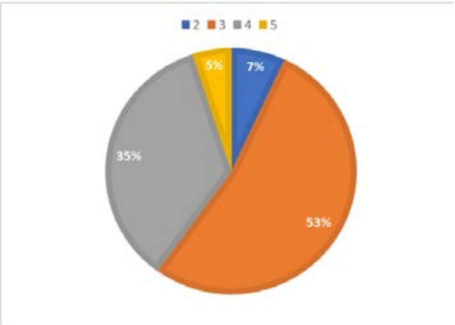

Figure 5: Results of the *control* experiment (control class).

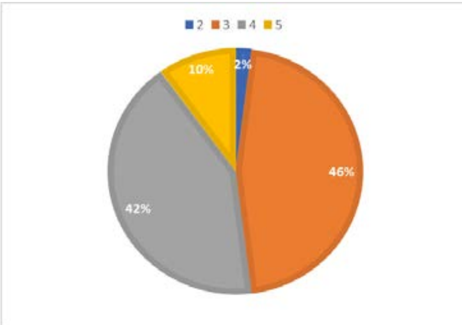

Figure 6: Results of the *control* experiment (experimental class).

It was found that the quality of training increased by 1.6 times in comparison with the results of the *detection* test and the *control* test of the experimental classes. These findings clearly indicate that the rational use of ICMs in physics lessons has a positive effect on students' independent acquisition of educational material, and thus their overall academic performance.

DISCUSSION

In the process of teaching physics, computer educational programs can be divided into: reference, calculation, testing and modelling. Reference programs as used in this article are databases that provide students with access to reference information needed for their studies. Programs for processing and interpreting experimental results are called calculations. Calculation programs are very useful when students perform complex calculations, create diagrams and graphs describing the dependence of parameters, and use l-micro measuring modules.

Testing programs provide an objective and unbiased review of students' past materials. Simulation programs are programs that provide the user with a computer model of a physical phenomenon or object. In the process of teaching physics, computer models are used when it is impossible to use physical equipment/objects or observe real-life phenomena due to their poor accessibility (or simply lack of equipment), low visibility or safety recommendations (when they pose danger to life or health).

Today, ICMs are considered as advanced programs of computer-aided learning. Such programs include the core part, surrounding phenomena and objects, complement each other in different ways in quality, availability, clarity, consistency and accuracy.

On the Internet, there are many on-line educational resources and sites where models can be used - this is a didactic, software-technical environment for teaching students, regardless of where they are and at what time they want to learn. In the modern world, there should be no school without computers.

However, it is necessary to improve the methodological guidelines for using computers in the classroom, taking into consideration the basics of interdisciplinary interaction. This is one of the main problems in self-education of students in today's schools. First of all, it is necessary to create electronic educational programs and educational resources, electronic textbooks, methodological tools for students' use, educational tools with a convenient and understandable interface, the same as the school curriculum.

Experience shows that the school needs electronic textbooks in the Kazakh language, ICMs for demonstrating physical phenomena and methodological tools for their use. What is necessary can be achieved by the competent use of ICMs of physical phenomena for the informal mastering of a physics subject and for the formation of a *physical* image of the world.

CONCLUSIONS

Based on the conducted literature review on using ICMs in education, it was found that the problems of computerisation of education are widely considered, but the research studies related to the creation of ICMs and their use for physics education are insufficient. The structure of physical interactive computer models is poorly developed, and manuals for the use of interactive computer models are very rare.

During the pedagogical experiment, it was observed that the experimental classes had a high level of competence in information/knowledge acquisition, most of them mastered the educational material well using the ICMs, and some of them began to show special interest in the subject of physics.

In the future, if educational materials aimed at independent learning are provided methodologically based on ICMs, educational activities aimed at forming students' knowledge, skills and entrepreneurship will be much more effective, the level of understanding of the subject will increase through the use of such educational materials, and physics-related specialisations will increase. The authors are sure that the number of choices will also increase.

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