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Impact of VR technology in physics teaching on students' knowledge: a study on body acceleration

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ABSTRACT

The integration of virtual reality (VR) technology into education represents a promising innovation, particularly in enhancing the effectiveness of physics teaching. Traditional physics instruction often lacks interactive and immersive elements, which can limit students' understanding of complex physical phenomena. This study addresses the challenge of improving comprehension of body acceleration by incorporating VR-based laboratory simulations. A quasi-experimental design was implemented, involving 222 university students randomly assigned to control and experimental groups. The experimental group conducted virtual experiments using VR simulations developed with Blender and Unity software, while the control group engaged in traditional lab activities. Data were collected through pre- and post-tests and analyzed using independent t-tests and G*Power software to assess statistical significance. The results revealed a notable improvement in learning outcomes for students exposed to VR-enhanced instruction, demonstrating increased engagement, deeper conceptual understanding, and improved ability to connect theoretical knowledge with practical application. This study confirms that VR technology is a powerful tool for modernizing science, technology, engineering, and mathematics (STEM) education and holds significant potential for improving cognitive outcomes and student motivation in scientific learning environments.

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1. INTRODUCTION

As society advances and the economy grows, there is a rising interest in acquiring knowledge, prompting a shift from conventional teaching approaches toward the integration of contemporary technologies. Among these, virtual reality (VR) has emerged as a prominent innovation in modern information technology, experiencing rapid development in recent years [1]. VR is a technology that completely integrates the user into a computer environment, which gives the user the opportunity to interact through special devices (glasses, gloves, and motion tracking devices) [2]. VR based learning is one of the most important trends in the modern education system. This technology makes the learning process more fun, effective and interactive. VR radically changes the content of teaching methods, not limited to the creation of new tools. In their research, An *et al.* [3] found that VR technology has great potential for an effective and innovative learning process. They note that with the help of VR technology, students can easily understand complex topics by visualizing them, and are also motivated to actively participate in the learning process.

Marougkas *et al.* [4] show that the use of VR in education can radically change the learning process. VR technology increases the educational motivation of students and allows them to combine theoretical knowledge with practical knowledge. Kuna *et al.* [5] emphasize the importance of using VR technology for educational purposes. VR technology proves to make the learning process more efficient by providing students with experiences that are not possible in the real world. VR technology occupies an important place as the future of education and makes it possible to modernize the learning process. This research confirms the importance of VR technology in improving the learning process, including increasing student motivation, practical application of theoretical knowledge, and interpretation of complex topics. VR is considered as an important technology for the future of the education system [6]. VR technology improves the learning process in physics lessons, helping to increase student interest and make it easier to interpret complex topics. This technology promotes the development of students' creative abilities and contributes to a deeper understanding of physical phenomena.

By creating immersive, interactive environments, VR has the potential to bridge the gap between theoretical knowledge and practical application, fostering deeper understanding and engagement [7]. Asencios-Trujillo *et al.* [8] study how modern technologies can be integrated to provide new quality in physical education. Scientists are using VR technology for the computer game market to correctly and accurately simulate physical experiments. With the help of this technology, students were able to create their own experience and study it [8]. In their study, Debs [9] examined ways to use VR technology in teaching physics lessons. The use of VR technology in physics lessons has shown that students can actively participate in classes, combine theoretical knowledge with practical skills, and that this technology contributes to improving the quality of knowledge by reproducing physics lessons. Saputro and Setyawan [10] have shown that VR technology is effective for improving cognitive outcomes in teaching the solar system. With the help of VR technology, students have a deeper understanding of complex astronomical concepts and better assimilate materials. In addition, VR technology has increased the interest of students and stimulated their active participation in the educational process. The results of the study prove that VR technology has a great future in teaching physics [10].

The use of VR technology in teaching physics at universities is becoming an increasingly effective and innovative area of modern educational methods. VR technology allows to visualize physical phenomena, develop students' research abilities and explore complex topics more deeply. This method complements traditional approaches to learning and provides a new level of learning. This research aims to use VR technology in physics education to answer the following research questions:

- How does the use of VR technology affect the level of knowledge of students in the interpretation of body acceleration?
- How does learning through VR technology change the efficiency of knowledge acquisition compared to traditional methods?
- Does the use of VR technology increase students' interest in physics lessons?

The primary purpose of this research is to enhance students' comprehension of physics concepts through immersive learning experiences. Specifically, the study aims to improve the effectiveness of teaching methodologies by integrating VR technology into the learning process. By demonstrating the physical experiment of determining body acceleration in a virtual environment, students are given the opportunity to visualize and interact with abstract concepts, leading to deeper understanding and increased engagement.

2. METHOD

The strategy and approaches to research differ in the degree of novelty and are implemented in accordance with the set goals, objectives, and scientific hypotheses. In the course of the research, a meta-analysis method was used using scientific literature data to determine the impact of using VR technology on the level of knowledge of students in physics lessons. Its influence has been comprehensively examined through a systematic analysis of the problem of using VR technologies in physics lessons. The models were developed using VR technology to understand the acceleration of the body in a virtual environment and its relationship to the laws of physics. Control tasks were obtained in order to assess the attitude of students to the use of VR technology, interest and cognitive activity in the educational process. The data obtained were calculated using G*Power software, and the correctness of the hypotheses was considered. In order to verify the reliability and statistical significance of the collected data, the method of mathematical and statistical analysis was applied.

The collection of primary information in determining scientific research problems and determining tasks that need to be solved is carried out on the basis of scientifically based methods. Preliminary selection works "Mendeley.com" is based on the analysis of highly rated articles from the database. The analysis of scientific sources for the keywords "virtual reality", "teaching physics", "acceleration", "physical experiments", "education" takes into account publications over the past 10 years. The content of the selected articles was systematically analyzed, methodological and practical aspects were considered, assessing the impact of using VR technologies on the level of students. Quantitative and qualitative methods, methods of pedagogical control are aimed at studying the interest and cognitive activity of students in the educational process. These methods make it possible to comprehensively evaluate the results of teaching physics students using VR technologies. Method of modeling allows the use of VR technology to modeling the physical experience to determine the acceleration of the body. Meta-analysis method combines the results of scientific work and allows to draw general conclusions. The meta-analysis method is implemented by the comprehensive meta-analysis 4.0 program. It performs calculations based on two parameters using software. The first represents a standardized average difference in effect size, and the second represents a standardized error. First of all, the size of the effect of the standardized mean difference is determined, which is expressed in (1):

$$Standardized\ difference = \frac{\overline{X_1}-\overline{X_2}}{S} \tag{1}$$

Where, S is the most necessary parameter in determining the mean of the total standard deviation. It follows from the standard deviation of the two results shown in (2):

$$S = \sqrt{\frac{(n_1-1){S_1}^2+(n_2-1){S_2}^2}{n_1+n_2-2}} \tag{2}$$

A standardized error is drawn through the GraphPad site. In the comprehensive meta-analysis 4.0 program, necessary data are introduced and the results of meta-analysis are obtained. To increase the interval of prognosis used Microsoft Office Excel 2010. The method of mathematical and statistical analysis allowed us to process the data obtained during the pedagogical experiment, to assess the level of development of students' interests. The mathematical and statistical analysis was based on the test results. A total of 222 students took part in the pedagogical experiment. The pedagogical experiment was conducted with students enrolled in the educational programs under the Department of Physics at Khoja Akhmet Yassawi International Kazakh-Turkish University and Sarsen Amanzholov East Kazakhstan University. Quantitative data were collected quasi-experimentally using a pre-experimental and post-experimental survey of two groups. General information about the students is presented in Table 1.

In order to determine the statistical significance of the result obtained from the test task, we have considered scientific forecasts: the use of VR technology in teaching physics does not significantly affect the level of knowledge of students when studying the topic "determining body acceleration" (H_{01}); the use of VR technology in teaching physics increases the level of knowledge of students in mastering the topic "determining body acceleration", which is manifested by significant positive changes in the results of their understanding of theoretical knowledge and acquisition of practical skills (H_{02}). Using the survey results, the effectiveness of the dependent variable between the control and experimental groups was evaluated using the T-test. Based on the data after the experiment, an independent sample t-test was used to compare the dependent variables of the two groups.

Table 1. General information about students

Group	Number			Percentage (%)	Total
Experimental	110			49	222 (100%)
Control	112			51	
Gender	Female (135)	Control	68	61	222 (100%)
		Experiment	67		
	Male (87)	Control	42	39	
		Experiment	45		

3. RESULTS

A comprehensive meta-analysis of scientific sources was conducted to examine how VR technologies influence students' learning outcomes in the educational process. This analysis allowed the identification of key patterns and trends in the integration of VR tools in various learning environments. The collected data reflect the synthesis of findings from numerous empirical studies conducted over the last decade. These studies, referenced from [11]–[41], form the foundation of the meta-analytical framework. The results of this analytical work are systematically summarized and presented in Table 2, providing quantitative insights into the effectiveness of VR-based educational interventions. Overall, the meta-analysis highlights the growing relevance of VR technologies in enhancing students' academic performance.

Table 2. Scientific sources collected by the method of meta-analysis

Study	Std diff means	Std error
Lee and Kim [11]	-2.19	0.095
Akman and Çakır [12]	0	0.25
Chang *et al.* [13]	4.082	1.306
Demitriadou *et al.* [14]	0.654	0.21
Fokides and Chachlaki [15]	0.657	0.143
Cao and Jian [16]	0.52	0.115
Ghazali *et al.* [17]	0.572	0.268
Innocenti *et al.* [18]	2.452	0.441
Kim and Ke [19]	0.289	0.175
Liou *et al.* [20]	0.626	0.279
Liu *et al.* [21]	0.912	0.222
Rincker and Misner [22]	-0.34	0.096
Sarioğlu and Girgin [23]	1.156	0.216
Weng *et al.* [24]	1.931	0.271
Kustandi *et al.* [25]	1.42	6.215
Godula *et al.* [26]	0.189	0.078
Mäkinen *et al.* [27]	0.433	0.272
Romano *et al.* [28]	0.234	0.11
Gunn *et al.* [29]	0.938	0.131
Cheon *et al.* [30]	0.083	8.202
Shudayfat and Alsalhi [31]	1.608	0.149
Güleryüz [32]	1.967	1.536
Chou [33]	0.783	2.66
Phoong *et al.* [34]	3.302	3.476
Elfakki and Sghaier [35]	7.09	1.394
Man *et al.* [36]	1.13	1.685
Bhakti *et al.* [37]	1.509	0.181
Widodo *et al.* [38]	0.221	0.332
Asıksoy and Islek [39]	3.539	4.24
Jiao *et al.* [40]	1.803	1.181
Wardian *et al.* [41]	0.005	0.066

The conclusions were drawn by including the results obtained in the comprehensive meta-analysis 4.0 program. The program analyzed all the quantitative data of the study and allowed to determine the reliability and statistical significance of the results. The funnel plot was used to visualize the results of the meta-analysis. This method is a graphical tool for identifying differences between publications or studies in meta-analysis, as shown in Figure 1.

The forest plot was used as the main tool for the synthesis and interpretation of scientific research results. This method allows to visualize comparative research results and assess their overall impact. In the course of the research, the results of 35 fundamental articles were graphically presented. Each article assessed the impact of using VR technology on the level of knowledge of students, as seen in Figure 2.

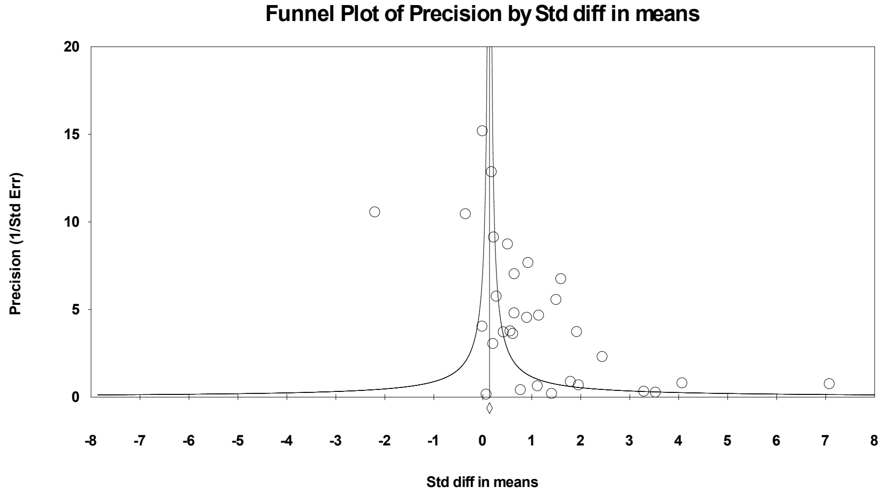

Figure 1. Funnel diagram for the analysis of scientific literature

Model	Study name	Statistics with study removed						
		Point	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Lee and	0.807	0.136	0.018	0.541	1.073	5.950	0.000
	Akman	0.828	0.214	0.046	0.408	1.249	3.862	0.000
	Chang et.al.	0.735	0.209	0.044	0.325	1.145	3.514	0.000
	Demitriadou	0.799	0.215	0.046	0.379	1.220	3.724	0.000
	Fokides	0.802	0.217	0.047	0.378	1.227	3.703	0.000
	Cao & Jian	0.813	0.220	0.048	0.383	1.244	3.703	0.000
	Ghazali	0.802	0.214	0.046	0.383	1.221	3.748	0.000
	Innocenti	0.722	0.210	0.044	0.310	1.134	3.436	0.001
	Kim et.al.	0.819	0.216	0.047	0.395	1.243	3.785	0.000
	Liou et.al.	0.799	0.214	0.046	0.380	1.218	3.739	0.000
	Liu et al.	0.786	0.214	0.046	0.367	1.205	3.678	0.000
	Rincker	0.856	0.221	0.049	0.422	1.290	3.869	0.000
	Sarioglu	0.774	0.213	0.045	0.357	1.191	3.635	0.000
	Weng et.al.	0.735	0.210	0.044	0.324	1.146	3.505	0.000
	Kustandi	0.790	0.208	0.043	0.381	1.198	3.790	0.000
	Godula	0.843	0.229	0.053	0.394	1.293	3.677	0.000
	Makinen	0.808	0.214	0.046	0.389	1.228	3.776	0.000
	Romano	0.829	0.221	0.049	0.395	1.263	3.746	0.000
	Gunn et.al.	0.787	0.215	0.046	0.365	1.208	3.658	0.000
	Cheon et.al.	0.791	0.208	0.043	0.383	1.199	3.797	0.000
	Shudayfat	0.743	0.207	0.043	0.337	1.149	3.585	0.000
	Hasan	0.775	0.210	0.044	0.364	1.185	3.697	0.000
	Chin-Cheng	0.791	0.209	0.044	0.381	1.200	3.786	0.000
	Phoong	0.782	0.209	0.043	0.373	1.191	3.750	0.000
	Elfakki et.al	0.692	0.207	0.043	0.286	1.099	3.338	0.001
	Man et.al	0.787	0.209	0.044	0.376	1.197	3.755	0.000
	Bhakti et.al	0.753	0.210	0.044	0.341	1.165	3.582	0.000
	Widodo	0.816	0.214	0.046	0.398	1.235	3.822	0.000
	Asiksoy	0.784	0.208	0.043	0.376	1.193	3.762	0.000
	Jiao et.al.	0.771	0.210	0.044	0.359	1.183	3.671	0.000
	Wardian	0.859	0.234	0.055	0.400	1.319	3.666	0.000
Random		0.790	0.208	0.043	0.382	1.198	3.797	0.000
Pred Int		0.790	0.000	0.000	-1.250	2.830	0.000	0.000

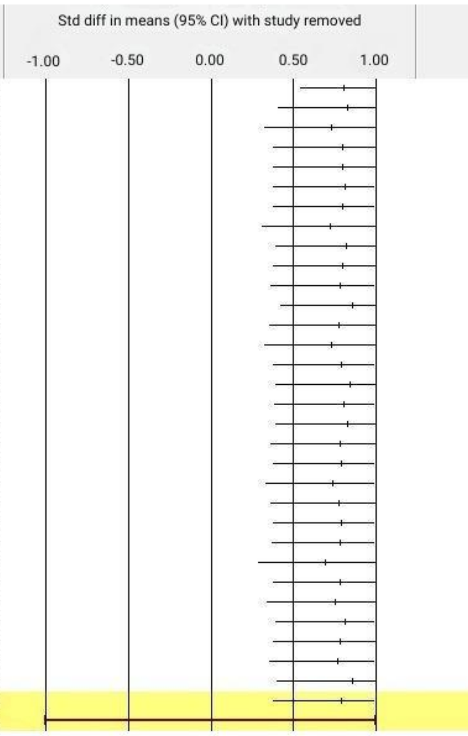

Figure 2. Representation of the results of scientific works in the form of graphs

3.1. Review

The analysis is based on 35 studies. The effect size index is the standardized difference (d) between the means. The random-effects model was used for the analysis. It is considered that this model was randomly selected from a set of potential studies that were presented in the research analysis. The results obtained using this model are used to derive an entire similar set of studies. The average impact rate is 0.727, with a confidence interval of 95% from 0.374 to 1.080. This indicator means that the average impact size of a similar set of studies can be at any point in this interval. The Z-statistic checks the null hypothesis (the assumption that the average effect size is zero). Z has a value of 4.037, and $p<0.001$. Since 0.050 is accepted as the Alpha criterion, the null hypothesis is rejected. Thus, it is concluded that the average effect size is not exactly zero in a set of populations similar to the studies in this analysis.

3.2. Q-test for heterogeneity

Q-statistics test the null hypothesis (the assumption that all studies in the analysis have the same amount of impact). If the effect size is the same in all studies, the value of Q is equal to the degree of freedom (the number of studies is minus 1). The value of Q is 1063.700, the degree of freedom is 34, and $p<0.001$. Since 0.100 is accepted as the alpha criterion, the null hypothesis is rejected. Consequently, these studies show that the number of true effects varies.

3.3. The I-square of statistics

The I-square statistic shows 97%, which means that about 97% of the variance of the observed amounts of the effect reflect the variance of the true amounts of the effect, and the remaining 3% indicate a selection error. A meta-analysis related to the studies reviewed and combining the results of scientific research on the research topic clarified the relevance of our research topic. The 35 articles under review provide accurate information and useful recommendations on the use of VR technology in physical experiments and in the educational process. Almost all of these studies are based on numerical methods that allow an objective assessment of the effectiveness of VR technology. These studies suggest new ways to improve the learning process using VR and show that widespread adoption of this technology is promising. The use of VR technology has shown that students have not only increased their level of knowledge, but also developed their practical skills and abilities to better understand physical phenomena.

More precisely, the widespread use of VR technology in the educational process will improve the quality of education and significantly increase the interest of students in science. VR technology is a virtual environment created using 3D images and computer technology. This environment is used with large screens or special VR glasses. VR glasses, as in Figure 3, allow the user to actively interact with the virtual world, creating the feeling that he is in the real world. They are widely used to improve practical knowledge and skills in various fields and provide a deeper immersion of students in the learning process.

Figure 3. VR glasses in the physics laboratory

When organizing laboratory and demonstration works presented in the “updated educational program” in the process of teaching physics, problems such as lack of equipment, equipment failure arise (such questions can be seen in the questionnaire of students of the specialty of physics and physics teachers). Currently, there are many virtual programs and websites for conducting physical experiments. However, many virtual experiments do not correspond to real-life experiments. If physical experiments are modeled in a VR space and it is possible to perform the task through VR glasses, then the actions taken by the person performing the laboratory work to measure physical quantities would be repeated in the virtual world in exactly the same way.

Although VR technology is well developed in the gaming industry, there is very little content for the physics learning process. Therefore, the formation of VR competencies of future physics teachers in the discipline “computer methods of physics” can be considered as a way to find solutions to the problems. We experimentally examined the possibilities of VR glasses in one of the laboratories works in the physics lesson “determining body acceleration”. In the laboratory work on the topic “determining body acceleration”, the necessary equipment is needed: a tripod, a ball, a tray, a measuring tapem and a stopwatch. To organize this physical experience in VR glasses, 2 programs will be required. The first necessary tool is a 3D modeling environment necessary to prepare a 3D model of the equipment. The second is a special game engine, which is necessary for interactive work in VR glasses with prepared 3D objects. The 3D program “Blender” was chosen as the environment for 3D modeling, which we can use for free, and the Unity program was chosen as the game engine. Actions taken to organize the mentioned laboratory work with these selected programs in VR glasses:

i) Making a tripod, tray, and long-length tape model in the Blender 3D program
ii) Creating a new project for VR glasses in Unity
iii) Import of ready-made models made in the Blender 3D program into the Unity program
iv) Placement of 3D models in Unity
v) Creating a cylinder model in Unity that stops the movement of a ball and a ball by colliding
vi) Making it possible to hold the ball with hands in the VR space
vii) We show how to write a script that starts a stopwatch when the ball is lowered, stops it when it hits the cylinder and shows the time elapsed during the movement of the ball along the tray. It is better that the ways of performing these actions are clear and simple for physics teachers. Creating 3D models is the basis for creating content for VR glasses. Therefore, in order to perform the action, we will explain how to create simple equipment necessary for physical experiments in Blender 3D.

– Making a tripod, tray, and long-length tape model in the Blender 3D program

Open Blender 3D and place a cubic object on the scene. This is achieved by executing the add-mesh-cube command. We set the cube size to 3 mm. In the inspectors window, rename the “Cube” object to “Naua”, in edit mode, select face select, stretch the upper surface of the Cube by 3 cm along the z axis, and also stretch the cubic surface located on the Y axis by 3 cm along the Y axis. We select the upper surface of the Cube and stretch it through the extruder by pressing the E button on the keyboard, giving a value of 0.03. We repeat this action along the Y axis. The length of the rectangular tray is stretched along the x axis by 1.1 meters. Selecting the surfaces located along the X axis of the Cube, press the E button and pull the value 1.1 through the extruder. Without leaving edit mode, press the A button on the keyboard, select all the elements of the object, pressing R and X give the value 45. From the “edit mode” mode, use the tab button to switch to the “object mode” mode, select the “Naua” object and press the R and Y buttons to give the value-30, as shown in Figure 4.

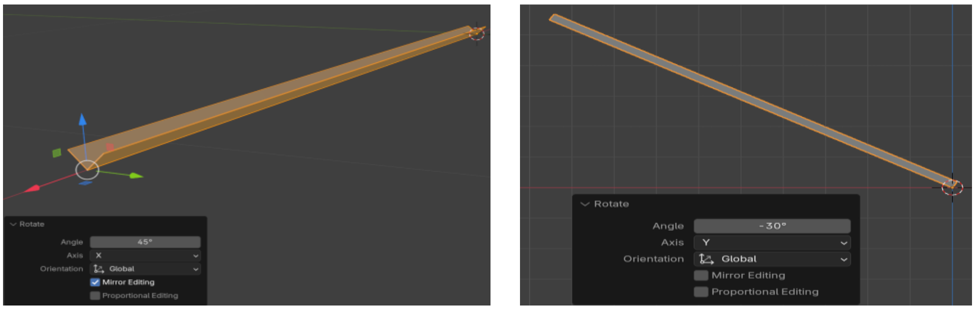

Figure 4. The progress of modeling using Blender 3D

Saving the file after modeling all objects. We save the file name as Naua by following the file-save commands. To develop a 3D tray model, students learn the basics of creating 3D models in Blender 3D by performing these actions, such as obtaining standard objects, modifying them with an extruder and bringing them into the desired format, working in “edit mode” and “object mode” modes and rotating objects. In the process of creating such models, you can use screwdrivers. Using these methods, this study will show how to model a tripod and measuring tape.

– Creating a new project for VR glasses in Unity

For the convenience of physics teachers, we use the VR core template to create the Unity VR program version 2022-3.44-f1 in Unity Hub. To do this, click new project in Unity Hub, select the VR core template and enter the project name project. The VR core template includes ready-made functions and tools for modeling virtual experiences and physical phenomena, which greatly simplifies the work of teachers.

– Importing models prepared in Blender program 3D into Unity program

To perform this action, first open the assets folder located in the project window of the Unity editor. Then, right-click inside the folder to open the context menu and select import new asset. From the file selection window, choose the model that was created using Blender 3D. This process is illustrated in Figure 5. Once imported, the selected 3D model will appear in the assets section of your Unity project. This step will allow to easily integrate models created in Blender 3D into the Unity project. Using imported models in VR projects, physical phenomena can be represented more clearly and visually.

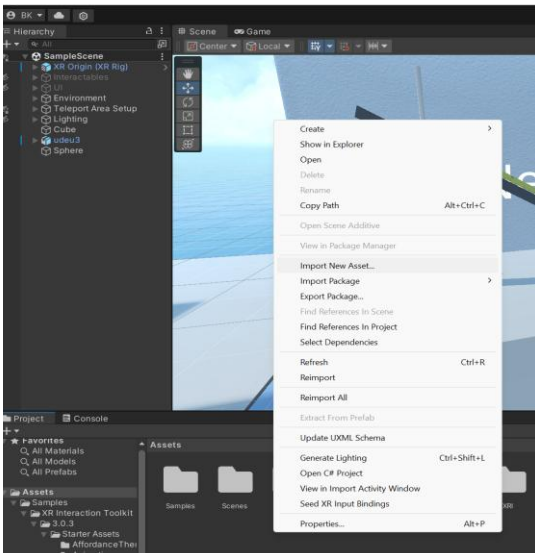

Figure 5. The process of importing models prepared in the Blender 3D program into the Unity program

– Placing 3D models in the Unity program

After importing the object into Unity, we navigate to the inspector window to configure its placement. Using the position and rotation fields, we manually adjust the object's location and orientation within the scene. This ensures that the model is accurately aligned with the virtual environment. Such adjustments are essential for presenting a realistic simulation or effectively demonstrating a physical phenomenon. Proper positioning also enhances user interaction and immersion in the virtual experience.

– Creating a cylinder model in Unity that stops the movement of a ball and a ball by colliding

To create a new 3D object in Unity, right-click in the hierarchy window to open the context menu. From the available options, select 3D object and then choose Sphere. This action will automatically add a spherical object to your scene. The new sphere will appear both in the scene view and the Hierarchy panel. Then, adjust its properties such as position, scale, and material to fit the needs of your simulation or project, as displayed in Figure 6.

After selecting the newly created sphere, we move to the inspector window to adjust its properties. Using the position fields, we place the ball in the desired location, specifically next to the tray. To make the ball more visible in the virtual environment, we modify the scale fields to set its diameter to approximately 5 cm. This ensures clarity and realism in the simulation. Following the same method, we create a cylinder and position it along the bottom edge of the tray. These steps help accurately represent the physical setup within the virtual space, as presented in Figure 7.

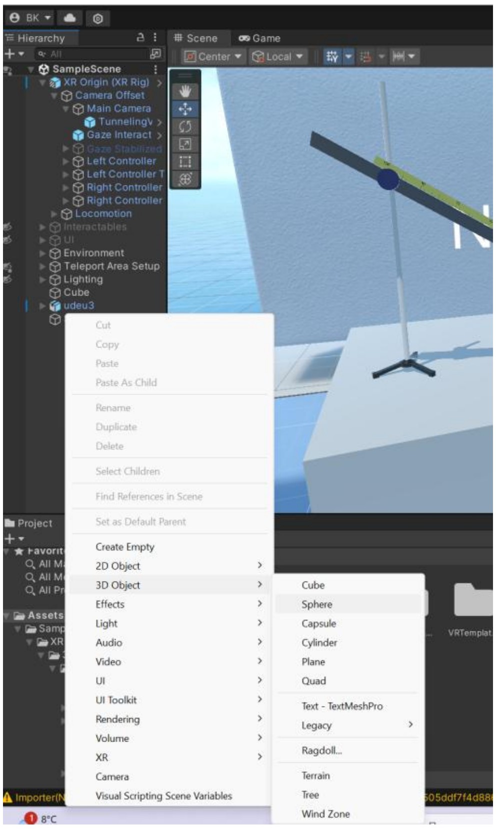

Figure 6. The first step to creating a cylinder model

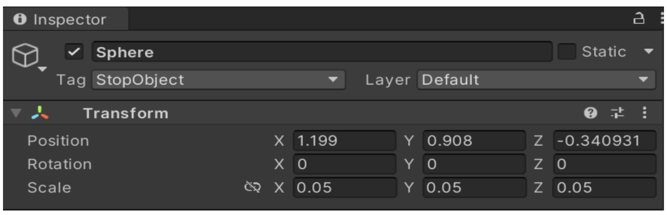

Figure 7. The process of creating a cylinder model

– Making it possible to hold the ball with hands in the VR space

After selecting the sphere, navigate to the inspector window and click the add component button to begin assigning interactive properties. From the list that appears, choose the XR Grab Interactable component. This component allows the object to be picked up, moved, or manipulated within the VR environment. Once added, the sphere becomes responsive to VR controller inputs. As a result, users wearing VR glasses can grab and move the ball in real-time, simulating a realistic interaction. This enhances the immersive experience and supports hands-on experimentation, as shown in Figure 8.

As a result of these steps, the user gets the opportunity to hold the ball in the VR space manually and move it. The XR Grab Interactable component simplifies interactive interaction with objects in a virtual environment and makes the VR experience more realistic. This method makes it possible to widely use physical phenomena in modeling and learning processes.

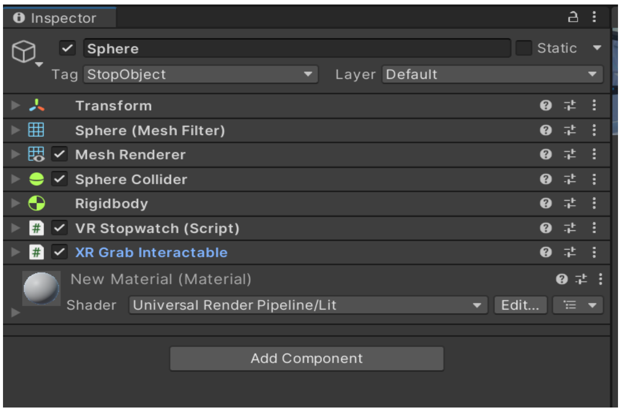

Figure 8. The process of creating the possibility of manually holding the ball in VR space

– Writing program code (script)

By writing a special script that executes the script we need, it becomes possible to perform the experience in VR glasses. Writing scripts can be a challenge for physics teachers. But time calculation, which is most often used in physical experiments, has the ability to use it in each projection, preparing a script for the conditions performed when two bodies collide. Alternatively, you can consider writing a script that allows you to interact with 3D objects using artificial intelligence. It is necessary to save the script written by artificial intelligence and add the cylinder tag to the cylinder object. To do this, select a tag from the list in the Inspector window and create an add tag. We bind the Text Mesh Pro object to the script. We check the finished program in VR glasses. After connecting the VR glasses to the computer and pressing the play button, the program is played in the VR glasses, as displayed in Figure 9.

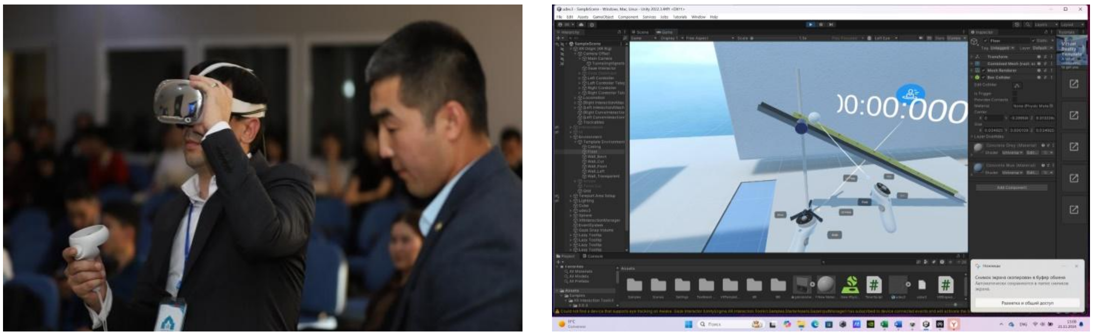

Figure 9. The process of creating an experiment “determining the acceleration of a body” in VR glasses

In this program, the performer of a physical experiment can hold the ball in his hand and place it at some distance from the cylinder along the tray. The Text Mesh Pro object is used as a stopwatch indicator. When the balloon is captured, the Text Mesh Pro object shows 0. When the stopwatch turns on when the ball is released, the stopwatch stops when the ball collides with the cylinder, indicating the selected distance for the time taken to pass the ball. Students can repeatedly measure the experience and make calculations in determining the error made in determining acceleration. VR technology allows to bring the process of studying and interpreting body acceleration to a modern, effective and interactive level. By observing the acceleration of the body in a virtual environment and changing the parameters, students clearly understand the concept of acceleration. The VR lab allows to safely and flexibly conduct real experiments. Students combine theoretical knowledge with practical tasks, develop research and analytical skills.

3.4. Experimental research results

The aim of the study is to determine the impact of using VR glasses when explaining the topic “determining body acceleration” to students. A total of 222 students participated in the study. The students were divided into control and experimental groups based on a random sample. First of all, a test task was received in order to identify the differences between the two groups without using VR technology. The test results between the two groups before practice are shown in Table 3.

Table 3. Results of students before the experiment

Group (before)	n	X	Sd	df	t	p
Control group	110	6.125	1.345	220	1.0850	0.2791
Experimental group	112	6.345	1.657			

n is the number of elements in the sample; X is the arithmetic mean value; Sd is the standard deviation; df is the degree of freedom; t is an independent t test; the average difference is important at $p \leq 0.05$

Compared with the results of the two groups before the study, the statistical data were as: $t(220)=1.0850$, $p>0.05$. This indicator indicates that before the study there was no significant difference in the level of knowledge among students, that is, the null hypothesis was accepted. The null hypothesis confirms that the initial position of the two groups is equal. To accept these results as completely reliable, the G*Power program was used, as shown in Figure 10. G*Power is an effective software widely used to test hypotheses. The T-test was selected for both groups in the power program to analyze the survey results. The arithmetic mean and standard deviation of each group were introduced. The program resulted in two curves that showed the distribution of groups before and after the experiment. Using the program, it was found that the results were not statistically significant.

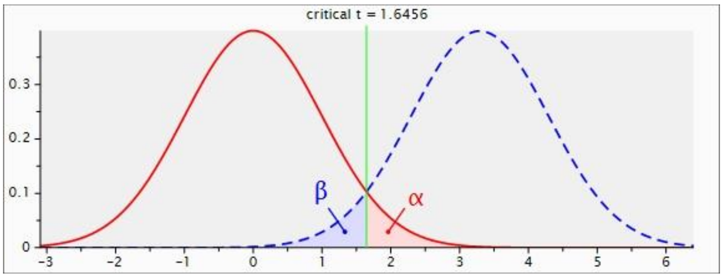

Figure 10. The result of the critical value of the G*Power program

The red curve shown in the figure indicates the null hypothesis, the blue curve indicates the equivalent hypothesis. Green vertical line critical value. α is the type I error, β is the type II error. The conclusion from this is that the critical value of t is equal to 1.6456. As a result of the study, there was no significant difference in the level of knowledge of students according to the initial data of the survey. In this case, $t_{cr}(1.6456)>t_s(1.0850)$, so the null hypothesis is accepted. We can say that there is no significant difference in the results of students using this traditional teaching method. The G*Power program also shows a graph summary between the relationship between the amount of power and the amount of impact (on 3 levels). The graph is shown in Figure 11.

The results obtained contributed to a study on the topic “determination of body acceleration” with the aim of determining the effect on students using VR technology. The impact of the use of VR technology on the results of students on the topic “determination of body acceleration” was determined based on the results of the test. The results of students after the experiment are shown in Table 4.

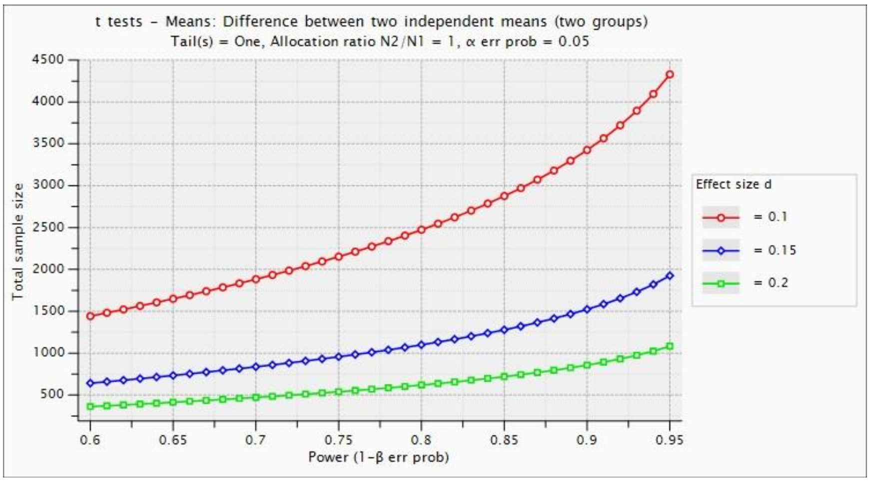

Figure 11. Graph between the relationship of power level and effect size

Table 4. Results of students after the experiment

Group (after)	n	X	Sd	df	t	p
Control group	110	6.985	1.24	220	11.3331	0.0001
Experimental group	112	8.765	1.097			

n is the number of elements in the sample; X is the arithmetic mean value; Sd is the standard deviation; df is the degree of freedom; t is an independent t test; the average difference is important at $p \leq 0.05$

The statistical significance of the test result on the level of students after the study was: $t(220)=11.3331$. $p<0.05$ that is, it shows that there is enough evidence to reject the null hypothesis. With the help of the G*Power program, we can confidently look at this result. The impact of using VR technology on the results of students on the topic "determining body acceleration" was determined based on the test results. We tested the hypotheses by including the test results in the program. The result is shown in Figure 12.

As we have already mentioned, we compare the results of the critical value and the statistical value. The critical value of t is equal to 1.78229. As a result of the survey, the statistical value of t is equal to 11.3331. This means $t_{cr}(1.78229)<t_s(11.3331)$. We can show enough evidence to accept the null hypothesis. The G*Power program also shows a graph summary between the relationship between the amount of power and the amount of impact (on 3 levels). The graph is shown in Figure 13.

Based on the results obtained, the null hypothesis was refuted. That is, the use of VR technology showed that there is a significant development of interest indicators between the experimental group and the control group. Summing up, it should be noted that the use of VR technologies in teaching physics has had an effective impact on increasing the level of knowledge of students in the process of mastering the topic "determining body acceleration" and developing their interest in the subject. With the help of VR technologies, students have the opportunity to visually study physical phenomena and assimilate complex concepts in an interactive environment. This method increased their active participation in the learning process and increased their motivation for physics.

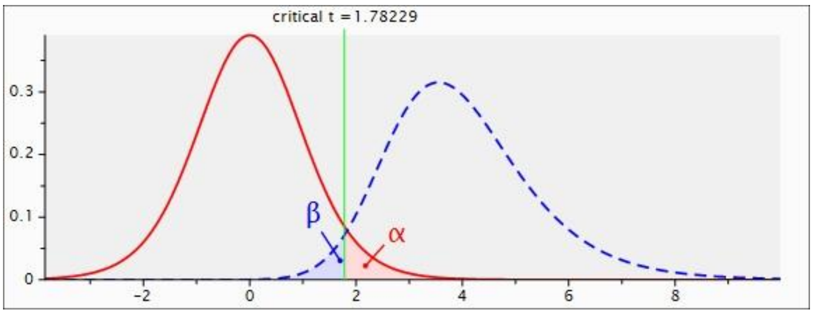

Figure 12. Conclusion of hypotheses using the G*Power program

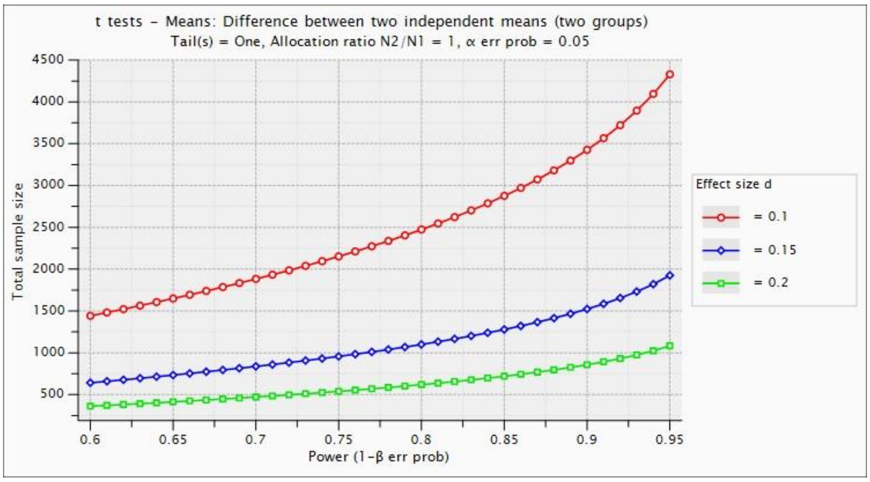

Figure 13. Graph between the relationship of the power level and the amount of impact after the study

4. DISCUSSION

The present study provides clear evidence that the integration of VR technology into physics education enhances student engagement, deepens conceptual understanding, and improves academic performance. Specifically, the use of a virtual laboratory to study body acceleration allowed students to visualize and interact with physical phenomena, making the learning process more immersive and effective. Compared to the control group, students in the experimental group who used VR glasses showed significantly higher test scores, indicating the positive impact of immersive learning environments.

These findings are consistent with previous studies [42], [43], who emphasized that VR can bridge the gap between theory and practice by offering students real-time, interactive experiences. VR is increasingly recognized as a potent tool for enhancing physics education [44], offering immersive, and interactive learning experiences that can significantly impact students' understanding of complex concepts like acceleration [45]. Traditional physics instruction often relies on abstract equations and textbook examples, which can be challenging for students to grasp, especially when dealing with dynamic phenomena such as body acceleration. VR provides a 3D digital environment that engages both visual and auditory senses, creating a richer psychological and physical experience [46]. Moreover, the use of meta-analysis enabled us to validate the consistency and strength of the findings across various related studies. The high effect size further supports the claim that VR is not merely an auxiliary tool, but a transformative element in science, technology, engineering, and mathematics (STEM) education [47], [48].

The substantial improvement in post-test scores among the VR group suggests a stronger conceptual linkage between theoretical knowledge and real-world applications. This supports the conclusions drawn by Mouttalib *et al.* [49] who argued that VR is especially effective in subjects that involve dynamic systems. In a similar vein, Rasheed *et al.* [50] reported that VR enhances conceptual comprehension by allowing repeated observation of experiments under varying conditions in STEM education. The use of VR simulations in the experimental group allowed students to visualize and manipulate physical systems in ways that traditional labs often cannot support. This outcome echoes the findings of Roussou and Slater [51], who noted that VR's interactive nature supports a deeper understanding of abstract scientific concepts. Although no significant cognitive overload was observed in this study, future research should address how instructional pacing and user interface complexity may influence outcomes.

Expanding the research scope to different physics topics and diverse educational levels would also contribute to a broader understanding of VR's role in STEM education. However, it is essential to acknowledge certain limitations [52]. While VR improved understanding and interest, not all students adapted equally to the technology. Some participants initially experienced difficulty navigating the VR environment, which may affect learning outcomes if not properly supported. Moreover, the implementation of VR requires technical infrastructure and training, which may pose a barrier in resource-limited institutions. Thus, while the study confirms the benefits of VR in physics education, it also signals the need for professional development for teachers and further research into long-term retention of knowledge acquired via immersive technologies. Future studies may also explore comparative effectiveness between VR and other emerging technologies such as augmented reality (AR) or mixed reality (MR) in physics instruction.

5. CONCLUSION

This research comprehensively explored the role of VR technology in enhancing physics education through the example of a virtual laboratory focused on determining body acceleration. The study involved a quasi-experimental design with control and experimental groups and confirmed that VR simulations significantly improve students' understanding of physical concepts. The visual and interactive nature of VR enabled learners to engage more actively with the material, resulting in improved test performance, increased interest in the subject, and development of higher-order thinking skills. The meta-analysis of 31 international studies further supported the conclusion that VR can be a powerful instructional tool across STEM fields. The virtual laboratory developed in this study allowed students to experience real-time, immersive simulations of physical experiments, effectively bridging the gap between theoretical learning and practical application. Unlike traditional methods, VR enabled learners to repeatedly perform and visualize experiments, promoting deeper comprehension and retention of complex content. Students expressed enthusiasm and confidence in using VR tools, and the findings showed significant gains in both cognitive and practical competencies. These results underscore the educational value of immersive technologies in fostering student-centered and experience-based learning.

For future studies, it is recommended to investigate the long-term impact of VR on learning retention, student performance across different physics topics, and its scalability across various educational contexts. Additionally, research could focus on optimizing VR-based instruction for diverse learning needs and incorporating artificial intelligence to personalize virtual learning environments. Exploring the integration of VR into pre-service teacher education programs may also promote more innovative pedagogical practices. Overall, the findings of this study offer a strong foundation for broader adoption of VR technology in STEM education and highlight its potential to transform traditional learning environments into dynamic and interactive spaces.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
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O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
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Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board. The ethical approval was granted by the Ethics Committee of Khoja Akhmet Yassawi International Kazakh-Turkish University on October 2, 2024 (Protocol No. 33).

DATA AVAILABILITY

All data supporting the findings of this study are clearly presented in the article to ensure transparency and reader understanding. Except for the personal information (such as participants' names), all relevant additional data are available from the corresponding author [MN], upon reasonable request to assist readers in further understanding or replicating the study.

REFERENCES

[1] K. C. Wang and L. Y. Hsu, "Effectiveness of an immersive VR system for construction site planning education," *KSCE Journal of Civil Engineering*, vol. 28, no. 5, pp. 1622–1634, May 2024, doi: 10.1007/s12205-024-1402-z.

[2] Y. Liu, T. Liu, and Q. Ma, "Immersive virtual reality teaching in colleges and universities based on vision sensors," *Wireless Communications and Mobile Computing*, vol. 2022, no. 1, pp. 1–15, Jan. 2022, doi: 10.1155/2022/5790491.

[3] M. Y. An, K. A. Ko, and E. J. Kang, "Problems and directions of development through analysis of virtual reality-based education in Korea," *International Journal of Information and Education Technology*, vol. 10, no. 8, pp. 552–556, 2020, doi: 10.18178/ijiet.2020.10.8.1423.

[4] A. Marougkas, C. Troussas, A. Krouska, and C. Sgouropoulou, "Virtual reality in education: a review of learning theories, approaches and methodologies for the last decade," *Electronics (Switzerland)*, vol. 12, no. 13, p. 2832, Jun. 2023, doi: 10.3390/electronics12132832.

[5] P. Kuna, A. Hašková, and Ľ. Borza, "Creation of virtual reality for education purposes," *Sustainability (Switzerland)*, vol. 15, no. 9, p. 7153, Apr. 2023, doi: 10.3390/su15097153.

[6] J. Roda-Segarra, S. Mengual-Andres, and R. Martinez-Roig, "Using virtual reality in education: a bibliometric analysis," *Campus Virtuales*, vol. 11, no. 1, pp. 153–165, Jan. 2022, doi: 10.54988/cv.2022.1.1006.

[7] J. Huang, S. Saleh, and Y. Liu, "A review on artificial intelligence in education," *Academic Journal of Interdisciplinary Studies*, vol. 10, no. 3, pp. 206–217, May 2021, doi: 10.36941/AJIS-2021-0077.

[8] L. Asencios-Trujillo, L. Asencios-Trujillo, C. Larosa-Longobardi, D. Gallegos-Espinoza, L. Piñas-Rivera, and R. Perez-Siguas, "Virtual assistance system for teaching physics experiments in university students," *Journal of Advanced Research in Applied Sciences and Engineering Technology*, vol. 40, no. 1, pp. 109–117, Feb. 2024, doi: 10.37934/araset.40.1.109117.

[9] J. E. Debs, "Scalable and effective use of virtual reality for physics education," in *Proceedings of The Australian Conference on Science and Mathematics Education*, 2021, p. 17.

[10] S. D. Saputro and A. Setyawan, "The effectiveness use of virtual reality media in physics education of solar system towards cognitive learning outcomes," *JPI (Jurnal Pendidikan Indonesia)*, vol. 9, no. 3, pp. 389–400, Sep. 2020, doi: 10.23887/jpi-undiksha.v9i3.23105.

[11] J.-H. Lee and E.-H. Kim, "Effects of the 4th industrial revolution and VR recognition on VR education application," *Journal of the Korean Society of Cosmetology*, vol. 29, no. 2, pp. 529–538, Apr. 2023, doi: 10.52660/jksc.2023.29.2.529.

[12] E. Akman and R. Çakır, "The effect of educational virtual reality game on primary school students' achievement and engagement in mathematics," *Interactive Learning Environments*, vol. 31, no. 3, pp. 1467–1484, Apr. 2023, doi: 10.1080/10494820.2020.1841800.

[13] H. Chang, J. Park, and J. Suh, "Virtual reality as a pedagogical tool: an experimental study of English learner in lower elementary grades," *Education and Information Technologies*, vol. 29, no. 4, pp. 4809–4842, Mar. 2024, doi: 10.1007/s10639-023-11988-y.

[14] E. Demitriadou, K.-E. Stavroulia, and A. Lanitis, "Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education," *Education and Information Technologies*, vol. 25, no. 1, pp. 381–401, Jan. 2020, doi: 10.1007/s10639-019-09973-5.

[15] E. Fokides and F. Chachlaki, "3D multiuser virtual environments and environmental education: the virtual island of the mediterranean monk seal," *Technology, Knowledge and Learning*, vol. 25, no. 1, pp. 1–24, Mar. 2020, doi: 10.1007/s10758-019-09409-6.

[16] F. F. Cao and Y. Jian, "The Role of integrating AI and VR in fostering environmental awareness and enhancing activism among college students," *Science of the Total Environment*, vol. 908, p. 168200, Jan. 2024, doi: 10.1016/j.scitotenv.2023.168200.

[17] A. K. Ghazali, N. A. Nor, K. Ab. Aziz, and N. T. Kian, "The usage of virtual reality in engineering education," *Cogent Education*, vol. 11, no. 1, pp. 1–13, Dec. 2024, doi: 10.1080/2331186X.2024.2319441.

[18] E. D. Innocenti *et al.*, "Mobile virtual reality for musical genre learning in primary education," *Computers and Education*, vol. 139, pp. 102–117, Oct. 2019, doi: 10.1016/j.compedu.2019.04.010.

[19] H. Kim and F. Ke, "Effects of game-based learning in an OpenSim-supported virtual environment on mathematical performance," *Interactive Learning Environments*, vol. 25, no. 4, pp. 543–557, May 2017, doi: 10.1080/10494820.2016.1167744.

[20] H. H. Liou, S. J. H. Yang, S. Y. Chen, and W. Tarng, "The influences of the 2D image-based augmented reality and virtual reality on student learning," *Educational Technology and Society*, vol. 20, no. 3, pp. 110–121, 2017.

[21] R. Liu, L. Wang, J. Lei, Q. Wang, and Y. Ren, "Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons," *British Journal of Educational Technology*, vol. 51, no. 6, pp. 2034–2049, Nov. 2020, doi: 10.1111/bjet.13028.

[22] M. Rincker and S. Misner, "The jig experiment: development and evaluation of a cultural dance active video game for promoting youth fitness," *Computers in the Schools*, vol. 34, no. 4, pp. 223–235, Oct. 2017, doi: 10.1080/07380569.2017.1387468.

[23] S. Sarioğlu and S. Girgin, “The effect of using virtual reality in 6th grade science course the cell topic on students’ academic achievements and attitudes towards the course,” *Journal of Turkish Science Education*, vol. 17, no. 1, pp. 109–125, Mar. 2020, doi: 10.36681/tused.2020.16.

[24] C. Weng, A. Rathinasabapathi, A. Weng, and C. Zagita, “Mixed reality in science education as a learning support: a revitalized science book,” *Journal of Educational Computing Research*, vol. 57, no. 3, pp. 777–807, Jun. 2019, doi: 10.1177/0735633118757017.

[25] C. Kustandi, D. N. Fadhillah, R. Situmorang, D. S. Prawiradilaga, and S. Hartati, “VR use in online learning for higher education in Indonesia,” *International Journal of Interactive Mobile Technologies*, vol. 14, no. 1, pp. 31–47, Jan. 2020, doi: 10.3991/ijim.v14i01.11337.

[26] B. J. Godula *et al.*, “Virtual reality for patient education about hypertension: a randomized pilot study,” *Journal of Cardiovascular Development and Disease*, vol. 10, no. 12, p. 481, Nov. 2023, doi: 10.3390/jcdd10120481.

[27] H. Mäkinen, E. Haavisto, S. Havola, and J. M. Koivisto, “Graduating nursing students’ user experiences of the immersive virtual reality simulation in learning-a qualitative descriptive study,” *Nursing Open*, vol. 10, no. 5, pp. 3210–3219, May 2023, doi: 10.1002/nop2.1571.

[28] M. Romano *et al.*, “Exploring the potential of immersive virtual reality in Italian schools: a practical workshop with high school teachers,” *Multimodal Technologies and Interaction*, vol. 7, no. 12, p. 111, Dec. 2023, doi: 10.3390/mti7120111.

[29] T. Gunn, P. Rowntree, D. Starkey, and L. Nissen, “The use of virtual reality computed tomography simulation within a medical imaging and a radiation therapy undergraduate programme,” *Journal of Medical Radiation Sciences*, vol. 68, no. 1, pp. 28–36, Mar. 2021, doi: 10.1002/jmrs.436.

[30] H. Cheon, S. Jung, J. Kim, Y. Yang, G. J. Kim, and J. A. Song, “Characteristics and preferences related to using virtual reality devices for education of families of persons with dementia: a descriptive study,” *Journal of Korean Gerontological Nursing*, vol. 24, no. 2, pp. 197–209, May 2022, doi: 10.17079/jkgn.2022.24.2.197.

[31] E. A. Shudayfat and N. R. I. Alsalhi, “Science learning in 3D virtual environment multi-users online in basic education stage,” *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 19, no. 1, Jan. 2023, doi: 10.29333/ejmste/12809.

[32] H. Güleryüz, “Attitudes of pre-service teachers on the use of 3D printing with Tinkercad in science education,” *European Journal of Mathematics and Science Education*, vol. 4, no. 4, pp. 217–228, Dec. 2023, doi: 10.12973/ejmse.4.4.217.

[33] C. C. Chou, “An analysis of the 3D video and interactive response approach effects on the science remedial teaching for fourth grade underachieving students,” *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 13, no. 4, pp. 1059–1073, Feb. 2017, doi: 10.12973/eurasia.2017.00658a.

[34] S. Y. Phoong, S. W. Phoong, and K. H. Phoong, “The effectiveness of frog virtual learning environment in teaching and learning mathematics,” *Universal Journal of Educational Research*, vol. 8, no. 3B, pp. 16–23, Mar. 2020, doi: 10.13189/ujer.2020.081502.

[35] A. O. A. Elfakki and S. M. Sghaier, “Scope for 3d virtual tourism through times of COVID-19 in the Kingdom of Saudi Arabia,” *SSRN Electronic Journal*, pp. 1–4, 2022, doi: 10.2139/ssrn.4051351.

[36] S. S. Man, H. Wen, and B. C. L. So, “Are virtual reality applications effective for construction safety training and education? A systematic review and meta-analysis,” *Journal of Safety Research*, vol. 88, pp. 230–243, 2024, doi: 10.1016/j.jsr.2023.11.011.

[37] Y. B. Bhakti, R. A. Sumarni, S. Mayanty, and I. A. D. Astuti, “Developing virtual physics practicum module of optic based on guided inquiry to improve students’ science process skills,” *Journal of Science and Science Education*, vol. 4, no. 1, pp. 39–49, Apr. 2023, doi: 10.29303/jossed.v4i1.2329.

[38] E. Widodo, D. Setyawarno, and D. Rosana, “Developing assessment as learning on basic physics virtual practicum as an asessment instrument of process and cognitive skills on online-learning,” *Journal of Science Education Research*, vol. 6, no. 1, pp. 37–45, Mar. 2022, doi: 10.21831/jser.v6i1.48321.

[39] G. Aşiksoy and D. Islek, “The impact of the virtual laboratory on students’ attitudes in a general physics laboratory,” *International Journal of Online Engineering*, vol. 13, no. 4, pp. 20–28, Apr. 2017, doi: 10.3991/ijoe.v13i04.6811.

[40] C. Jiao, J. Qian, and H. Liu, “The relationship between preschool inclusive education teachers’ organizational support and work engagement: the mediating role of teacher self-efficacy,” *Frontiers in Psychology*, vol. 13, p. 900835, May 2022, doi: 10.3389/fpsyg.2022.900835.

[41] J. L. Wardian, T. M. Wells, and T. M. Cochran, “Creating patient context: empathy and attitudes toward diabetes following virtual immersion,” *Journal of Diabetes Science and Technology*, vol. 17, no. 5, 2023, doi: 10.1177/19322968231174441.

[42] W. Tarng and M. C. Pei, “Application of virtual reality in learning quantum mechanics,” *Applied Sciences*, vol. 13, no. 19, p. 10618, Sep. 2023, doi: 10.3390/app131910618.

[43] E. Analyti *et al.*, “Virtual reality in education: Transforming learning through immersive technology,” *Technium Education and Humanities*, vol. 10, no. 1, pp. 1–11, Oct. 2024, doi: 10.47577/teh.v10i.11766.

[44] Y. Georgiou, O. Tsivitanidou, and A. Ioannou, “Learning experience design with immersive virtual reality in physics education,” *Educational Technology Research and Development*, vol. 69, no. 6, pp. 3051–3080, Dec. 2021, doi: 10.1007/s11423-021-10055-y.

[45] E. Battipede *et al.*, “Physics playground: insights from a qualitative-quantitative study about VR-based learning,” in *International Conference on Intelligent Human Computer Interaction*, 2024, pp. 97–108, doi: 10.1007/978-3-031-88881-6_8.

[46] A. Cabrera-Duffaut, A. M. Pinto-Llorente, and A. Iglesias-Rodríguez, “Immersive learning platforms: analyzing virtual reality contribution to competence development in higher education-a systematic literature review,” *Frontiers in Education*, vol. 9, p. 1391560, Jul. 2024, doi: 10.3389/feduc.2024.1391560.

[47] N. Pellas, A. Dengel, and A. Christopoulos, “A scoping review of immersive virtual reality in STEM education,” *IEEE Transactions on Learning Technologies*, vol. 13, no. 4, pp. 748–761, Oct. 2020, doi: 10.1109/TLT.2020.3019405.

[48] F. S. Díaz, J. C. Rosúa, G. F. Ferrer, R. M. Carmona, and R. Narváez, “Assessment of immersive technologies and STEM focus in initial teacher training,” *RIED-Revista Iberoamericana de Educacion a Distancia*, vol. 27, no. 1, pp. 139–162, Oct. 2024, doi: 10.5944/ried.27.1.37688.

[49] H. Mouttalib, M. Tabaa, and M. Youssfi, “Towards a platform for higher education in virtual reality of engineering sciences,” in *Communications in Computer and Information Science*, vol. 1728, 2024, pp. 107–119, doi: 10.1007/978-3-031-47366-1_8.

[50] G. Rasheed, M. Khan, N. Malik, and A. Akhunzada, “Measuring learnability through virtual reality laboratory application: a user study,” *Sustainability*, vol. 13, no. 19, p. 10812, Sep. 2021, doi: 10.3390/su131910812.

[51] M. Roussou and M. Slater, “Comparison of the effect of interactive versus passive virtual reality learning activities in evoking and sustaining conceptual change,” *IEEE Transactions on Emerging Topics in Computing*, vol. 8, no. 1, pp. 233–244, Jan. 2020, doi: 10.1109/TETC.2017.2737983.

[52] A. Hamad and B. Jia, “How virtual reality technology has changed our lives: an overview of the current and potential applications and limitations,” *International Journal of Environmental Research and Public Health*, vol. 19, no. 18, p. 11278, Sep. 2022, doi: 10.3390/ijerph191811278.

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