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# Formation of cognitive activity of technical university students using elements of blended learning in the study of quantum physics


Formação da atividade cognitiva de estudantes técnicos universitários utilizando elementos de aprendizagem combinada no estudo da física quântica

Formación de la actividad cognitiva de los estudiantes universitarios técnicos utilizando elementos del aprendizaje combinado en el estudio de la física cuántica


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**Abstract:** The study aims to analyze the expediency of using the capabilities of LMS Moodle for the implementation of blended learning in physics at a technical university in the study of quantum physics. The opportunities presented by the Moodle online environment are analyzed. It is demonstrated that online learning combined with in-person learning greatly improves learning outcomes. An instrument for e-learning in quantum physics in the Moodle environment is described and its educational capabilities are determined. The article examines the method of creating computer models using Easy Gif Animator. Modeling is examined as a means of promoting the formation of students' cognitive activity. The use of modeling and thought experiments contributes to enhancing students' understanding of real-life experiments and theories in physics. The study results support the hypothesis that the introduction of an electronic learning component in teaching quantum physics will increase students' cognitive activity levels.

**Keywords:** Electronic learning, Traditional learning, Lecture, Cognitive activity level, Students.

**Resumo:** O estudo tem como objetivo analisar a oportunidade de utilizar as capacidades do LMS Moodle para a implementação de blended learning em física em uma universidade técnica no estudo da física quântica. São analisadas as oportunidades

apresentadas pelo ambiente online Moodle. É demonstrado que o aprendizado online combinado com o aprendizado presencial melhora muito os resultados do aprendizado. Um instrumento para e-learning em física quântica no ambiente Moodle é descrito e suas capacidades educacionais são determinadas. O artigo examina o método de criação de modelos de computador usando o Easy Gif Animator. A modelagem é examinada como um meio de promover a formação da atividade cognitiva dos alunos. O uso de modelagem e experimentos mentais contribui para melhorar a compreensão dos alunos sobre experimentos da vida real e teorias da física. Os resultados do estudo suportam a hipótese de que a introdução de um componente de aprendizagem eletrônica no ensino de física quântica aumentará os níveis de atividade cognitiva dos alunos.

**Palavras-chave:** Aprendizagem eletrônica, Aprendizagem tradicional, Palestra, Nível de atividade cognitiva, Alunos.

**Resumen:** El estudio tiene como objetivo analizar la conveniencia de utilizar las capacidades de LMS Moodle para la implementación del aprendizaje mixto en física en una universidad técnica en el estudio de la física cuántica. Se analizan las oportunidades que presenta el entorno online de Moodle. Está demostrado que el aprendizaje en línea combinado con el aprendizaje en persona mejora en gran medida los resultados del aprendizaje. Se describe un instrumento para el e-learning en física cuántica en el entorno Moodle y se determinan sus capacidades educativas. El artículo examina el método de creación de modelos informáticos con Easy Gif Animator. El modelado se examina como un medio para promover la formación de la actividad cognitiva de los estudiantes. El uso de modelos y experimentos mentales contribuye a mejorar la comprensión de los estudiantes de las teorías y los experimentos de la vida real en física. Los resultados del estudio apoyan la hipótesis de que la introducción de un componente de aprendizaje electrónico en la enseñanza de la física cuántica aumentará los niveles de actividad cognitiva de los estudiantes.

**Palabras clave:** Aprendizaje electrónico, Aprendizaje tradicional, Conferencia, Nivel de actividad cognitiva, Estudiantes.

## INTRODUCTION

The objectives of developing students' competencies necessary for a modern specialist predetermine the restructuring of the educational process and the modernization of the methodological system of education and elements of the educational environment, in particular, the form, methods, and means of teaching based on the widespread use of information and communication technologies. This creates favorable conditions for the intensification of students' cognitive activity. It also determines the increase in the role of active forms of educational process organization and the emergence of new forms of it such as distance, mobile, and blended learning (Dudin et al., 2019; Dudin & Shishalova, 2019).

Until recently, students were mastering new knowledge through communication with teachers and independent work with publications. This characterizes the classroom-lesson system that has been formed over hundreds of years and is hence called traditional. An important feature of such learning is the presence of live communication of students with a teacher and with one another. This creates the conditions for the development of each student's personality, accelerates the pace of learning, and contributes to the development of not only cognitive but also emotional and connective abilities. It also determines the socialization of an individual and forms their ability to work and

communicate in a team. Nevertheless, this form of education allows communicating a large amount of information to students in a short time.

The existing shortcomings of the traditional system are that the presentation of the material is oriented on a certain average student developing knowledge-copies and the reproductive style of cognitive activity which do not contribute to the development of creative abilities, independence, and activity. Despite these drawbacks, traditional training is necessary for the formation of the primary knowledge base. Its level determines the zone of proximal development and the lack of it makes it impossible to master more complex knowledge and skills. Neither teachers nor students are ready to completely abandon the traditional form of educational process organization. Moreover, educational programs based on traditional learning are well-established.

The use of the means of ICT has significantly expanded the possibilities of organizing the educational process. At the initial stage, it was also believed that ICT instruments would be capable of replacing a teacher and it would be possible to carry out all learning in a distance form (the so-called electronic learning – e-learning). However, it turned out that such training has several disadvantages including the lack of direct contact between the educational process participants, the risk of misinterpretation of theoretical provisions, limited opportunities for acquiring practical skills, and the need for the high long-lasting internal motivation of the individual and their self-learning abilities. Besides, the most important thing is that e-learning does not yet ensure a high quality of knowledge acquired by students (Alexander, 2006).

The advantages of e-learning compared to traditional learning indicated in scientific and methodological literature include that it disciplines and accelerates the knowledge acquisition process, improves students' cognitive skills, develops their independence, creative inclinations, and intellectual potential, that is, results in the formation of information competence. Studying in this form, students can independently determine the time and place of learning, choose sections of the curriculum of educational material and the sequence of their study, and study sections or topics from different sources repeatedly until they master this knowledge completely. ICT instruments provide an opportunity to diversify the forms of educational material presentation and carry out objective and regular control of its assimilation (Pavel et al., 2015).

Physics is a natural science that uses a complex mathematical apparatus. Many students are unable to understand most physical concepts, laws, and theories without full-time participation. Therefore, we consider e-learning only as an auxiliary form to in-person learning.

Teaching physics becomes more difficult if students are not motivated to study it since the cognitive needs of students are determined by their intrinsic motivation. Students will be unable to understand the educational material if they are not motivated to study it. The purposeful work of teachers is necessary to promote the formation of students' cognitive activity (Guido, 2013; Cracker, 2006; Eryilmaz et al., 2011).

Authors describing the advantages of e-learning (Levy, 2007; Mansvelt et al., 2009; Judrups, 2015) most commonly refer to humanitarian sciences and economics or computer programming. They avoid discussing the fact that all these areas are largely related to the spheres of advanced professional development or retraining of personnel which are characterized by strong and stable internal motivation due to the need for career growth, satisfaction of one's own cognitive needs, etc. As for full-time students who receive technical education, it is advisable to organize their training in the form of blended learning that combines the best features of traditional and electronic learning.

Blended learning is a result of the development of information and communication teaching instruments. It is associated with the processes of informatization and computerization of society, the use of ICT in the educational process, the use of computer-oriented learning systems, the formation of information and technical competencies of a specialist, the widespread use of network technologies for organizing the educational process, and the introduction of mobile-oriented learning (Dangwal, 2017).

However, the implementation of blended learning in the study of fundamental disciplines (physics and mathematics) is not sufficiently covered in the literature despite that these disciplines significantly affect the formation of engineering thinking and universal methodological knowledge. They serve as a basis for further self-development, self-improvement, and self-education throughout one's life and allow mastering new knowledge and competencies and finding solutions to new professional problems.

The hypothesis of the present study on the use of blended learning in teaching quantum physics is that the level of students' cognitive activity will increase.

According to the obtained results, it can be concluded that the goal set in the study was achieved.

## LITERATURE REVIEW

The analysis of scientific literature shows that most scholars adhere to the definition indicating that blended learning is a process of acquiring knowledge, skills, and abilities accompanied by a combination of various learning technologies (Woods et al., 2004; Rovai & Jordan, 2004), a combination of offline (or in-person) and online learning in different proportions (Garrison & Kanuka, 2004; Jeffrey et al., 2014), and a combination of various educational technologies (traditional, distance, mobile) and learning strategies (Rooney, 2003; Tynan et al., 2015). Learning strategies are understood as certain educational models that define clear learning outcomes and are aimed at achieving them as a result of the implementation of educational programs developed with consideration of various learning technologies (Boelens et al., 2018; Selwyn, 2007).

The aforementioned definitions imply the following characteristics of blended learning. Teaching an academic discipline involves the use of ICT and technical teaching equipment (TTE) (PC, mobile phones, tablets, projectors, etc.). ICT is used not only for storing and delivering educational material but also for carrying out control activities and organizing the educational interaction (consultations, discussions) (Ma et al., 2013). Students have independent control over the time, place, routes, and pace of their learning (De George-Walker & Keeffe, 2010).

C.R. Graham (2006) indicates two approaches to understanding blended learning that determine its definition and implementation. The first approach involves understanding blended learning as distance courses in which students study pre-planned material using electronic sources and discussions, knowledge assimilation, and practical task completion take place in a classroom under the teacher's guidance. The second approach views blended learning as the use of information educational resources in in-person learning in asynchronous and synchronous distance learning modes. In the asynchronous mode, students carry out independent work. They search for educational information in a global or local network and study it. In the synchronous mode, students work with the teacher online, for example, via Internet conferences, Skype, chats, Google Talk, etc.

In accordance with these approaches, the corresponding definitions of blended learning are provided. For example, V. Demirer and I. Sahin (2013) interpret blended learning as a combination of traditional technologies with innovative technologies of electronic, distance, and mobile learning. According to D. Lowe (2013), blended learning is a mix of distance and electronic online learning with the traditional forms: full-time and part-time learning. In a different article (Means et al., 2013) blended learning is interpreted as a formal educational program that involves learning within an educational institution, distance learning, and methods that combine these forms of learning. Tynan et. al. (2015) understand blended learning as an educational program that involves students studying online, in control of the time, place, paths, and/or pace of their learning at least partially and partly on the grounds of the educational institution. The forms and ways of the organization of learning are designed for students in each course in a way that ensures an integrated learning experience.

Despite a large number of different interpretations and definitions, scholars (Evans et al., 2019; Moskal et al., 2013; Engelbertink et al., 2020; Swenson & Redmond, 2009) adhere to a common opinion on the combination of various learning technologies, traditional and electronic (specifically, computer, distance, mobile, etc.), the use of which is an important condition of the effective implementation of blended learning models.

The category of "blended learning" can be seen in the narrow and broad sense. In a narrow sense, according to researchers (Picciano, 2009; Kim et al., 2008), blended learning should be understood as a purposeful learning process carried out by various types of educational institutions within the



framework of formal education a part of which is implemented remotely using ICT and TTE to store and present educational material, implement control measures, and organize interaction between the subjects of the educational process (consultations, discussions). It involves students' independent control over the time, place, routes, and pace of their learning. In a broad sense, blended learning implies various combinations of the forms and methods of organizing formal, non-formal, and informal learning, as well as self-study carried out to achieve a person's predetermined educational goals that preserve the mechanism of control over the time, place, routes, and pace of learning (Osguthorpe & Graham, 2003; Stockwell et al., 2015).

R. Launer (2010) believes that through its multifunctionality blended learning allows organizing various forms of education, among which the following should be identified:

- the traditional form of organization of learning (lectures, laboratory and practical training, etc.);
- the distance form of organization of learning (synchronous: virtual classes, webinars, coaching, instant messaging, etc.; asynchronous: ENC, cooperative creation of documents, e-mail, forums, instant messaging, etc.).

Experts from the Clayton Christensen Institute for Disruptive Innovation in California, USA have great experience in the field of blended learning. Since 2011, the Institute has published a series of studies on blended learning detailing its definitions, models, implementation experiences, and more. Studies of specialists of the Clayton Kristen Institute present four models of blended learning: the Rotation Model, the Flex Model, the Self-Blend Model, and the Enriched Virtual Model (Poon, 2013).

Blended learning allows combining the use of digital educational resources and a variety of online services for carrying out educational activities. Specifically, researchers indicate the following means that can ensure such a combination: learning management systems (Moodle, aTutor, ILIAS, etc.), online learning courses (Prometheus, Coursera, edX, Udacity, Duolingo, etc.), instruments for creating educational resources and objects (test constructors, forms, questionnaires, interactive tasks), the means of communication and feedback, instruments for organizing joint activities (mainly based on cloud technologies), instruments for creating online groups (social networks, forums, blogs), and the means of planning educational activities (electronic journals, calendars, etc.) (Lim & Wang, 2017).

The implementation of blended learning changes the nature of information interaction between the educational process participants, the ways of information presentation, and the composition of educational and methodological support of the educational process. Consequently, a new methodological training system is created, and corresponding information and an educational environment are formed.

The methodological system of learning is a set of interrelated elements including the goals, content, methods, forms, and means of teaching.

These elements have to account for the established technology of carrying out the educational process, the specifics of the academic discipline, and the individual characteristics of students to ensure the effectiveness of training, a high level of knowledge obtained by students, and the fulfillment of requirements regarding their competencies in terms of educational and qualification characteristics. This calls for, first, selecting the optimal model of blended learning, second, thorough analysis and evaluation of the expediency of introducing particular resources into educational courses and students' readiness and ability to work with these resources, as well as determining which sections of the educational material are to be mastered independently or in the classroom (Napier et al., 2011; Bowyer & Chambers, 2017).

According to M.R. Sarmadi et. al. (2016), educators must create a learning environment in which learners with different thinking styles can benefit from their strengths and compensate for their weaknesses in thinking and learning. In line with this approach, we will explore the possibilities of studying quantum physics offered by the LMS Moodle environment.

In Moodle, there are several user roles with varying degrees of access to the system: an administrator, a teacher, and a student. This platform provides students with access to numerous educational opportunities. Teachers can follow students' work during class, send new messages to students, distribute resources and information, collect assignments, and grade students' works. Students can communicate with each other in discussion forums and chats. Forums provide space for discussions and consultations. Forum posts can be automatically sent to students via email (Oproiu, 2015).

Moodle implements the "Lesson" (or "Lecture") activity element which provides for the possibility of combining the presentation of theoretical material in text, video, or audio format and control of its assimilation (Shan, 2012).

The structure of a "Lesson" in Moodle considers the well-known feature of the human psyche that involves information presented in small parts being easier to perceive and better assimilated when the need to perform mental actions on it is present. Thus, the structure of a "Lesson" in Moodle allows dividing material into small logically complete parts that can be divided by control tasks in the format of tests: matching, essays, short answer, multiple-choice, true/false, or multiple answer tests. The course creator has the opportunity to ensure the transition to a certain part of the educational material in case of correct or incorrect completion of the task. The results of students' work are recorded in an electronic journal and monitored by the teacher (Sanchez & Hueros, 2010). To ensure that a student does not receive the same tasks when re-taking a test, it is possible to create several tasks similar in content and combine them into a cluster from which the system selects one task randomly.



## METHODS

Based on the purpose of the study and the conducted literature review, the following research objectives are set:

1. To develop a course on quantum physics in Moodle.
2. To determine the impact of using Moodle on the level of students' cognitive activity.

The experiment was carried out at the physics and mathematics faculty of a university in one semester. The study involved five academic groups of the control group (92 students) and five academic groups of the experimental group (91 students).

Students' remote work with the quantum physics course in Moodle included several stages:

- familiarization with the general rules of using and visiting the website (instructions, gaining access to the platform, creating a personal account, exploring the curriculum, schedule, and structure of the discipline) during the briefing conducted by the teacher in class or personally;

- receiving assignments to complete independently or during a physics class;

- student's work on completing independent assignments (the course contains various types of tasks; the tasks with an unambiguous, programmed answer are checked and evaluated by the system);

- discussion and evaluation of the results of students' work.

Answers to assignments requiring the expression of their thoughts and creativity were sent by students to the teacher via internal email. All grades given by the teacher were available for viewing to each student in the "Electronic Journal" section. During students' learning, the teacher was assisting by consulting students on the technical challenges they faced.

Measuring the levels of cognitive activity was aimed at diagnosing the structural components of cognitive activity, namely the motivational, content (skills and abilities), and emotional components. The motivational component of cognitive activity refers to students' positive attitude towards learning, cognitive interest in the discipline, and desire to gain knowledge. The formation of thinking and cognitive processes (perception, attention, imagination, and memory) constitutes the content of the cognitive activity. Positive emotions – hardworking nature, the ability to organize one's learning, self-control, and self-improvement – determine the emotional component of cognitive activity.

For the present study, we developed and implemented a test with 10 open-ended questions. Each student filled out the questionnaire presented in Table 1.

**Table 1**  
The list of questions

No.	Question	Yes	No
1.	You can define the concept of quantum physics (please write an example and explanation)		
2.	Do you know an example of quantum physics from daily life (please write an example and an explanation)		
3.	You know an example of quantum physics from engineering (please write an example and an explanation)		
4.	You know an example of current research in quantum physics (please write an example and an explanation)		
5.	You know an example of a real-life experiment in quantum physics (please write an example and an explanation)		
6.	You know an example of a material model in quantum physics (please write an example and an explanation)		
7.	You know an example of a thought experiment in quantum physics (please write an example and an explanation)		
8.	You know an example of a mental model in quantum physics (please write an example and an explanation)		
9.	Do you know the last name of a physicist who is a Nobel laureate in quantum physics (please write the name of the scientist)		
10.	You are reading additional literature on quantum physics (please write the title of the book)		

According to the results of the questionnaire, three levels of students cognitive activity, low, average, and high, were determined as follows:

0-4 “yes” answers indicate a low level of cognitive activity;

5-7 “yes” answers indicate an average level of cognitive activity;

8-10 “yes” answers indicate a high level of cognitive activity.

Following the results of the questionnaire, the level of cognitive activity of each student in the control and experimental groups was determined using a preliminary test. During the academic semester, training in the experimental group (EG) was carried out according to the developed methodology (using e-learning) while in the control group (CG), training was carried out following traditional methods (without using e-learning). The assessment of the cognitive activity of students from both groups was carried out in the final test.

## RESULTS

The experiment results are presented in Table 2.

**Table 2**  
Measurement results in CG and EG.

Cognitive activity level	Preliminary test (%)		Final test (%)	
	CG	EG	CG	EG
low	29.5	29.0	30.5	16.5
average	46.0	46.1	45.5	54.0
high	24.5	24.9	24.0	29.5

To analyze the results of the experiment, we formulated two statistical hypotheses:

- 1) no difference hypothesis (the null hypothesis);
- 2) hypothesis about the significance of the difference (the alternative hypothesis).

The measurement was carried out using a three-level gradation scale (high, average, and low levels of cognitive activity). Pearson's  $\chi^2$  test was used to decide which hypothesis (the null or the alternative) should be accepted. The critical theoretical value  $\chi^2_{0.01}$  for a significance level of 0.05 in a three-level gradation scale was:  $\chi^2_{0.01} = 9.21$ . The empirical value  $\chi^2_{\text{emp}}$  of the changed level of cognitive activity in CG and EG in the final test was:  $\chi^2_{\text{emp}} = 34.30$ . Since  $\chi^2_{\text{emp}} > \chi^2_{0.01}$ , the accuracy of the statistical significance of the characteristics of EG and CG after the final test is 99%.

Thus, the analysis of the experiment confirmed the alternative hypothesis: the difference between the theoretical and empirical values of Pearson's  $\chi^2$  test was not accidental but resulted from significant reasons – the implementation of the developed methodology (the use of e-learning in teaching quantum physics).

## DISCUSSION

We will now proceed to examine the organization of e-learning in Moodle in greater detail.

The quantum physics course in Moodle was available on the university website. All registered students had access to the course. The course included the curriculum, educational materials, reference materials, tests, a chat, and a forum. The design requirements for the course included appropriate background and color and the absence of any redundant information that would distract students.

E-learning allows students the following:

- 1) to receive messages from the lecturer (the “message” block);
- 2) to view the course curriculum (the “curriculum” block);
- 3) to view educational materials (the “lectures” block);
- 4) to develop skills and abilities (the “practical assignments” block);
- 5) to study additional resources and materials (the “reference material” block);
- 6) to undergo the measures of control of their knowledge, skills, and abilities (the “control” block).

The “lectures” block. Each lecture included: 1) the relevant content of the lecture (for example, “Lecture 1”); 2) animation (for example, of “a black body”); 3) demonstrations (for example, video “the rays of cold”). Students were able to download the needed lecture file.

The problem teaching method was used in the presentation of lectures. For example, research on the topic “Thermonuclear reactions” begins with stating a problem. The Sun is the source of energy on Earth. This energy reaches our planet during radiation. The mass of the Sun decreases by about  $4 \cdot 10^9$  kilograms per second. But the next day the sun continues to shine. Why is the mass of the Sun not decreasing?

E-learning in quantum physics was supplemented with specially created animations revealing the content of physical concepts (black body, black body radiation, infrared radiation, visible light, ultraviolet radiation, external photoelectric effect, de Broglie waves, planetary atomic model, quark model of the nucleus) and computer models explaining the principles of operation of physical devices (radiometer, the Large Hadron Collider).

Many ideas of quantum physics contradict the ideas of classical physics (for example, an increase in body mass if the body moves at a speed comparable to the speed of light). To master quantum physics, students must have a high level of abstract thinking. Thus, teaching quantum physics has to involve teaching models.

A scientific model replaces the object in the process of learning and provides information about the object. A model is used when studying the object directly presents significant difficulties or is impossible. Researchers (Hughes, 1997; Morrison, 1998) have long formulated the requirements for the creation of scientific models: 1) illustrative design; 2) elements of abstraction; 3) elements of science fiction; 4) the use of analogies; 5) elements of the hypothesis.

The study of quantum physics is impossible without the use of scientific models. I. Henze et. al. (2007) argue that scientific models result from the work of scientists' creative imagination and this statement is also applicable to teaching models. Thus, the use of teaching models will also develop students' thinking in the process of studying quantum physics. We analyzed the works of scholars (Justi & Gilbert, 2002; Krajcik et al., 2008; Lehrer & Schauble, 2004) and identified two types of teaching models that can be used in teaching physics: material models and mental models.

Material models include material elements that interact in a specific way. Methodologists (Windschitl et al., 2008) determined the following requirements for material models: 1) compliance with safety regulations; 2) simple equipment; 3) curiosity; 4) consistency with the curriculum; 5) dynamism (the ability to demonstrate a phenomenon in motion).

Mental models and their visualization contribute to the formation of abstract thinking in students. Visual computer models allow students to better understand various physical phenomena. Thus, mental models help develop students' skills of conducting thought experiments using which a person performs a deliberate, structured process of intellectual reflection to speculate within a specific problem area about the potential consequences for a specific antecedent (or consequent) (Snir et al., 2003). A thought experiment is a method of scientific cognition of physics as a science. Several physical laws were discovered by scientists through thought experiments.

Although modeling is a central component of modern science, scientific models are, at best, approximations of the objects and systems they represent and not their exact replicas. Thus, scientists are constantly working to improve and refine the models (Schwarz & White, 2005). In the process of modeling, it is necessary to abstract from the

insignificant features of the phenomenon. Only the main characteristics of the phenomenon are reflected. It is difficult to explain any physical phenomenon using only one teaching model.

As an example, we will consider a mental model of a black body. A black body is an idealized model of a body that completely absorbs all incident light radiation of any wavelength at any temperature. The model of a black body is a freeform cavity with a small hole and opaque walls. Light rays entering the cavity are completely absorbed by multiple reflections from the cavity walls.

The animation of a black body was created using Corel DRAW X6 and Easy Gif Animator programs. The designed animation includes a set of images played over some time. In every image, the cavity remains unchanged. A ray of light entering the cavity always shifts the same distance closer to the hole. Once a ray enters the cavity, after multiple reflections, its thickness decreases as each reflected ray becomes thinner. All images were uploaded into Easy Gif Animator with the animation size set in percentage and a time interval of several milliseconds between each image transition and saved in the Gif format (the animation can also be saved in the AVI video format).

The computer model of black body radiation was created in the same way as the black body model. The light ray exiting the cavity undergoes multiple reflections. Its thickness increases after each reflection. When the ray exits the hole, its thickness is the greatest. Computer models of a black body and black body radiation allow students to better understand the laws of heat radiation.

The lecture demonstrations were created in video format. Students could download every video. Demonstration analysis allows students to better understand the theoretical material.

The “*practical assignments*” block promotes the formation of students’ problem-solving skills. This block presented examples of solving typical problems for all sections of the course. Since most students do not understand the practical application of the laws of physics, physics assignments should be related to real life. For example, let us examine the problem of radiocarbon dating: nitrogen atoms are constantly in the Earth’s atmosphere (78.082% of the volume of dry air). Under the influence of cosmic radiation, nitrogen nuclei are converted into radioactive carbon nuclei. Carbon enters the plants but the amount of this radioactive isotope gradually decreases once the plant dies. If an archaeological find is made of wood, scientists can determine the amount of carbon in the archaeological find using radiocarbon dating. This value is compared to the amount of radioactive carbon in a recently felled tree. Students determine the age of an archaeological find using the law of radioactive decay.

The “*reference material*” block contained information on modern research in the field of quantum physics. The block presented photographs of experimental installations, material models, and recommendations for correct demonstrations.

For example, the Large Hadron Collider (LHC), the largest experimental facility in the world. It is located near Geneva, Switzerland in a tunnel 27 kilometers in circumference and runs 175 meters underground. The goal of the research is to test the predictions of various theories of elementary particle physics, high-energy physics, and other unsolved problems of physics. The LHC is an accelerator for charged particles (for instance, protons). Scientists record the process of collision of particles. In 2012, scientists discovered a Higgs-like particle (the only missing link in the so-called "Standard Model" predicted half a century ago). The collision data was analyzed using a computer network infrastructure connecting 140 data centers in 35 countries. The LHC Worldwide Computing Network is the world's largest computing network.

The "control" block contains grading criteria and the list of questions for the midterm and final tests. Testing ensures the demonstration of students' knowledge, skills, and abilities. Students could have multiple test attempts. The electronic journal allowed students to see the results of their work thereby contributing to their self-improvement in learning.

The results of our study are consistent with the data from other works. For example, L. Shaw and D. Kennepohl (2013) proved the feasibility of online science teaching by examining the problem of how distance learners can participate in undergraduate research programs.

## CONCLUSION

The introduction of computer-oriented learning and, therefore, blended learning is about to accelerate significantly as a result of innovative activity of educational and scientific subjects, constant renewal of the innovative and technological support in all spheres of human activity, and the active use of digital technologies and the Internet.

Today, one of the most promising areas of education development is the combination of traditional and electronic learning in the form of blended learning defined as a purposeful process of transferring and assimilating knowledge, abilities, skills, and methods of human cognitive activity based on a combination of technologies of traditional, computer-oriented, and distance learning. Blended learning involves the rational use of study time, the adaptation of the educational process to the individual needs of each student, the diversification of sources of knowledge, the use of flexible instruments for diagnostics and monitoring educational achievements, the organization of feedback, and, as a result, an increase in the productivity of students' educational activities.

Blended learning as an innovative form of educational activity is complex and dynamic education that takes place under the influence of the external and internal environment conditions and the effectiveness of its functioning depends directly on the initial conditions. Compliance with these conditions allows determining the direction of development of blended learning and ensuring its success.



Blended learning in the theoretical part of the physics course can be conveniently organized based on the capabilities of Moodle using the “Lesson” (or “Lecture”) activity element which provides for the possibility of combining the presentation of theoretical material and the control of its assimilation.

The study results show that students who worked with educational materials in Moodle regularly demonstrate higher levels of cognitive activity.

Thus, the study hypothesis suggesting that the use of blended learning for teaching quantum physics increases the level of students’ cognitive activity was confirmed. Consequently, e-learning in quantum physics in Moodle ensures the development of students’ cognitive processes. Moodle can also be used to teach other physics disciplines such as mechanics, molecular physics, thermodynamics, electrodynamics, optics, and even other natural sciences such as chemistry, geography, and biology.

The creation of electronic teaching aids for physics in other virtual learning environments and the choice of the most effective learning environment are the prospects for further research in this work.

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