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ORGANIZATION AND CONDUCT OF PHYSICAL EXPERIMENTS: FEATURES OF VR TECHNOLOGY APPLICATION

Abstract

Today, it is important to organize and conduct physics experiments at a high modern level. Practices based on phenomena and laws from physics include not only theoretical knowledge, but also practical skills. However, the need for expensive equipment that requires time and safety measures when performing traditional laboratory work in the field of physics causes difficulties. It also limits the possibility for students to comprehensively study physical patterns during practice. The use of VR (virtual reality) technology in the organization and conduct of physical experiments will eliminate these problems and make a significant contribution to achieving learning outcomes. VR technology creates conditions for students to conduct experiments without hazardous materials and complex equipment. This, in turn, makes the activities in the educational process more optimal and safe. In this sense, the main idea and purpose of this study is to determine the features of the use of VR technology in teaching physics, effectiveness in achieving learning outcomes. The study examined examples of teaching some complex physics topics and determined the impact of VR on the assimilation of the topic, the possibility of improving the learning outcomes of laboratory classes. In the course of implementing the research objective, research methods were used: meta-analysis, questionnaires, mathematical and statistical analysis, etc. The results of the study showed the methodological features of the use of VR technology in physical experiments and the effectiveness in improving learning outcomes with ease of mastering the topic. In addition, at the end of the pedagogical study, the students expressed a desire to increase their interest and motivation in learning using VR technology.

Keywords: physical experience, virtual reality, learner, VR technologies, educational process, conducting experiments.

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ФИЗИКАЛЫҚ ТӘЖІРИБЕЛЕРДІ ҰЙЫМДАСТЫРУ ЖӘНЕ ӨТКІЗУ: VR ТЕХНОЛОГИЯСЫН ҚОЛДАНУДЫҢ ЕРЕКШЕЛІКТЕРІ

Аңдатпа

Бүгінгі таңда физика пәні бойынша тәжірибелерді заман талабына сай жоғары деңгейде ұйымдастыру және өткізу маңызды болып табылады. Физикадан құбылыстар мен заңдарға негізделген тәжірбиелер теориялық білімді ғана қамтымайды, практикалық дағдыларды да ұштастырады. Алайда, физика саласындағы дәстүрлі зертханалық жұмыстарды іске асыруда қымбат жабдықтардың қажеттілігі, уақытты және қауіпсіздік шараларын талап ететіндігі қиындықтар тудырады. Сондай-ақ, тәжірибе барысында физикалық заңдылықтарды білім алушылардың жан-жақты зерттеу мүмкіндігін шектейді. VR (виртуалды шындық) технологиясын физикалық тәжірбиелерді ұйымдастыру мен өткізуде қолдану бұл шеутеулерді жойып, оқу нәтижелеріне қол жеткізуде елеулі үлес қосады. VR технологиясы білім алушылардың қауіпті материалдарсыз, күрделі жабдықтарсыз тәжірибелерді жүргізуіне жағдай жасайды. Бұл өз кезегінде оқу үдерісіндегі іс-әрекеттерді оңтайлы әрі қауіпсіз етеді. Осы тұрғыдан бұл зерттеудің негізгі идеясы мен мақсаты VR технологиясын физиканы оқытуда қолданудың ерекшеліктерін, оқу нәтижелеріне қол жеткізудегі тиімділігін айқындау болып табылады. Зерттеуде физиканың кейбір күрделі тақырыптарын оқыту мысалдары қарастырылды және тақырыпты меңгерудегі VR әсері, зертханалық сабақтардың оқу нәтижелерін жақсарту мүмкіндіктері айқындалды. Зерттеудің мақсатын іске асыру барысында мета-анализ, сауалнама, математикалық-статистикалық

талдау және т.б. зерттеу әдістері қолданылды. Зерттеу нәтижелері VR технологиясын физика тәжірбиелерінде қолданудың әдістемелік ерекшеліктерін және тақырыпты жеңіл меңгеріп, оқу нәтижелерін жақсыртудағы тиімділігін көрсетті. Сонымен қатар, педагогикалық зерттеу соңында білім алушылар VR технологиясын қолдану арқылы, оқуға деген қызығушылығы мен мотивацияларын күшейте алғандарын білдірді.

Түйін сөздер: физикалық тәжірибе, VR технология, виртуалды шындық, 3D модел, оқу үдерісі, білім алушы.

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ОРГАНИЗАЦИЯ И ПРОВЕДЕНИЕ ФИЗИЧЕСКИХ ОПЫТОВ: ОСОБЕННОСТИ ПРИМЕНЕНИЯ ТЕХНОЛОГИИ VR

Аннотация

На сегодняшний день важным является организация и проведение экспериментов по физике на высоком современном уровне. Практики, основанные на явлениях и законах из физики, включают не только теоретические знания, но и практические навыки. Однако необходимость дорогостоящего оборудования, требующего времени и мер безопасности при выполнении традиционных лабораторных работ в области физики вызывает трудности. Также ограничивает возможность всестороннего изучения обучающимися физических закономерностей в ходе практики. Применение технологии VR (виртуальной реальности) в организации и проведении физических опытов устранит эти проблемы и внесет существенный вклад в достижение результатов обучения. Технология VR создает условия для проведения обучающимися экспериментов без опасных материалов, сложного оборудования. Это, в свою очередь, делает деятельность в учебном процессе более оптимальной и безопасной. В этом смысле основной идеей и целью данного исследования является определение особенностей применения технологии VR в обучении физике, эффективности в достижении результатов обучения. В исследовании рассматривались примеры преподавания некоторых сложных тем физики и определялись влияние VR на усвоение темы, возможности улучшения результатов обучения лабораторных занятий. В ходе реализации цели исследования были использованы методы исследования: метаанализ, анкетирование, математико-статистический анализ и др. Результаты исследования показали методологические особенности применения технологии VR в физических экспериментах и эффективность в улучшении результатов обучения с облегчением освоения темы. Кроме того, в конце педагогического исследования обучающиеся выразили желание усилить интерес и мотивацию к обучению с помощью технологии VR.

Ключевые слова: физический опыт, VR-технология, виртуальная реальность, 3D-модель, образовательный процесс, обучающийся.

Main provisions

The idea of the prospective study is to increase the possibility for students to comprehensively study physical patterns in the process of practice based on VR (virtual reality) technology. During the study, examples of teaching some complex physics topics were considered and the influence of VR on the assimilation of the topic, the possibilities of improving the learning outcomes of laboratory classes were revealed. The study used methods of meta-analysis, questionnaires, mathematical and statistical analysis. The results of the study showed the methodological features of the use of VR technology in physical experiments and the effectiveness in improving learning outcomes with ease of mastering the topic.

Introduction

It is known that the conduct of traditional laboratory classes in teaching subjects in the field of physics presents a number of difficulties. Indicators of these difficulties are the inability of students to demonstrate the theoretical knowledge gained in lecture classes in the course of practical work, time constraints in laboratory classes, and lack of access to the equipment necessary for performing many physics experiments. Currently, several studies are being conducted to identify new

technologies to overcome these difficulties. The fact that the pace of technology is changing faster than ever makes it necessary to develop skills related to these technologies early in the student.

In recent years, the widespread use of virtual reality in the field of Education has opened up new opportunities for organizing and conducting physical experiments. Working in an immersive environment based on virtual reality technologies is carried out using specially developed software tools. The importance of virtual reality (VR) technology in teaching physics can be explained by the ability of students to make virtual trips using traditional methods. VR technology allows you to comprehensively demonstrate, study, analyze experiences based on physical phenomena and laws, entering the world of virtual reality.

The work of researchers on the use of VR technology in chemistry and physics laboratories shows that the results of training had a significant positive effect. In the chemistry laboratory, the performance of tasks using VR technology increased by 92.63%, in the Physics Laboratory-by 93.38%. Scientists have proven that VR technology is easy to use in laboratories and improves practical skills [1]. VR technologies create the conditions for making physical experiences more interactive and visually interesting. Students in the educational process can control experiments with their own hands and monitor the results in real time, changing various parameters. Scientific research shows that VR technology can improve the quality of learning and increase the motivation of students [2]. T. Li paid special attention to the advantages and design principles of VR technology in order to deepen students ' knowledge and improve the efficiency of the educational process [3]. Therefore, we are convinced that the use of VR virtual reality technology in order to increase the motivation of students using interactive and visual elements in teaching physics has a significant potential. In improving the process of teaching physics, augmented reality (XR) technologies, Virtual Reality (VR) and augmented reality (AR) technologies have given students confidence that they will increase learning motivation [4]. The smartphone-based model of virtual reality (VR) technology provided a free tool for creating visualizations for STEM courses, allowing students to easily create VR visualizations across multiple platforms without the need to learn a complete VR development system [5]. In addition, there are studies that have shown the need to develop VR-based learning, that is, the attitude of participants to The conducted survey among students to this conclusion [6]. Thus, it can be concluded that the development of educational resources using innovative technologies on the way to learning physical knowledge plays an important role in developing students ' interest in learning. Among the works that can serve as the basis for the use of the virtual environment in the educational process, E. Shudaifat, N. Alsalhi were able to find out the level of participants by dividing them into experimental and control groups. The experimental group, trained in a virtual environment, found that there was a statistical difference compared to the control group, showed a positive result [7]. H. Guleryuz conducted a study with the view that the introduction of new technologies in the educational process will make learning more sustainable and effective. As a result, a study that lasted 8 weeks showed that 3D technology gives positive results in the educational process [8].

As one of the most important principles of using VR technology in organizing physical experiments, one can cite the ability to make laboratory classes more interesting and increase their methodological significance. S. Chou showed the importance of teaching students of the fourth grade of primary school using interactive technologies in the direction of improving learning outcomes through research [9]. In his article, H. Alsouat noted that VR technology gives good results in the educational process, in the gaming industry, and also has a positive effect on improving digital literacy [10]. In order to increase the level of education of students in the educational process, M. Kumalasari, M. Trieno conducted a study of students in 11 classes, as a result of which they found that the lower-level group was able to increase the level of education by 33%, the middle-level group by 60%, and the upper-level group by 7%. He argued that the virtual world of physics helps students to create physical experiments on their own [11]. The use of VR technology requires conducting research aimed at increasing the interest of students, these studies are used in the organization and conduct of physical practices in the educational system or in the STEM field. These studies show the benefits of VR, which allows you to visualize physical processes in a virtual environment, which in

turn contributes to the development of the educational system. This work focuses on the use of VR technology in teaching physics to answer the scientific questions of the following study:

- Are there any significant differences in the motivation of students using VR technology to master theoretical knowledge in physics?
- What is the role of VR technology in the development of practical skills of students?
- What are the advantages of using VR technology in creating physical experiments over traditional methods?

The purpose and main idea of this study is to determine the solution to the above problems, to demonstrate the advantages of using VR technology in organizing and conducting physical experiments.

Research methodology

In the course of the study, the selection of scientific papers was selected according to predetermined criteria. The search was carried out using the keywords" physical education"," virtual reality"," 3D model " and the publications of the last 5 years were taken into account. To increase the statistical significance of the results, we used meta-analysis – a method of combining the results of several scientific papers to formulate general conclusions. Each method is aimed at solving specific research questions and contributes to the conduct of research on a systematic and scientific basis. Depending on the goals and objectives of the study, methods of metaanalysis, survey, as well as mathematical and statistical analysis were used. The reliability and accuracy of the data obtained ensures the scientific validity of theoretical conclusions, the logical structure of the study and the results of testing in the experimental environment. In 2024, a study was conducted at the Khoja Ahmet Yassawi International Kazakh-Turkish University. The total number of participants was 80 students (Bachelor, Master, PhD). The participation of participants in a one-time survey made it possible to find out the benefits of using VR technology in the organization and conduct of physical experiments. 62 students in the specialty 6B01510-Physics, 16 students in the specialty 6b05348-Physics, 2 participants in the specialty 6B05310-physics made a choice according to their point of view. The questionnaire includes 14 main questions related to the topic and 2 additional questions related to the direction of study. The questionnaire is designed to identify the features of the use of VR technology in the educational process. Scientific assumptions were studied to determine the statistical significance of the survey results. The content of scientific forecasts is as follows:

H_{01}: From the point of view of the survey participants, there is no advantage in using VR technology in teaching physics.

H_{02}: Physical experiments conducted using VR technology significantly increase students ' experience skills and interest in the subject compared to traditional methods.

In processing the data from the survey, we used the t test (one sample t test), which is the most effective test for determining whether there is a statistical difference in only one survey. we can determine its value using the Formula (1).

$$t = \frac{\bar{X} - \mu_0}{\frac{S}{\sqrt{n}}} \tag{1}$$

$\bar{X}$ - arithmetic mean value, (2) we define by the expression.

$$\hat{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \tag{2}$$

μ_0 - the hypothetical average value. Based on the hypothesis, the accepted mean is the value.
S – standard deviation.

Standard deviation is a statistical parameter that shows how much the values obtained in the result deviate from the average value. In determining the standard deviation (2), the mean value was determined according to the formula. Then determine the difference of each value from the average and calculate the square of each difference. Determine the sum of the found squares and divide it by the number of elements. Find the square root of the last result. The general conclusion of these operations is shown in Formula (3).

$$S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \hat{X})^2 \quad (3)$$

n – sample size.

Results of the study

As a result of 10 articles taken as a basis, the meta-analysis data are shown in Table 1.

Table 1. Collected scientific sources by the method of meta-analysis.

Study name	***Std diff in means***	***Std Err***
1	***2***	***3***
Shudayfat et.al (2021)	*1,608*	*0,149*
Hasan Güleryüz (2023)	*1,967*	*1,536*
Chin-Cheng Chou (2016)	*0,783*	*2,66*
Hamad H. (2022)	*0,803*	*0,191*
Phoong et.al. (2020)	*3,302*	*3,476*
Elfakki et.al (2016)	*7,09*	*1,394*
Kumalasari et.al (2018)	*1,13*	*1,685*
Bhakti et.al (2023)	*1,509*	*0,181*
Widodo et.al (2022)	*0,221*	*0,332*
Asıksoy and Islek (2017)	*3,539*	*4,24*

The results obtained in Comprehensive Meta-Analysis 4.0. we can get a conclusion by entering it into the program. The first conclusion was determined by the plot of the pit. The funnel drawing is a graphical tool for detecting deviations in meta - analysis. Conclusion of the drawing of the pit in US (Figure 1).

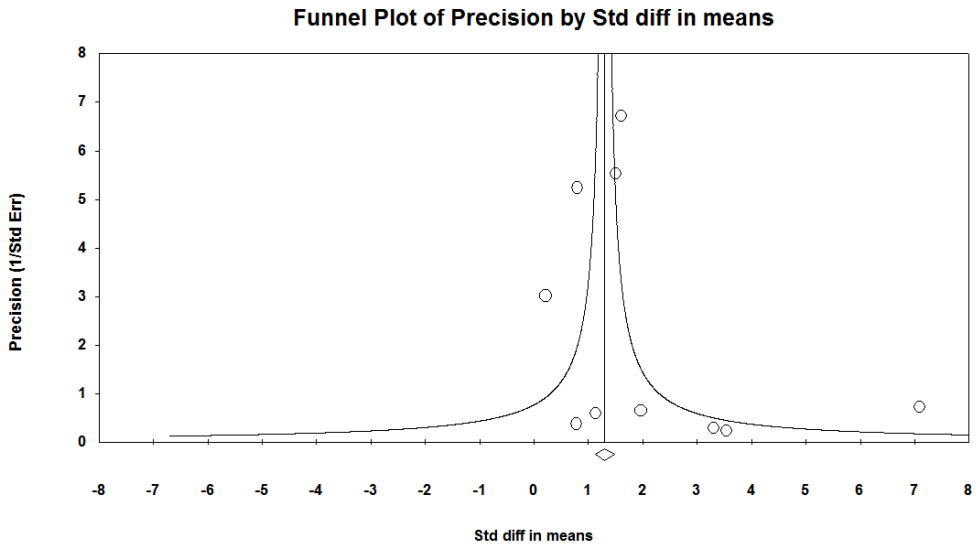

Figure 1. Pit drawing according to the analysis of the scientific literature

For the synthesis and interpretation of the results of scientific research, the Forest plot (forest plot) is the basis tool. The results of 10 articles taken as a basis were shown graphically (Figure 2).

Model	Study name	Statistics for each study						Std diff in means and 95% CI
		Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	-1,00 -0,50 0,00 0,50 1,00
	Shudayfat	0,149	0,022	1,316	1,900	10,792	0,000	
	Hasan	1,536	2,359	-1,044	4,978	1,281	0,200	
	Chin-Cheng	2,660	7,076	-4,431	5,997	0,294	0,768	
	Hamad H.	0,191	0,036	0,429	1,177	4,204	0,000	
	Phoong	3,476	12,083	-3,511	10,115	0,950	0,342	
	Elfakki et.al	1,394	1,943	4,358	9,822	5,086	0,000	
	Kumalasari	1,685	2,839	-2,173	4,433	0,671	0,502	
	Bhakti et.al	0,181	0,033	1,154	1,864	8,337	0,000	
	Widodo	0,332	0,110	-0,430	0,872	0,666	0,506	
	As?ksoy	4,240	17,978	-4,771	11,849	0,835	0,404	
Random		0,311	0,097	0,770	1,991	4,433	0,000	
Pred Int				-0,244	3,005			

Figure 2. Forest plot (forest plot) reflection of the results of scientific works in the form of a graph

Let us dwell on the main conclusion of the analysis. The analysis is based on ten studies. The average impact was considered with a confidence interval of 95% from 0.770 to 1.991. The Z-value evaluates the null hypothesis, which checks whether the average effect value is zero. With a Z-value of 4.433 and a significance level of 0.05, with a value of $p < 0.001$, we conclude that the magnitude of the average effect is significantly different from zero, which refutes the null hypothesis.

The results of such a meta-analysis show that the use of virtual materials in physical experiments has a positive effect [12-16]. In this way, we can continue our research with confidence. In connection with these studies and combining the results of scientific research on the research topic, meta-analysis has revealed the relevance of our topic. The analysis of 10 articles provides accurate information and useful recommendations regarding the use of VR technology in physical experiments and in the educational process. Most of the works studied were based on quantitative methods, in which researchers used questionnaires, experiments, tests and control work to collect data. The results of the analysis showed that the use of VR technology in the organization and conduct of physical experiments has advantages.

Thus, the use of VR technology in teaching physics offers many opportunities and advantages:

- Improve the visualization and understanding of educational material;
- Increase the intellectual interest of students;
- Increase the level of security and reduce costs;
- Convenience of conducting laboratory work.

In particular, the widespread use of VR technology in the educational process has a great impact on the quality of education and increasing students ' interest in science. VR technology is a reality created using 3D images and computers. It is used either through large screens or through VR glasses mounted on the head. VR glasses (Figure 3) are distinguished by the fact that they give the impression of being in the real world. VR glasses can allow the user to interact in a realistic way in the virtual world and allow them to improve practical knowledge in different areas.

We have experimentally examined the possibilities of VR glasses in the interpretation of physical phenomena and laws in the course of training. The use of VR glasses provides students with new opportunities in the study of physics when explaining the working principles of various devices, such as ballistic pistols, barometers, Transformers, internal combustion engines and jet engines. The most effective way to explain the principle of operation of any physical equipment is to break it down into components. Using VR technologies, it is possible to create a 3D model of any device, which students can divide into parts and reconstruct, which significantly improves the understanding and assimilation of the material.

Figure 3. VR glasses in the Physics Laboratory

For example, you might consider using VR glasses with the IXR Labs program installed. This program shows the working order of the transformer, which helps to better understand the working principle of physical equipment (Figure 4).

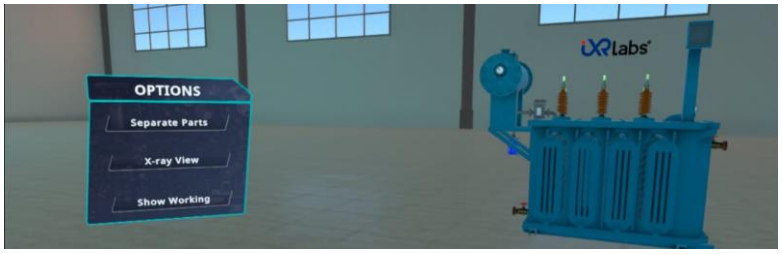

Figure 4. Transformer composition. IXR Labs program.

Each theme consists of three parts called Separate Parts, X-ray View, Show Working. In the Separate Parts section, the unit is arranged divided into parts. Each of them is transmitted in Test and audio formats with information about the function of this particle when touched by a beam from the VR helmet controller. In the X-ray View section, the external body of the unit is transparent, the internal mechanisms and the ongoing phenomena, the principle of operation of the unit are clearly visible. VR technology has reached a high level due to fierce competition in the gaming industry. However, in the field of educational content, competition is much lower, which leads to many disadvantages. For example, in the program mentioned earlier, limited interactive interaction can be observed, although each student wants to have the opportunity to literally "catch" the objects they are studying. Therefore, the development of VR technologies aimed at education, especially in the preparation of future physics teachers, and providing students with the opportunity to independently interact with teaching aids, should be considered as one of the main tasks of modern physical education. Let's consider the results of the survey based on the research topic. The results of the t test for one questionnaire in order to determine the features of the use of VR technology in teaching physics are shown below. 80 students took part in the survey. The average value of their accepted result for each question was determined using the formula (M) (2).

$$M = \frac{8+10+10+10+8+20+13.3+13.3+13.3+10+8+8+9.6+13.3}{14} = 11.1$$

t is another quantity required to calculate the test standard deviation. We calculated the value of the standard deviation (S), as shown in the expression (3).

$$S^2 = \frac{1}{14-1}((11.1-8)^2 + (11.1-10)^2 + (11.1-10)^2 + (11.1-10)^2 + (11.1-8)^2 + (11.1-20)^2 + (11.1-13.3)^2 + (11.1-13.3)^2 + (11.1-13.3)^2 + (11.1-10)^2 + (11.1-8)^2 + (11.1-8)^2 + (11.1-9.6)^2 + (11.1-8)^2 + (11.1-13.3)^2 = 11.1$$

$$S = \sqrt{11.1} = 3.33$$

We determine the value of the Test (t) by putting the calculated results in the Formula (1). (1) the hypothetical mean in the expression is equal to 20.

$$t = \frac{20 - 11.1}{\frac{3.33}{\sqrt{14}}} = 10.0002$$

The main parameter in determining the degree of freedom (df) p value. Its definition varies depending on the type of survey. Since we only have the results obtained for one survey, the determination of the degree of freedom (df) is determined by the expression below.

$$df = n - 1 = 14 - 1 = 13$$

After the parameter required to calculate the entire p value is determined, we calculate the p value using the SPSS program. In our case, the value of the p value (2) is shown in Table.

Table 2. Data result

Category	*n*	*M*	*SD*	*SEM*	*df*	*t*	*p*
	14	*11.1*	*3.33*	*0.89*	*13*	*10*	*0.0001*

**M is the arithmetic mean; SD is the standard deviation; SEM is the standard error; df is the degree of freedom; the average difference is important at p ≤ 0.05;*

From the point of view of students, the statistical significance of the survey result was: t(13)=10. $p < 0.05$, that is, it shows that there is enough evidence to reject the null hypothesis.

Based on the results obtained, the H_{01} hypothesis was refuted. That is, the results of a survey of participants showed that the use of VR technology in organizing and conducting physics experiments has its advantages. In conclusion, it should be noted that the use of VR technology in teaching physics makes a great contribution to improving the quality of education and awakening their scientific interest.

Discussion

The results of the current study open up prospects for a deeper application of VR technologies, especially in aspects of improving the efficiency of laboratory classes, strengthening interactive elements of the educational process and improving the quality of education in general. Comparison of these results with data from other scientific studies makes it possible to comprehensively assess both the advantages and existing limitations of VR technologies, which contributes to their integration into educational practice in a more grounded way. In experiments using VR technologies on the topics of force and mass of the mechanics course, it was shown how innovative technologies can be integrated into the physics teaching process [17]. Traditionally, teachers communicate physical knowledge to students through textbooks or oral explanations, which often leads to difficulties in fully understanding physical phenomena. The use of interactive technologies, including VR, allows you to overcome these difficulties and provides visual and understandable ways of learning the material [18]. Independent implementation of physical practices contributes to the better assimilation by students of the basic concepts of mechanics, where the active activity of the student plays an important role. In this sense, VR technologies significantly increase the effectiveness of the

educational process, allowing students to recreate and experience physical phenomena themselves [19]. It is also worth noting a scientific study in which VR was used to create virtual laboratories in quantum physics, which made it possible to conduct experiments with quantum gates as part of a full-time training program. The results showed that the use of VR allowed students to gain a deeper understanding of the concepts of quantum gates.

Thus, in our study, we can conclude that VR technologies significantly expand educational opportunities, which significantly affect the quality of teaching physics and open up new prospects for the educational process as a whole.

Conclusion

Modern educational processes require the active introduction of new technologies. These technologies can significantly improve students ' learning opportunities and increase the effectiveness and attractiveness of learning. The benefits that new technologies bring to the education system can contribute to the direct improvement of its quality. This scientific study suggests the use of VR technology in the creation of physical experiments. In particular, it was shown that VR technology has a significant impact on the quality of physics teaching and the ability of students to understand. The benefits of using VR technology, such as increasing motivation for learning, creating a safe and comfortable experience, are recognized as a new and effective method of using VR technology in physics. In the future, the widespread use of VR technology in the education system will make a great contribution to the awakening of scientific interest of students. This research has been/was/is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No.).

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