Development of e-learning resources in the discipline of «Physical chemistry» and study of its effectiveness

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Abstract.
This article is devoted to the development of an electronic educational resource on the discipline «Physical Chemistry» and the study of its effectiveness. The paper examines the process of creating an electronic educational resource, defining goals and objectives, structure, methods of presenting the material, as well as conducting an efficiency study using the example of this discipline.

Keywords:
electronic educational resource
physical chemistry
efficiency
learning
interactivity
Introduction. Modern education is increasingly focused on the use of digital technologies, including electronic educational resources. The discipline of Physical Chemistry requires a deep understanding of the theoretical foundations and practical skills. The development of an electronic educational resource can greatly facilitate the learning process and increase its effectiveness.

Literature review. In modern conditions of universal informatization and the development of information technologies, the ways of obtaining and perceiving information are also changing. This is especially evident in the modern generation, which has been receiving information from various electronic sources since childhood. The Internet is a place for leisure activities, social networking, but also a working tool in gaining knowledge. Teaching methods should correspond to modern realities; therefore, more and more systems are appearing in the educational process to ensure the availability of educational and methodological materials in electronic form, called electronic educational resources. An electronic educational resource (hereinafter referred to as EOR) is electronic materials intended for use in the process of implementing educational programs and developing ideas for preparing and transmitting information to a student using information and computer technologies. Their application contributes to the implementation of the following tasks:

- to support and develop the systematic thinking of the student;
- support of all types of cognitive activity of the student in the acquisition of knowledge, development and consolidation of skills and abilities;
- implementation of the principle of individualization of the educational process while maintaining its integrity.

N.G. Gureev [1] notes that the textbook on physical chemistry, made in electronic form, performs new roles and functions, because it can simultaneously be a simulator and a controller in the course of independent work, and, consequently, significantly increases the effectiveness of training. The authors [1] have accumulated a fairly large amount of information and methodological material using
computer technologies and have begun the development of an electronic textbook.

E.E. Goncharenko [2], considering the problem of innovations in the process of teaching physical chemistry, also notes the huge role of computer technology. In this regard, a didactic complex of information support for the discipline was created for students studying the discipline «Physical and colloidal Chemistry». It includes a database necessary for completing two homework assignments and five laboratory works in a computer workshop, as well as a set of other didactic tools and methodological materials that ensure the learning process.

T.L. Anisova [3] suggests using MS Excel to solve problems in physical chemistry. The paper shows an example of solving a problem in chemical kinetics. It should be noted that the entire process of solving the problem is performed by the students themselves, i.e. the program acts only as a tool, and ready-made forms and already developed information environments are not offered.

N.V. Zhukova [4] reports on the development of an electronic educational resource on physical chemistry, containing six substantive blocks: «Aggregate states», «Basic Laws of Thermodynamics», «Thermodynamic equilibrium», «Chemical kinetics», «Solutions of nonelectrolytes», «Solutions of electrolytes» [5]. Each block consists of a theoretical part that reveals the main issues of the block; simulator tasks with a detailed solution; simulator questions, which are test tasks with feedback; a control test designed to carry out the current control of students' knowledge. In addition, the student has all the necessary reference material for solving tasks.

Materials and methods:
To develop an electronic educational resource on the discipline «Physical Chemistry», goals and objectives were defined, the structure of the resource was developed, methods and forms of presentation of the material were selected [6]. To study the effectiveness of the resource, an experimental study was conducted using intermediate testing. The purpose of the work is to develop an electronic educational resource on the discipline «Physical Chemistry» and analyze the study
of its effectiveness using electronic educational resources in the process.

When developing an electronic educational resource on the discipline «Physical Chemistry», the following principles were observed:

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<th>Principles observed when developing an electronic educational resource for the discipline «Physical Chemistry»</th>
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<td><strong>1. The principle of information accessibility</strong></td>
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<td>Providing convenient access to materials and assignments for students. For example, in chemistry, animations, simulations, and interactive reaction demonstrations can be used to explain the principles of chemical kinetics.</td>
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<td><strong>2. The principle of interactivity:</strong></td>
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<td>Creating assignments and exercises that allow students to actively participate in the learning process. For example, the development of virtual laboratories where students can conduct experiments and observe the results.</td>
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<td><strong>3. The principle of individualization of training</strong></td>
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<td>Providing students with the opportunity to choose the pace and format of learning, as well as receive personalized feedback. For example, creating tests with different difficulty levels for different groups of students.</td>
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<td><strong>4. Multimedia principle</strong></td>
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<td>Use of various types of content (text, video, audio, images) for a more complete and visual presentation of the material. For example, in chemistry, you can explain the laws of physical chemistry using video lectures and graphical diagrams.</td>
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<td><strong>5. Principle of performance assessment</strong></td>
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<td>Implementation of a system for tracking and assessing student progress in order to analyze the effectiveness of the educational process and make adjustments to the operation of the resource. For example, using online tests and surveys to assess students' knowledge.</td>
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**Results:** The developed electronic educational resource allowed students to study the discipline “Physical Chemistry”
more conveniently and effectively. Interim testing showed an improvement in students’ mastery of the material, which indicates the positive effectiveness of the resource.

Thus, at present, in the process of teaching physical chemistry, various electronic educational resources and electronic educational resources and methodological manuals are quite actively used, and attempts are being made to introduce electronic practical and laboratory work.

To successfully master the discipline “Physical Chemistry,” an electronic educational resource has been developed in the discipline “Physical Chemistry (EER) for students enrolled in undergraduate programs of various specialties. So for the specialties: Chemical technology of synthetic biologically active substances, chemical pharmaceuticals and cosmetics; chemical technology of organic substances is widely used by ESM students [7]. When constructing the EER, a multi-level modular principle was applied, because it is known that a well-structured EER not only provides quick and convenient access to electronic educational resources and materials, but also helps to plan course mastery and contributes to more rhythmic and effective student work during the semester.

All lecture material in electronic form is included in the electronic educational resources of the discipline “Physical Chemistry” and is issued to students, which contributes to the successful completion of the course.

The lecture course is conducted using electronic presentations shown on a projector. This allows:
- visually present mathematical formulas, use a large and clear font, which makes it easier for students to understand and speeds up the process (compared to using a traditional blackboard);
- display portraits of scientists, accompanied by a short story, which increases interest in the classes;
- show drawings and graphs with animation – this improves the perception and memorization of dependencies and helps students concentrate.

Video lectures have been developed for some sections of the course. In addition, to increase motivation for studying physical chemistry, a video film “The Emergence of Physical
Chemistry” was created, which in a bright and entertaining form tells about the period of formation of chemical science, preceding the emergence of physical chemistry. The prerequisites for the emergence of physical chemistry, the features of this process are shown, the outstanding scientists who contributed to the formation of this science and the main quantitative laws that formed its basis are described.

When working in practical classes, special presentations are used: they are designed in such a way that the formulas necessary for solving problems appear gradually, at a speed set by the teacher. This facilitates the flow of dialogue with the student, gives the student time to think about the problem, and not copy everything off the screen.

To solve problems that require lengthy calculations, special calculation programs have been created. These programs are used:
- to calculate changes in the extensive properties of a system due to the occurrence of a gas reaction in it;
- to determine the molar excess isobaric heat capacity of a solution;
- to determine the partial molar isobaric heat capacities of the components of a binary solution;
- to determine the molar volumes of mixing during the formation of binary solutions;
- to determine the most probable chemical reaction occurring in a multicomponent gas system;
- to calculate the equilibrium composition of the gas system formed during the cracking of hydrocarbons;
- to calculate the equilibrium composition of an ideal gas system when several reactions occur in it;
- to calculate changes in the extensive properties of a system when a heterogeneous reaction occurs in it.

These programs, created on the basis of Excel, allow the student to make calculations much faster than manually. In addition, in the programs, before the actual calculations, all the necessary formulas are given, there are explanations of the symbols included in these formulas, and approximate graphical dependencies of the properties being studied are shown. Such repetition of theoretical material undoubtedly contributes to its better assimilation. The use of these
programs is possible both in the department’s PC room and on a home PC.

For independent work of students when doing homework and preparing for intermediate tests, electronic educational resources and methodological manuals are provided with detailed explanations for solving problems in physical chemistry [8]. More complex problems, which were presented at several All-Russian Olympiads in physical chemistry, are discussed in a special electronic educational resource manual [9]. They are also issued to students electronically. In addition, all necessary reference materials are prepared electronically and given to students for work.

The use of information technology in laboratory classes includes entrance computer testing and electronic laboratory work, which is carried out along with experimental laboratory work.

Entrance computer testing (remove repetition before laboratory work) allows you to assess the student’s readiness to perform laboratory work. Currently, the department uses MyTestX for testing - a software system (student testing program, test editor and results journal) for creating and conducting computer testing, collecting and analyzing results, and assigning grades on the scale specified in the test. The tests compiled in this program for the disciplines of the department are based on different types of tasks: single or multiple choice, establishing the order; establishing compliance; an indication of the truth or falsity of the statements given.

Electronic laboratory work has a number of advantages over experimental work (fig. 1).

Electronic laboratory work covers almost the entire physical chemistry course. There are works on the following topics:
- Constructing fusibility diagrams for various systems.
- Calculation of changes in the extensive properties of a system due to the occurrence of a gas reaction (homogeneous and heterogeneous) in it.
- Determination of partial molar isobaric heat capacities of the components of a binary solution.
- Determination of molar volumes of mixing during the
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formation of binary solutions.
- Determination of the molar excess isobaric heat capacity of a solution.
- Determination of the most probable chemical reaction occurring in a multicomponent gas system.
- Calculation of the equilibrium composition of the gas system formed during the cracking of hydrocarbons.
- Calculation of the equilibrium composition of an ideal gas system when several reactions occur in it.
- Construction and analysis of boiling diagrams of binary systems.
- Determination of rates of chemical reactions using a kinetic curve.
- Determination of partial reaction orders by the integral method
- Determination of partial reaction orders by the Ostwald-Noyes method.
- Determination of particular reaction orders by the differential method.
- Calculation of the activation energy value.

1. Since they are not directly related to reagents, they can simulate working with substances that, due to safety precautions, cannot be used in student practical work, for example, the use of methanol, benzene, etc.

2. Sometimes electronic laboratory work simulates the use of high-temperature instruments, which also cannot be implemented in a student laboratory workshop.

3. Electronic laboratory work is often based on data, the obtaining of which in experimental conditions goes far beyond the time allotted for laboratory work and on equipment that is not available in the laboratory workshop.

4. Safety and environmental friendliness. Conducting experiments in a virtual environment eliminates the risk of possible accidents and avoids the use of hazardous chemicals.

Figure 1
Benefits of electronic laboratory work
Guidelines for such work are available in both paper and electronic versions; some works are combined into workshops [10].

To test students' knowledge within the framework of intermediate control - differentiated testing, it is also convenient to use developed computer tests in physical chemistry.


The number of students who used the development was 100%. A survey of students showed that the use of electronic courses in electronic educational resources in the new process makes the presentation of electronic educational resources with information more interesting and memorable. A flexible schedule for completing assignments, the comfort of studying at home, a more relaxed schedule, and the ability to access theoretical material at a particular convenient time are convenient.

At the initial stage of testing electronic courses, lagging students had no correlation between grades for intermediate knowledge control tests taken on electronic educational resources on a non-university portal and grades obtained using the traditional method of conducting classroom lessons with solving proposed problems and individual assignments. Subsequently this problem was resolved. In general, the use of an extensive database of test tasks for intermediate control of material mastery, as well as for solving practical problems, has shown their high efficiency.

An analysis of the experience in the development and practical application of electronic courses in the disciplines “Physical Chemistry” showed that their implementation makes it possible to activate and increase the productivity of electronic educational resources of the process, creates motivation for studying the discipline, and makes it possible to visually present electronic educational resources and information. An important property is interactivity, modularity of the structure, focus on independent development, technological and content continuity of the various stages of teaching the discipline, professional orientation, and integrated use of multimedia.
Thus, the use of electronic courses in the disciplines “Physical Chemistry” made it possible to improve the quality of training, facilitate the study of electronic educational resources, and make the learning process more attractive for students. The best results were shown by students of the specialty “Training of Chemistry Teachers” who studied the “Physical Chemistry” course. All students passed the exam on time (100%) with positive marks, the average score of the group was 6.9 points, of which two students received marks of “ten”, four – marks of “eight”, one student received a mark of “four”.

Based on the practical experience gained in introducing electronic courses in the disciplines “Physical Chemistry” into the electronic educational resource process, it is planned to develop similar electronic courses for students of all specialties, taking into account the specifics of their educational standards, as well as further improvement and expansion of the base of test tasks, lecture multimedia classes, implementation in electronic educational resource process of computer programs for practical classes.

**Discussion.** Thus, in the process of teaching the discipline “Physical Chemistry”, the use of information technologies is implemented at all stages of training. These include electronic presentations at lectures and practical classes, and special calculation programs for solving problems, and electronic laboratory work, and computer tests before laboratory work and for intermediate control, and methodological and reference materials in electronic form. All these modern forms of training are organically combined with traditional ones (experimental laboratory work, traditional forms of testing, etc.). All this undoubtedly contributes to the successful mastery of the discipline by future engineers and the creation of a solid foundation for their study of special subjects.

**Conclusion.** Thus, the use of an electronic educational resource in teaching the discipline “Physical Chemistry” allows students to independently study the material, carry out interactive tasks, and increase motivation for learning. This contributes to a deeper assimilation of knowledge and development of skills.

The development and use of an electronic educational resource in the discipline “Physical Chemistry” is an
effective tool in modern education. Such resources help students learn more effectively, interactively, and independently, thereby enhancing learning and developing competencies in physical chemistry.

References:


