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Application of cloud computing in the process of professional training of physics teachers

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Abstract. The use of cloud computing in the form of virtual laboratory workshops is a way to solve the existing problems of training future physics teachers, especially in the widespread use of e-learning. The world educational community has developed and is using a variety of electronic educational resources combined in collections and libraries, and the use of them in the educational activities of future physics teachers helps not only to diversify educational material but also to increase digital competence of all participants in the educational process. The study analyzed the available virtual laboratory workshops, proposed a scheme for the use of physical simulations, gave examples of their use in the study of physics.

Keywords: training of physics teachers, e-learning, virtual laboratories, electronic educational resources, cloud computing

1. Introduction

Education is deeply influenced by the progressive introduction of information and communication technologies, which leads to the creation and development of e-learning or intelligent learning environments for educational technologies on a global scale [5]. E-learning uses modern multimedia Internet technologies, cloud computing, virtual and augmented reality to enhance learning experiences and quality, providing students with easy access to the resources and services on the one hand, and facilitating remote exchange and collaboration on the other.

Being popular all over the world, virtual laboratories are the parts of various fields of education. Virtual labs not only help students overcome the problem of lack of practical skills, but also help to overcome digital alienation and gain digital skills and abilities. It is clear that a virtual laboratory cannot completely replace experimental work and teacher work. But they provide practical support for the teaching activities of modern teachers and student learning activities. Thus, this study aims to promote the use of virtual laboratories by students majoring in physics education with the expected effectiveness.

The COVID-19 pandemic has accelerated the digitalization of university education and

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the development of e-learning [1, 12]. The education system is undergoing a paradigm shift, which creates new opportunities in the learning environment, encourages the creation of new educational projects based on ICT. The acquisition of ICT competence by teachers and students is an urgent need for many universities due to the many benefits they can bring to teaching, learning and research. Over the last few years, ICT has entered all levels of education, changing the roles of teachers, lecturers and students. ICT make it possible to create an effective creative learning environment in the learning process, which can lead to significant changes in the roles of both students and teachers, promote individualized learning and improve student motivation [11].

The specifics of the training of future physics teachers is the free possession of physical instruments, staging a physical education experiment, the use of modern digital laboratories. The equipment needed for this in a modern Ukrainian school is a rare phenomenon. However, to design the learning process based on the existing educational environment is one of the tasks of a physics teacher. Physical experimentation in physics is a must, so the teacher tries to use all possible means to organize it. Various options for improving the current situation should be considered, including the involvement of mobile devices for learning, the use of cloud computing to organize virtual laboratory work, computational experiments, joint research and publishing activities, and so on.

2. Literature review

The system of secondary school teachers training is beginning to reform. Teachers are given the freedom to improve their professional level through non-governmental organizations, various forms of such training are recognized as acceptable. The requirements of the new standard of natural education define the skills associated with research. Dementievska [4] outlines the basics of Inquiry Based Science Education, which explains why research education should be important for educating science teachers. The challenges that the teachers are facing in accordance with the main provisions of New Ukrainian School reform [15] and Ukraine's participation in the international PISA study can be realized through the development of new forms of improving the professional level of teachers of science education.

Training future physics teachers is a complex and multidimensional process that must combine pedagogical orientation and deep knowledge of physics. Researchers consider the process of professional training of physics teachers from different positions and try to apply not only modern pedagogical technologies but also modern technical and information tools. According to Martyniuk, Martyniuk and Muzyka [10], it is necessary to develop students' information and digital competence by actively implementing existing software and hardware in the physics educational process such as, in particular, laboratory workshops. The example of laboratory work carried out in educational institutions shows how modern software can be used to analyze the movement of bodies and determine the physical characteristics of this movement. The specific ways of performing laboratory work and the analysis of its results and conclusions are given. The main way of forming information and digital competence is seen in the combination of existing learning practices with modern gadgets, specialized and general programs. Further ways of modernization and improvement of the described methods of increasing the level of information and digital competence are proposed, which will lead to improved training of future physics teachers.

The study by Kiv et al. [8] shows the possibilities of using the specialized software (virtual laboratories and simulators, software for modeling natural processes) and the general software (CAS, programming languages and libraries, electrical libraries) in physics research in school studies. Kiv et al. [8] believe that programming languages and libraries of programming language extensions in school research can be used to model phenomena that cannot be studied in a school laboratory (for example, to model radioactive decay or to demonstrate relativistic mechanics). Also, virtual laboratories in school practice are usually used in cases when students can not perform the experiment in real laboratories. For example, it is convenient for distance learning. The use of programming languages and libraries in physics research requires both students' competence in physics and programming competence. Therefore, the use of this software in physics lessons can hardly be recommended. However, programming languages and extension libraries can be a powerful tool for the formation and development of research competencies of physics students in extracurricular educational activities. The introduction of spreadsheets and CAS in school physics studies is the simplest step and it has its advantages.

In the general picture of informatization of education, more and more information tools are used to teach physics at any university. Information technology has not only effectively improved the quality and efficiency of teaching, but also has placed increased demands on teachers and students. Ma [9] describes the impact of information technology teaching on the teaching of physics at the university explored from three aspects of cloud computing, smartphones and smart classrooms in the Internet age. At the same time, the Ma [9] discusses the direction of development of reforms and innovations in physics teaching in order to change the existing model of physics teaching at the university and improve the quality of physics teaching through information technology teaching in the Internet age. The author concludes that the information approach to learning can not completely replace the traditional method of learning. In the era of information-oriented learning, more attention should be paid to the combination of information education technologies and traditional teaching methods in the Internet age. It is necessary to optimize the approach to classroom learning, and use information technology learning in the Internet age as a catalyst to improve the quality of teaching and open a new section of teaching physics at the university.

3. Research results

The training of future physics teachers involves the formation of mastery of both general and specific skills of professional activity. The specific skills of training future physics teachers include: in-depth knowledge of physics; skills in working in physical laboratories; work with physical devices; selection and adjustment of equipment for physical workshops and experiments; organization of students' work during the physical workshop; ability to explain physical phenomena; ability to conduct experiments and experiments with physical phenomena and processes; solving physical problems.

The specifics of the training of future physics teachers is the widespread use of experimental research. Experimental work is one of the most important sources of knowledge. In combination with modern equipment, technical devices and appropriate means of the educational process, experimental work contributes to a deeper acquisition of knowledge, skills and abilities. The regular use of experimental work in teaching and studying physics helps to acquire skills and understand mechanisms and phenomena, explains their origins in the context of theories, develops and improves experimental skills and abilities that will be very useful in future professional activities, and finally nurtures maximum accuracy of experiments. Experimenting certainly helps to understand the peculiarities of physical processes, as it is the most important way to understand the connection between theory and practice by transforming knowledge into beliefs.

Practical classes are among the features of educational programs in natural sciences at universities. However, these activities require a lot of modern equipment and special technical devices and appliances. Unfortunately, Ukrainian universities face a number of problems with the purchase of technology and modernization of equipment due to the lack of money. The next factor is quarantine restrictions due to biological threats or even armed conflicts and the need to move to save lives. Even if the laboratory is fully equipped with the necessary tools and materials, real experience requires much more time to prepare, complete the task, as well as to analyze the results of work. Virtual labs and virtual experiments can be a good alternative to real experimental work. They allow teachers and students to be flexible, to train practical skills before real life situations. In addition, many students can study theory online, but there are some significant limitations when trying to gain skills online or using traditional methods. Indeed, virtual labs can be effective in helping students acquire analytical and research thinking skills, develop strong persuasion skills, and make decisions in uncertainties [2].

The real discovery in the teaching of school physics is the fact that modern mobile devices include a set of sensors capable of measuring time, acceleration, angular velocity, magnetic field induction, illumination, noise level, atmospheric pressure, humidity. What is important is that the student, using the device available to him, becomes a real researcher of the world around him, and this is one of the main goals of teaching physics.

The technology of using mobile devices in the learning process of students is called BYOD (Bring your own device) and today it is one of the areas of pedagogical research [3, 13, 14]. The use of sensors of mobile devices for these purposes is possible with the help of such applications as Smart Tools, Sensor Kinetics, Physics Toolbox Suite, Sensor Multitool and others. Mobile applications allow not only to measure physical quantities, but also build graphs of changes in measured parameters in real time. With the help of a mobile device, you can measure values both in class and at home or on the street.

Based on the above considerations, we can identify the following meaningful line of professional training of future teachers of physics:

- organization of practical research of the environment taking into account the conditions of use of information technologies;
- use of specialized software to turn mobile devices of learners into a device for measuring various physical parameters in real time;
- processing of the received data by available applications of the comprehensive data analysis.

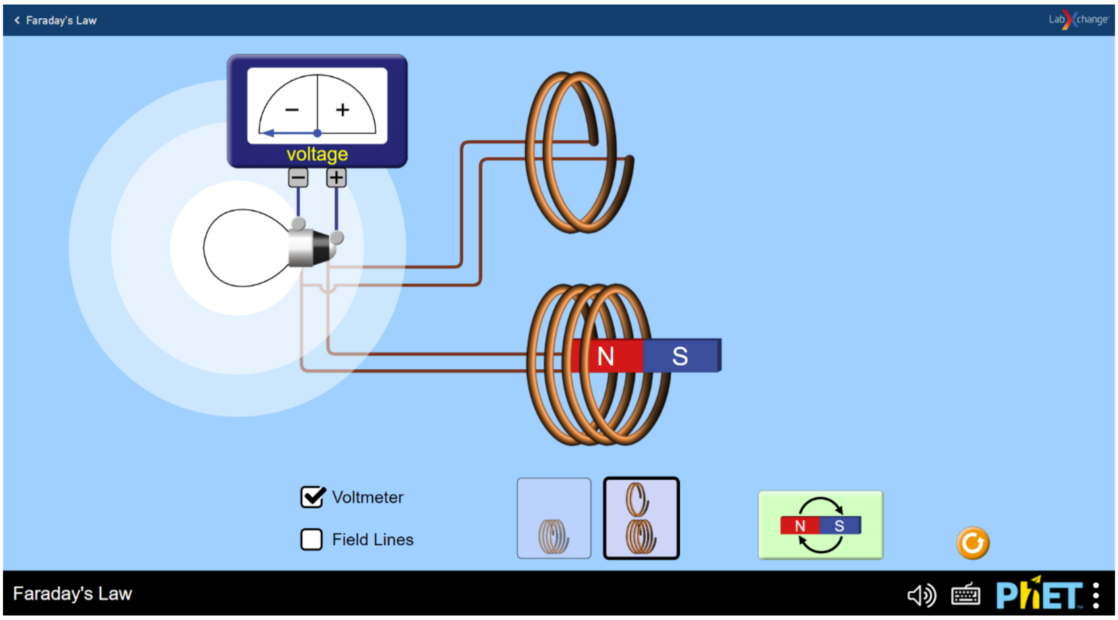

Figure 1: Example of a physics simulation from the PhET collection.

The implementation of a mixed form of education with components of non-formal education in the educational program 014 "Secondary Education (Physics)" can be very useful [6]. E-learning allows future teachers of physics to update their knowledge, get acquainted with new devices and methods of experiments, update their knowledge of the use of ICT in educational activities [7]. The use of virtual laboratories has many advantages: it allows you to conduct experiments at any time, feel safe when conducting dangerous experiments, see all the details of the experimental process and take an active part in conducting experiments. On the basis of virtual laboratories, students have the opportunity to conduct repeated experiments until they are completely satisfied with the results of the experiment.

Open education, among others, provides an opportunity to involve simulations and virtual laboratories in educational activities. For the educational program 014 "Secondary Education (Physics)" PhET simulations (https://phet.colorado.edu/uk/) developed by the University of Colorado are well known. Harvard University has combined a variety of world-class e-learning resources on the LabXchange platform (https://www.labxchange.org/). As of November 2021, LabXchange contains 3,674 links to e-learning resources and their physics-related kits. Videos, simulation texts cover all sections of modern physics, contain information on the history of physics and the latest physical theories. In addition to simulations from the University of Colorado (figure 1), there are simulations from The Concord Consortium (https://concord.org/). The simulations located on the GitHub resource (https://github.com/) are constantly evolving, but unfortunately these electronic educational resources are not cataloged.

No less interesting, but unfortunately not free to use, is the resource PraxiLabs (https://praxilabs.com/). The resource contains electronic educational resources in the form of virtual 3D simulations of laboratory experiments (figure 2). The format of educational resources allows

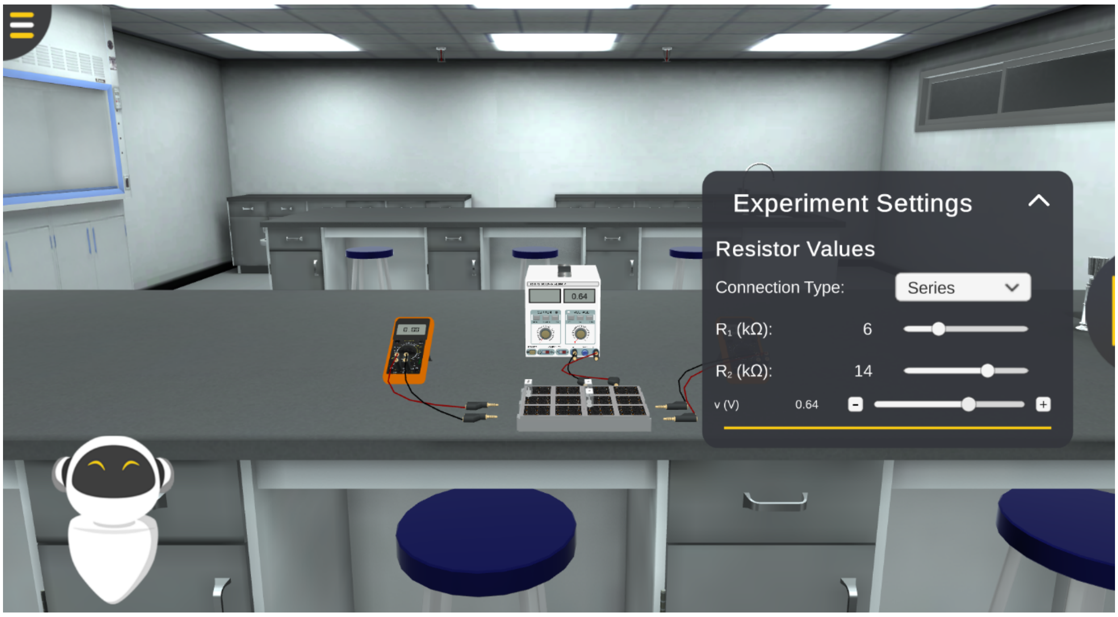

Figure 2: Laboratory study of Ohm's law for a section of a circle in the virtual laboratory PraxiLabs.

them to be integrated into popular learning management systems (Moodle, Canvas and others) using Learning Tools Interoperability technology. You can get acquainted with the possibilities of the PraxiLabs resource through demonstration simulations.

Also quite interesting is the Labster virtual lab (https://www.labster.com/). Once a week, the company holds a 30-minute webinar, which can be attended by no more than 100 people (https://wp.labster.com/introduction-to-labster/). It is at this webinar that the company introduces the conditions of use and opportunities for their development. It should be noted that virtual experiments are built into learning management systems. The Labster platform has a free trial account (https://www.labster.com/pricing) and is constantly updated.

Useful for use in e-learning is a set of open e-learning resources from California State University, Long Beach (https://www.csulb.edu/) called MERLOT (https://www.merlot.org/merlot/index.htm). More than 6.8 thousand electronic educational resources are contained in the MERLOT collection related to physics. In addition, the system allows you to search other libraries and sites of popular educational resources on the Internet.

The Go-Lab online laboratory (https://www.golabz.eu/) is supported by the University of Twente (http://www.utwente.nl/en), École polytechnique fédérale de Lausanne (EPFL) (https://www.epfl.ch/) and Information multimedia communication AG (https://www.im-c.com/). The purpose of the Go-Lab is to promote the development of innovative learning technologies with a focus on virtual laboratories, which positions itself as a "Sharing and Authoring Ecosystem". From the sections of physics, the laboratory currently contains 715 virtual laboratory works, 70 of which are available in Ukrainian.

The Physics at School kit (https://www.vascak.cz/) contains simulators in the following sections: mechanics, gravitational field, mechanical oscillations and waves, molecular physics and thermodynamics, electrostatics, electric current, semiconductors, electric current in liquids, electric current gases and vacuum, magnetic field, alternating current, optics, special relativity, atomic physics and nuclear physics. The simulators are developed by Vladimír Vaščák and are available for both desktops and mobile devices. The policy of free translation into various languages has made it possible to translate into more than 30 languages, including Ukrainian.

The Apps on Physics simulator collection (https://www.walter-fendt.de/html5/phen/) is developed and maintained by Walter Fendt and is constantly updated. As of November 2021, the collection contains 55 simulations implemented in HTML5 and implemented in 19 languages, the Ukrainian language is not available. The simulations cover all sections of the school physics course and can be run on different devices.

The online laboratory OLABS (http://www.olabs.edu.in/) contains simulations in physics, chemistry, biology, mathematics and English. Created with the support of the Ministry of Electronics & Information Technology of India. In physics, laboratory work is related to secondary education and is designed for grades 9–12 and consists of the following components: theoretical block, laboratory work procedure, animation with explanation (on virtual equipment), video recording of work on real equipment, list of additional learning resources, self-test, a simulator for working with a form of execution (which can be saved as a file or printed) and a feedback unit. Similar simulations are available at VALUE @ Amrita (https://vlab.amrita.edu/?sub=1).

The myPhysicsLab.com resource (https://www.myphysicslab.com/) offers to study simulations in mechanics, oscillations and waves. Simulations from Erik Neumann represent not only a visual model of the interaction between the parts, but also build graphs of various kinds for further analysis of the results of the experiment.

Consider in more detail the example of the use of virtual laboratory workshops in the training of future physics teachers. Professional training of future physics teachers identifies physical experiment as the main source of knowledge about the world and its laws, and if in the classroom on molecular physics future teachers have the opportunity to conduct experimental research with the necessary laboratory equipment, during self-education physical experiments can not be conducted. In this case, it is necessary to use physical simulators and empirical data processing programs. And since independent work is not always performed in the laboratories of higher education institutions, it must be provided in the conditions of extracurricular activities. This requirement involves a review of methods and tools for studying the discipline "Molecular Physics" with the introduction of a new means of learning – information and communication technologies to support the study of the discipline.

The software to support the study of the discipline "Molecular Physics" includes simulators of physical processes, tools for processing and visualization of measurement data, tools for creating electronic educational resources and more. Studying thermodynamic isoprocesses in gases, you can use the established laboratory installation (figure 3). In this case, to calculate the results it is necessary to use software for processing tabular information.

Physical simulators have animation and detailing of processes that the researcher during the physical experiment can not observe the available methods. Physical simulation of PhET "Properties of gases" also has such properties (figure 4). The motion of molecules, their velocity distribution, the number of molecules that have been "pumped", etc. provide additional opportunities for research. Despite the existing advantages of computer simulation of physical

Figure 3: Device for studying gas laws (https://www.didact.com.ua/product/nabir-dlya-vivchennya-gazovih-zakoniv/).

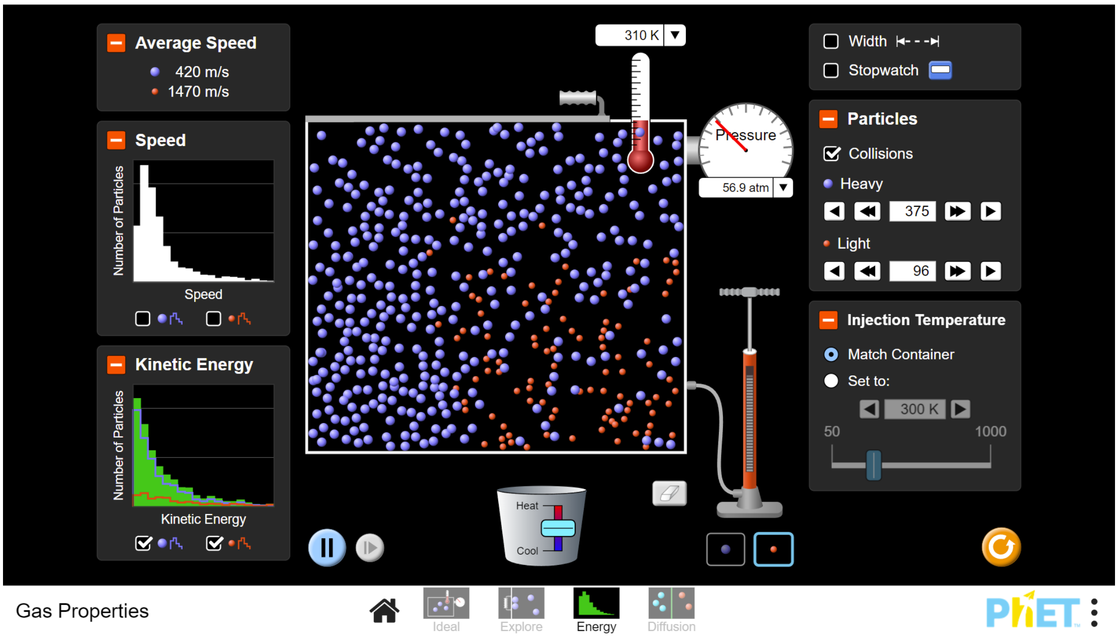

Figure 4: PhET simulation “Gas properties”.

processes, their use in educational activities should correspond to the following scheme:

- forecasting the physical phenomena that will be demonstrated;
- the familiarisation with computer models of physical processes, conditions of change of sizes and their parameters;

- conducting an experiment on a computer model, collecting the obtained data;
- analysing the obtained results.

The proposed scheme of using physical simulations is suitable for both independent work and group work, without excluding the distance learning option. In addition, the data obtained during the computer simulation can be processed collectively. Each of the participants makes measurements with the specified step and different initial values. This results in a large amount of data, the processing of which with the help of tabular data software makes it possible to obtain more accurate general conclusions.

An example of a task using computer simulation is as follows: using computer simulation of physical processes PhET "Gas Properties" (https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_en.html) at a constant volume to determine the relationship between gas temperature and pressure for different gases and their concentrations (low, high), different number of gas molecules. Record the results of research in the table, the results of measurements are presented in the form of a graph of pressure versus temperature for different numbers of molecules of different types.

The obtained results of the simulation are entered into a table and possible regularities are calculated. An example of such a table is the table in figure 5 made in the Google Spreadsheets cloud application. During the simulation, the data of gas temperature and generated pressure in the chamber at a constant volume are entered. After completing the task, the relationship between temperature and pressure is analyzed, it will be sufficient to construct a diagram of the dependence of these two quantities.

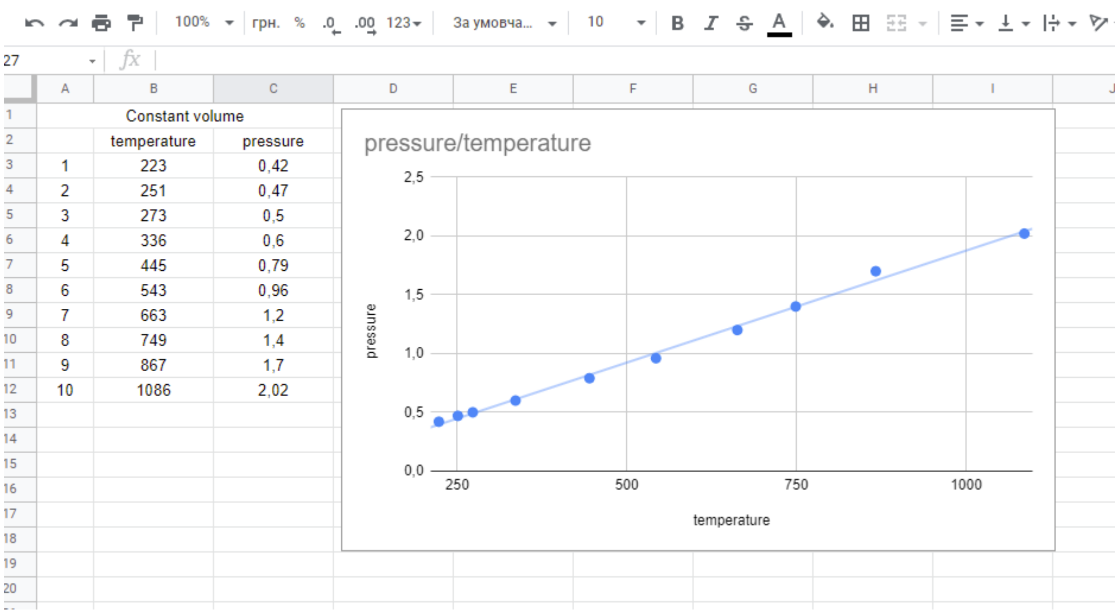

Figure 5: Analysis of the data obtained after the physical simulation.

4. Conclusions

Modeling is a necessary element of scientific knowledge, a mean of research of objects, phenomena and events. The application of modeling in physics is conditioned both by the impossibility of conducting research on real objects and by the danger of some physical processes. The application of experimental physical laboratory practices is the specific of the training of future teachers of physics. Today, the organization of the educational process involves the wide application of e-learning, in which virtual laboratory practices play an important role. Thus, the use of virtual educational laboratories for studying physics and methods of teaching physics considerably increases efficiency of educational process, makes it more informative, deeper, promotes development of digital skills and skills in students and teachers, improves quality of training and simplifies realization of distance learning and/or mixed teaching, which became very popular during the COVID-19 pandemic. Indeed, the virtual simulator cannot completely replace the physical experimental work and explanations of the teacher, but virtual laboratories can support the teaching activity of the modern teacher, the student's educational activity, increase professionalism, open new horizons and, most importantly, will strengthen the motivation component of the training through active dialog of the student with the computer, by its orientation on the way to success and mastering elementary knowledge of natural sciences, including physics.

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