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RESEARCH OF THE EFFICIENCY OF USING SOFTWARE PRODUCTS FOR SIMULATION OF PHYSICAL PROCESSES

Abstract. The introduction of new information and communication technologies in the educational process requires a transition to a new high-quality level of teaching physics, the revitilization of students' educational activities.

The successful use of pedagogical software helps the teacher to present educational material at a high and quality level, to control educational activities, to increase the self-organization of the educational process.

Computer demonstrations can be an organic part of any class and effectively help the teacher and learners. Some physical processes or phenomena cannot be observed visually in the laboratory. Modeling of various phenomena certainly does not replace "live" experiments, but in combination allows explaining the meaning of a particular educational material at a higher level.

This article discusses the practical use of pedagogical software products for modeling physical processes: software product "Laboratory work "Study of hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5", mobile application "Pedometer", software product "Educational software in physics. Electrodynamics".

Software products form subject of competencies in physics. There is a more complete realization of students' potential resources in the process of forming new knowledge about basic physical principles and approaches to the study of processes in living nature, physical and technical principle of the functioning of devices, the use of mathematical methods in research. Solving professionally oriented tasks and performing laboratory work in physics improves the quality of the professional component of education. The priority of computer models is that the process of

their perception takes place in the same way as the process of perception of real objects, increasing the success of learning.
The authors carried out an experimental test on the effectiveness of implementing the proposed pedagogical software products in the educational process in physics. The article presents the results of experimental research at the Volodymyr Vynnychenko Central Ukrainian State Pedagogical University, which showed positive changes in the attitude of students to the study of physics.

Keywords: physics; information and communication technologies; pedagogical software; virtual laboratory work; pedagogical experiment.

1. INTRODUCTION

Statement of the problem. The development of scientific and technological progress, the widespread introduction of automation systems for physical and mental work, requires the education to increase the demand for the level and quality of professional training of future specialists, to increase the role and importance of the theoretical stage of training, one of the structural elements of which is a training course in Physics [1].

Increasing the success of education through the activation of students' educational activities, and thus the attainment of a new qualitative level of physics training is achieved through the introduction of information and communication technologies (ICT) in the educational process [2]. Achieving positive results is possible because it makes the process of teaching physics more visual and interesting. The combination of ICT with traditional methodology makes it possible to increase the motivation of teaching physics, to lay a solid foundation of knowledge in physics that contributes to a better assimilation of the necessary educational material of professional direction [3].

Pedagogical software is a type of ICT that is successfully used in higher education. Pedagogical software helps the teacher to explain the lecture material at high quality level, to control the educational activity, to increase the self-organization of the educational process by students, to promote deep learning of any discipline, in particular physics [4].

Analysis of recent research and publications. The use of information and communication technologies in the educational process is considered in the works of such scientists as V. Bykov [5], V. Zabolotnyi [6], N. Morze [7], O. Pinchuk [8], M. Shyshkina [9] and others.

The development and application of educational tools based on ICT and the creation of methodological support for their use are presented in the works of scientists: M. Acher, R. Lopez-Herrejon, R. Rabiser [10], O. Kuzminska, N. Morze [7], S. Mirn [11], V. Oleksiuk [12], S. Semerikov, A. Striuk [13] and others.

A thorough scientific search indicates development of author's pedagogical software products for educational process of higher education institutions. Thus, the problem of design and development of author's pedagogical software products is expanded in the works of scientists: Yu. Dementiev, L. Burulko, E. Suvorkova [14], St. Coomans, G. Lacerdab [15], L. Sukhovirska, O. Lunhol, O. Zadorozhna [4], P. Gao, A. Nagel, H. Biedermann [16], A. Drach [17] et al. However, this scope of research is characterized by the lack of sufficient viable data on the methodology of implementation author's pedagogical software products for modeling physical processes and their application in the professional activities of future professionals in various fields in our country.

Therefore, **the article's goal** is to show the practical use of software products in the educational process of educational institutions and to investigate the effectiveness of the use of pedagogical software products for modeling physical processes.

2. RESERCH METHODS

The theoretical and empirical research methods included the analysis of psychological, pedagogical, methodological and professional literature. Conducting a pedagogical experiment; pedagogical observation; systematization of students' academic performance and projects; generalization of lecturers' experience during the introduction into the educational process of author's software products of Ukrainian production.

Olha Slobodianyk formulated the main provisions for modeling physical phenomena and processes, which are the basis for the development of a mobile application "Pedometer" for its implementation in a physical practicum on "Mechanics".

Vladylena Fedorenko conducted a content analysis, generalization, comparison of different views on the problem of implementing software products in the educational process of medical education institutions, in particular in the Kryvyi Rih Medical College. She described the implementation of the method of combining virtual and real educational experiments in the preparation and implementation of physical practicum in the sections "Hydrodynamics" and "Electrodynamics".

Vasyl Bolilyi is the developer of the mobile application "Pedometer", proposed, described and implemented a mathematical model of counting steps.

The author's contribution of Vitalii Dmytruk was to analyze and determine the psychological and pedagogical features of the innovative technologies introduction in the educational process of institutions of higher education in the humanities. The problem of formation and development of subject competence of students in the process of solving physical problems is substantiated.

Valerii Kushnarov studied the didactic possibilities of web-applications and services, on the basis of which modern means of teaching physics have been developed. The author conducted an experimental test of the software products implementation effectiveness described in the article, which confirms the feasibility of their use in the educational process and testified to the increase in the efficiency of students' learning activities.

3. RESERCH RESULTS

We have tested the indicated author pedagogical software products "Laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5", "Educational software in physics "Electrodynamics" and mobile application "Pedometer" [18] – [24], in the course of teaching the disciplines of the physics cycle in various educational institutions. As a result, we established that these software products are aimed at:

- fuller realization of students' potential resources: development of interest, creativity and students' motivation to study discipline Physics;
- formation of students' new knowledge about basic physical principles and approaches to the study of different processes in nature;
- study of physical and technical principles of device functioning;
- the use of mathematical methods in research.

The priority of such computer models is that the process of their perception occurs in the same way as the process of perception of real objects, increasing the success of vocational training.

The effectiveness of teaching physics in the process of training future specialists should be expressed in the ability to recognize the situation as a whole by its specific characteristics, as well as by incomplete information about it; to make inductive conclusions, that is, to summarize individual facts into a single system; solve problems with no single algorithm that requires flexibility and the ability to adapt to changing conditions that are difficult to predict in advance.

The combination of information and communication technologies with traditional methods of teaching, has allowed to increase the motivation of teaching physics and to form a solid foundation of knowledge for future specialists.

Developed by a team of authors [4], [20], [21], [22] software product "Laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5" is used in the study of the topic "Hydrodynamics" (Fig. 1).

Fig. 1. Heart-lung machine SORIN C5

Laboratory work in physics is one of the powerful means of enhancing the educational and cognitive activity of students, since it allows them not only to get acquainted with the theoretical material, but also to gain practical skills in measuring and calculating physical quantities, their errors, to analyze the results obtained and draw appropriate conclusions.

The complex implementation of real and virtual laboratory work provides for students to conduct research aimed at a multifaceted study of physical phenomena and processes with subsequent analysis and generalization of the results. Real and virtual experiments are performed to study a physical phenomenon in its various manifestations, in a wide range of parameters, using both a real object of cognition and an idealized one. This approach allows students to obtain more complete and accurate information about the phenomenon or process being studied: independently determine the external signs by which a physical phenomenon can be detected and distinguished from others; to establish the conditions of the physical phenomenon; to identify and understand the essence of this phenomenon; independently develop a mathematical model of a physical phenomenon and determine the limits of its use; to establish a functional dependence between physical quantities and to determine the limits of physical law [25].

The software "Laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5" is based on the Object Pascal programming language in Delphi 6. The software consists of 10 files with a total size of 63 MB. Its small size makes it easy to install and use.

The main sections of the software are "Theoretical information", "Structural elements of the Heart-lung machine SORIN C5", "Glossary", "Web-resources", "Performing laboratory work", "Start".

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In the "Start" section begins virtual implementation of the laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5" (Fig. 2).

Fig. 2. Virtual laboratory

The developers have clearly defined the structure of the laboratory work and the automatic verification of the entered data correctness.

Solving professionally oriented problems and performing laboratory work in physics classes improves the quality of training, forms practical skills and abilities that are manifested in practice in real technical systems (for example, during the work with medical equipment).

Using the software product "Educational software for physics. Electrodynamics" is an example of implementing the methodological system of teaching the section "Electrodynamics" [3], [18], [19]. This software is used during practical classes, laboratory works, consultations in order to acquaint students with new theoretical material, test theoretical knowledge, skills and ability to solve problems, to develop students' skills of independent educational activity.

The software is based on Action Script 2.0 programming language in Adobe Flash Professional CS6. ActionScript tools allow the developer to provide the ability for a user to perform certain actions in a clip, that is, make the user an active participant in the viewing.

Software "Educational software in physics. Electrodynamics" consists of 45 Flash Movie files that are imported into one main shell-file "Electrodynamics.swf" and consists of two main sections: "Theoretical Information" and "Problems Solving".

The "Theoretical information" section is an electronic textbook of the "Electrodynamics" module. It contains the main key questions of this section in physics, but there are additions and extensions of these questions with theoretical information on the construction direction. The "Theoretical information" section is also filled with animation drawings, sound effects and explanations for theoretical material (Fig. 3).

Fig. 3. The interface of the window "Theoretical information. Electromotor"

Section "Problems Solving" includes qualitative and quantitative tasks of the construction direction in "Electrodynamics" section: "Fuses", "Generator", "Transformer", "Battery", "Power Plants", "Capacitor", "Electromotor" (Fig. 4).

Fig. 4. The interface of the window "Solving problems. Fuses"

Advantages of using the software product "Educational software in physics. Electrodynamics" in the educational process:

1. Stimulation and development of mental cognitive processes: attention (perceptual, involuntary and, in our opinion, intellectual) due to the use of various types of information.

2. Logical and algorithmic type of thinking, due to the interactivity of the program and the ability of the user independently manage the educational process.

3. Sensations – visual and auditory sensitivity.

4. Perception, imagination, memory (through the use of dynamic circuits, animations of models of physical phenomena and processes, idealized material objects).

During distance learning, the use of the specified pedagogical software product provided an illustration of physical processes, laws and concepts; independent work of students in studying theoretical material (using an electronic textbook); training problem solving (using educational testing); self-assessment (using control testing), performing computational and graphic works (using the tasks for independent solution); learning process to solve problems (by examples of problem solving).

During the explanation of topics in physics in the "Mechanics" section, to increase students' interest in this topic, we analyze the principles of pedometer and accelerometer operation, consider the algorithm for counting steps taking into account the parameters that directly affect its operation, in particular: step, distance, speed and calories. The concept of the algorithm is based on the use of three axial digital ADXL345 type accelerometers.

Pedometers are popular devices used to measure the number of steps a person takes during the day. Modern pedometers are based on microelectromechanical systems, inertial sensors and sophisticated step detection software.

The authors of the article developed a mobile application "Pedometer". It is focused on tracking the daily physical activity of the user, calculating the calories burned and received, tracking the body's water balance, storing statistics on the amount of work performed and calories burned for the entire period of use of the mobile application. Due to the active promotion of a healthy lifestyle and physical activity, this application is especially relevant for medicine, physical education and sports.

The application is developed for the iOS platform, the Swift language is chosen for its implementation. For user, the application provides next functions: registration and identification in the application; filling in and changing personal data; calculation of the ideal number of calories individually in accordance with the requirements and physical data of the user; adding calories consumed or expended; adding consumed fluids; adding activity; the ability to add new products / workouts / liquids to the database; start pedometer; viewing statistics such as: the number of steps per day, the number of consumed and spent calories, the state of the body's water balance, viewing the activity for the last week (this information is displayed in the form of a graph); receiving a notification about the consumed / spent number of calories and the amount of fluid.

Among the non-functional requirements for the application are the following: output of statistical data in the form of a graph; animations; display on the home tab statistics on user activity for the current day; option to enter and select data by the user.

On the authorization page, the user can log in to the application or create a new account (Fig. 5). The procedure involves entering a login and password. If the option "create an account" is selected, then after entering the email and password for registration, a new window will open to provide information. After providing the necessary information, the application calculates the optimal number of calories for daily consumption, depending on the chosen purpose of using the application.

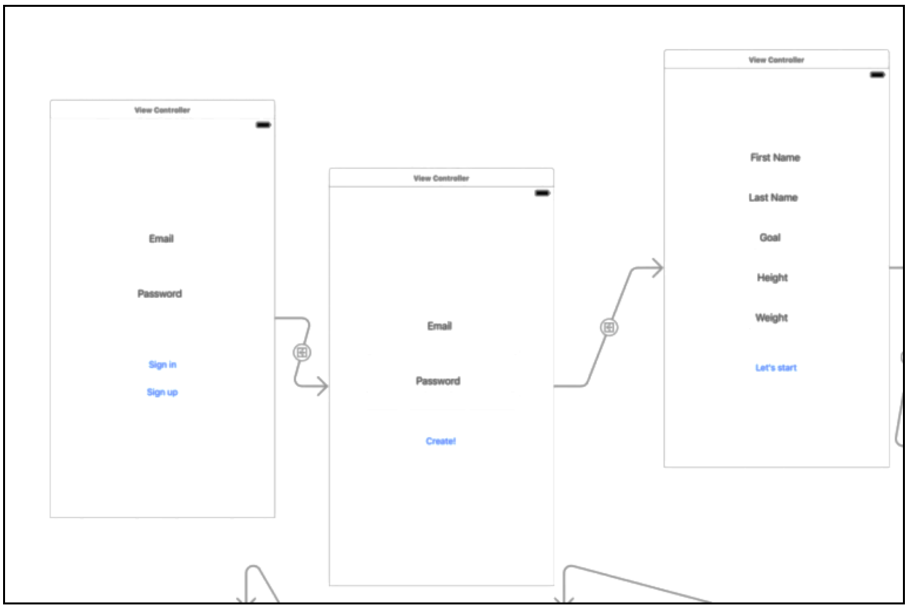

Fig. 5. Authorization and account creation pages

The personal information page displays statistical data entered by the user during registration, in particular: name, surname, email, height, weight, purpose of using the application. The user is also given the opportunity to update the data by clicking on the "Update" button (Fig. 6).

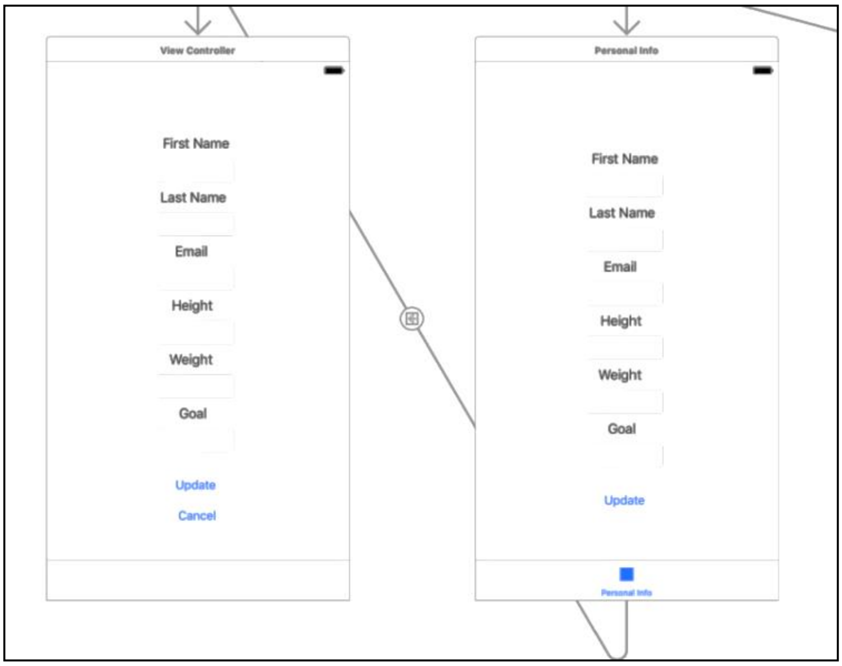

Fig. 6. Personal information and data update page

On the activity page there is an additional button "Start!" which activates the pedometer. On the page, the user can see his/her own progress during the current day. The following data are provided here: the number of calories consumed / used / left and the amount of fluid consumed / left (Fig. 7).

Fig. 7. General information page

The developed mobile application "Pedometer" is useful for users interested in controlling their daily physical activity, tracking the number of calories consumed and expended, monitoring fluid levels in their own body and focused on a healthy lifestyle. The simple interface provides ease of application use and does not provide special knowledge and skills, which makes the product attractive for user.

The use of visual information model "Pedometer" in the process of teaching physics increases the cognitive activity of students through the visualization of idealized physical concepts, makes it possible to facilitate the understanding of the content of physical theories, create a meaningful basis for solving applied problems and conduct elementary theoretical research.

Experimental verification of the effectiveness of implementing the proposed pedagogical software products in the educational process in physics confirmed the feasibility of their use.

For statistical verification of the effectiveness of students subject competencies formation, the Student's t-test was used. The sample size was calculated according to the law of sufficiently large numbers:

$$n = \frac{t^2 pq}{\varepsilon^2},$$

where n is number of students whose level of knowledge quality needs to be established (sample size); t is the argument of the function $F(t)$, the value of which is equal to a predetermined probability P (Student's ratio); p – the probability of the event; $q = 1 - p$ – the probability of the opposite event; ε is the error of the obtained results.

The effectiveness of the method was investigated by comparing the academic achievements of two independent samples of students in experimental and control groups of a sufficiently large sample size. The value of the average indicator of knowledge assimilation separately for the control and experimental groups corresponds to the conditions of use – the Student's criterion.

The obtained data were processed according to the method proposed by [26], [27].

The coefficient of knowledge elements assimilation (K) is determined by the ratio of the number of reproduced knowledge elements to the maximum possible number of elements:

$$K = \frac{N}{N_0}$$

where N is the number of correct answers, determined by the product of the correct answers number to the number of students (n) participated in the experiment; N_0 – the maximum possible number of answers to questions, determined by the product of the number of knowledge elements on the number of students (n) participated in the experiment.

The pedagogical experiment was conducted on the basis of educational institutions: Kryvyi Rih Medical College, Volodymyr Vynnychenko Central Ukrainian State Pedagogical University, "Lviv Branch of the Kyiv National University of Culture and Arts", Kyiv National University of Culture and Arts, Kropyvnytskyi construction college.

The article presents the results of a pedagogical experiment for students of Volodymyr Vynnychenko Central Ukrainian State Pedagogical University.

For students who took part in the experiment created two variants of learning conditions: traditional conditions and learning with the use of the proposed pedagogical software products.

During the analysis of the content of the sections "Mechanics" (Fig. 8), "Hydrodynamics" (Fig. 9), "Electrodynamics" (Fig. 10), we identified 47 physical concepts, phenomena, processes.

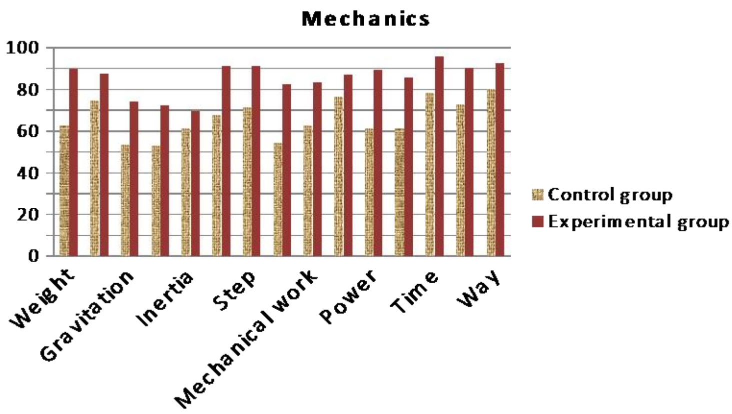

Fig. 8. Selective histogram of students’ knowledge on the section "Mechanics"

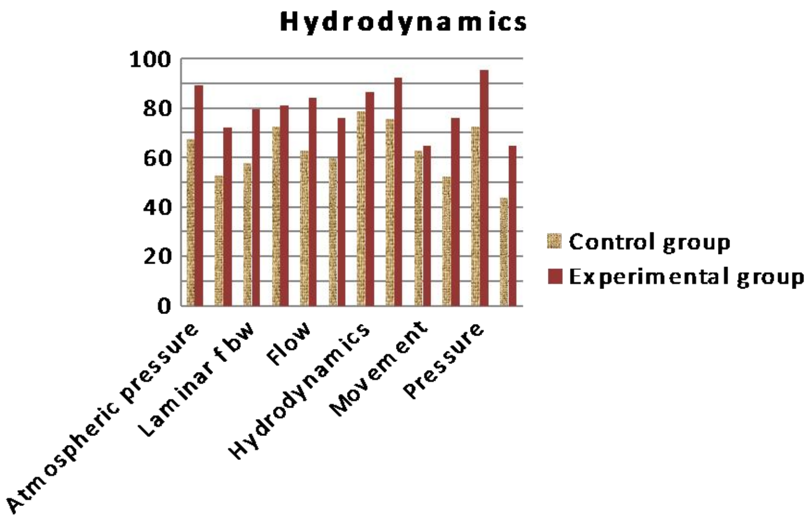

Fig. 9. Selective histogram of students’ knowledge on the section «Hydrodynamics»

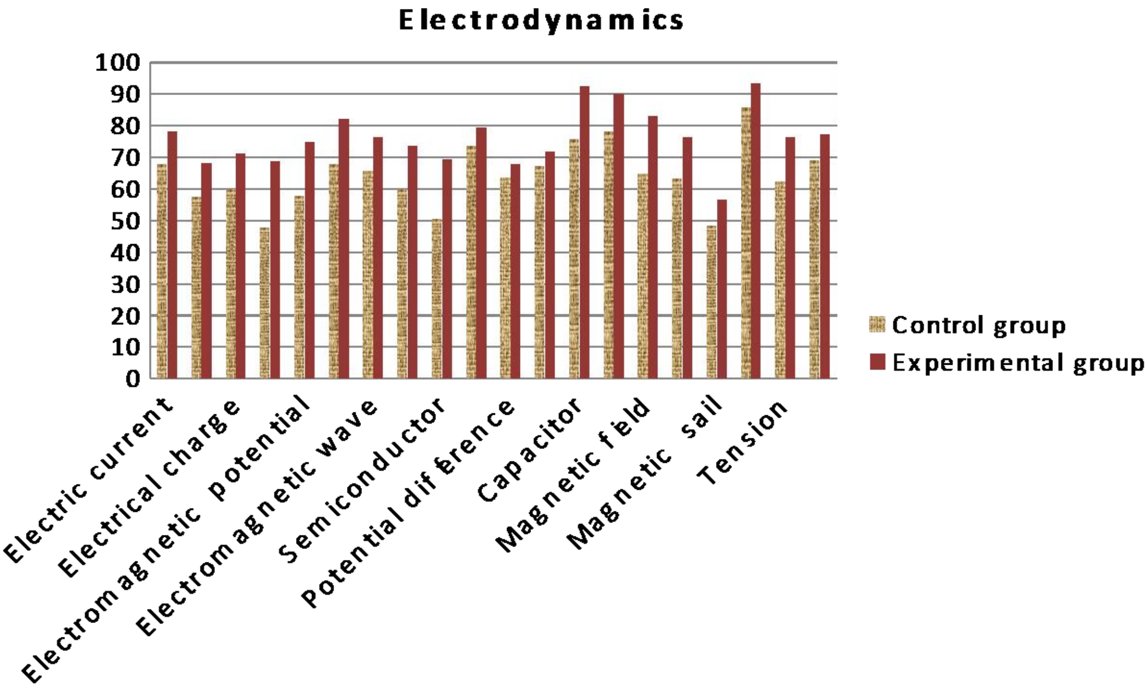

Fig. 10. Selective histogram of students' knowledge on the section «Electrodynamics»

The results of experimental research (Fig. 8, 9, 10) showed positive changes in the students' attitude to the study of physics. The experiment showed that the use of the proposed pedagogical software products in physics and virtual laboratory work contribute to the formation of the logical structure of educational material and strengthen the role of fundamental generalizing concepts and theories, as well as optimize the training time for practical tasks. Computer models allow to demonstrate experiments without equipment, but the process of perceiving them is the same as the process of perceiving real objects, increasing the success of learning.

For the control and experimental groups: the total number of elements is calculated as the product of the number of students (*n*) for the total number of answers. The total number of knowledge elements is 47. The total number of knowledge elements for the control and experimental group, respectively, are equal: 123 • 47 = 5781; 86 • 47 = 4042 (Table 1).

Table 1

Generalized results of pedagogical experiment

Groups	Number of students, *n*	The total number of knowledge elements, N_0	Reproduced knowledge elements, *N*	$K_k = \frac{N}{N_0} \cdot 100\%$
Control	123	5781	4253	73,57
Experimental	86	4042	3712	91,84

The difference between the coefficients of knowledge acquisition in the experimental and control groups: $d = K_e - K_k = 0{,}1827$. During the pedagogical experiment, we calculated the average sampling error in the experimental training. Mathematical efficiency of the educational material structure and methods of its study was checked through the reliability of the difference in the coefficients of knowledge elements assimilation.

$$P_k = \sqrt{\frac{K_k \cdot (1 - K_k)}{n_k}},\ p_k = 3{,}976 \cdot 10^{-2},$$

$$P_e = \sqrt{\frac{K_e \cdot (1 - K_e)}{n_e}},\ p_e = 2{,}953 \cdot 10^{-2},$$

whrere $P_e, P_k, K_e, K_k, n_e, n_k$ respectively, the average errors of correct answers; coefficients of knowledge acquisition; number of students in experimental and control classes.

The average probability of correct answers to the questions is calculated by the average error of their difference.

$$P_\alpha = \sqrt{P^2_e + P^2_k},\ P_\alpha = 4{,}953 \cdot 10^{-2}$$

Estimation of probability of the received difference reliability is carried out by means of a normal deviation:

$$t_\alpha = \frac{K_e - K_k}{P_\alpha} = \frac{d}{P_\alpha},\ t_\alpha = 3{,}69.$$

Since t >> 1,96, the difference in the coefficients of knowledge acquisition in the experimental and control groups is significant and depends not on random samples, but on the difference in the structure and methods of teaching physics organization at Volodymyr Vynnychenko Central Ukrainian State Pedagogical University.

A pedagogical experiment conducted at the Volodymyr Vynnychenko Central Ukrainian State Pedagogical University confirmed the effectiveness of the methodology of teaching physics using the proposed software products and performing virtual laboratory work.

4. CONCLUSIONS AND PROSPECTS OF FURTHER STUDIES

Modern advances in science and technology require modern classes in higher education institutions. Teachers must take these requirements into account when using information tools in physics classes.

The main advantage of information technology is that computer demonstrations can be an integral part of any lesson and can effectively help teachers and learners. Some physical processes or phenomena cannot be observed visually in the laboratory. Simulation of different phenomena does not replace real experiences, but in combination with them allows explaining at a higher level the content of a training material. Such classes arouse students' real interest, make everyone work, and the quality of knowledge increases significantly.

Methods of teaching physics using information technology are a powerful mechanism with many possibilities. Educational software is an external resource for activating the potential of the individual. It allows to increase the motivation to study physics, to lay a solid foundation of knowledge in physics, contributes to the better assimilation of the necessary educational material by students.

For modeling of physical processes we actively use such software in pedagogical activity: software product "Laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5", mobile application "Pedometer", software product "Educational software in physics "Electrodynamics". The use of these software products allowed laying the foundation for the formation of students' subject competencies in physics.

Further research of the authors are detailed demonstration of the experimental testing results of the introduction into the educational process of educational institutions the software products for modeling physical processes. Prospects for further development are the introduction into the educational process pedagogical software products "Physics. Molecular kinetic theory"; "Physics. Spectral analysis".

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ДОСЛІДЖЕННЯ ЕФЕКТИВНОСТІ ВИКОРИСТАННЯ ПРОГРАМНИХ ПРОДУКТІВ ДЛЯ МОДЕЛЮВАННЯ ФІЗИЧНИХ ПРОЦЕСІВ

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Анотація. Упровадження нових інформаційно-комунікаційних технологій в освітній процес вимагає переходу на новий якісний рівень навчання фізики, активізації навчальної діяльності студентів.

Успішне використання педагогічних програмних засобів допомагає викладачу на високому та якісному рівні викладати навчальний матеріал, контролювати навчальну діяльність, підвищувати самоорганізацію освітнього процесу.

Комп’ютерні демонстрації можуть бути органічною складовою будь-якого заняття та ефективно допомогти викладачу та суб’єктам навчання. Деякі фізичні процеси або явища неможливо спостерігати візуально в лабораторних умовах. Моделювання різних явищ ні в якому разі не замінює «живих» дослідів та в поєднанні з ними дозволяє на більш високому рівні пояснити зміст того чи іншого навчального матеріалу.

У даній статті розглядається практичне використання педагогічних програмних продуктів для моделювання фізичних процесів: програмний засіб «Лабораторна робота «Вивчення основ гемодинаміки за допомогою апарату «Штучний кровообіг SORIN C5», мобільний додаток «Крокомір», програмний продукт «Навчальний програмний засіб з фізики. Електродинаміка».

Програмні продукти формують предметні компетентності з фізики. Відбувається більш повна реалізація потенційних ресурсів студентів під час формування нових знань про базові фізичні принципи та підходи до дослідження процесів у живій природі, фізико-технічні принципи функціонування пристроїв, використання математичних методів у дослідженнях. Розв’язування на заняттях з фізики професійно спрямованих задач і виконання лабораторних робіт поліпшує якість професійної складової навчання. Пріоритет комп’ютерних моделей для підвищення успішності студентів в тому, що процес їх сприйняття відбувається в такий же спосіб, як і процес сприйняття реальних об’єктів, підвищуючи успішність навчання.

У сатті описано проведену експериментальну перевірку ефективності впровадження запропонованих педагогічних програмних продуктів у навчальний процес з фізики. Представлені результати експериментальних досліджень у Центральноукраїнському державному педагогічному університеті імені Володимира Винниченка, які показали позитивні зміни у ставленні студентів до вивчення фізики.

Ключові слова: фізика; інформаційно-комунікаційні технології; педагогічний програмний засіб; віртуальна лабораторна робота; крокомір, педагогічний експеримент.

ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ ИСПОЛЬЗОВАНИЯ ПРОГРАММНЫХ ПРОДУКТОВ ДЛЯ МОДЕЛИРОВАНИЯ ФИЗИЧЕСКИХ ПРОЦЕССОВ

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Аннотация. Внедрение новых информационно-коммуникационных технологий в образовательный процесс требует перехода на новый качественный уровень обучения физике, активизации учебной деятельности студентов.

Успешное использование педагогических программных средств помогает преподавателю на высоком и качественном уровне излагать учебный материал, контролировать учебную деятельность, повышать самоорганизацию образовательного процесса.

Компьютерные демонстрации могут быть органической составляющей любого занятия и могут эффективно помочь преподавателю и субъектам обучения. Некоторые физические процессы или явления невозможно наблюдать визуально в лабораторных условиях. Моделирование различных явлений ни в коем случае не заменяет «живых» опытов, и в сочетании с ними позволяют на более высоком уровне объяснить смысл того или иного учебного материала.

В данной статье рассматривается практическое использование педагогических программных продуктов для моделирования физических процессов: программное средство «Лабораторная работа «Изучение основ гемодинамики с помощью аппарата «Искусственное кровообращение SORIN C5», мобильное приложение «Шагомер», программный продукт «Учебный программное средство по физике. Электродинамика».

Программные продукты формируют предметные компетентности по физике. Происходит более полная реализация потенциальных ресурсов студентов в процессе формирования новых знаний о базовых физических принципах и подходах к исследованию процессов в живой природе, физико-технических принципов функционирования устройств, использования математических методов в исследованиях. Решение на занятиях по физике профессионально направленных задач и выполнение лабораторных работ улучшает качество профессиональной составляющей обучения. Приоритет компьютерных моделей для повышения успеваемости студентов в том, что процесс их восприятия происходит таким же образом, как и процесс восприятия реальных объектов.

В статье описано проведенную экспериментальную проверку эффективности внедрения предложенных педагогических программных продуктов в учебный процесс по физике. Представлены результаты экспериментальных исследований в Центральноукраинском государственном педагогическом университете имени Владимира Винниченко, которые показали положительные изменения в отношении студентов к изучению физики.

Ключевые слова: физика; информационно-коммуникационные технологии; педагогическое программное средство; виртуальная лабораторная работа; шагомер, педагогический эсперимент.