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THE IMPACT OF FORCE-SPECIFIC VIRTUAL LABORATORIES IN GRADE VII ON STUDENT ASSIMILATION

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Abstract. In this article, the technology of using virtual laboratory works in the teaching of force-related topics in the teaching of physics in school is shown. PhET (University of Colorado Physics Education Technology) simulations were used for this purpose. The pedagogical experiment related to the conducted research work was conducted in the Educational Complex No. 132-134 located in Azerbaijan. The results of the statistical analysis carried out according to the SPSS program showed that students studying both in the control and experimental group have approximately the same level of knowledge and skills. The differences between the groups were observed in the responses to complex test tasks. The results of the pedagogical research show that the use of virtual laboratories in the teaching of physics helps students master the subject better by creating visualization.

Keywords: *physics subject, virtual laboratory, simulation, PhET, force.*

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1. Introduction

Virtual laboratories were first established in 1977 to study the human body in the field of physiology and medicine. However, later, the application possibilities of simulations in the field of education were investigated and started to be applied. As a result of the joint cooperation of computer engineers and teachers, a number of simulators were created to be used in the teaching of physics, chemistry, biology, and mathematics. The most common virtual laboratory program in high school science education is called PhET (University of Colorado Physics Education Technology). This simulation program was developed by employees of the University of Colorado, USA. In the conditions of the pandemic caused by the Covid-19 virus, Phet simulations have been widely used in distance education. The use of computer technology and e-learning technologies in teaching physics in high school increases the fluency of the lesson, creates conditions for the assimilation by students of incomprehensible parts of the topic. Using virtual laboratories, it is possible to demonstrate physical phenomena and processes that are not visible in real life. Virtual labs are a simulation program, a model that reflects the similarity of real events. According to Tuysuz (2010), the use of computer when performing laboratory work in physics increases students' interest in learning and has a positive effect on their learning outcomes.

Redha's note that the use of computer technology also has some negative effects on students' learning of the subject (Redha, 2010). A number of researchers have conducted research on the role of simulations in teaching. Finkelstein et al. (2005)

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investigated the impact of replacing traditional laboratories with computer simulations on the teaching process when conducting pedagogical research at the University of Colorado. Gunawan et al. (2019) found that male students were more creative than female students when investigating the application of virtual laboratories in education from a gender perspective. Alexiou et al. (2005) investigated the use of virtual laboratories in the teaching of physics in secondary schools in Greece and determined the advantages of virtual laboratories. Mishra (2012) states that digital technologies have given great impetus to the development of students' creative thinking. Sharifov (2022) investigated the effect of virtual laboratories on student achievement in lyceums. Studying the role of virtual laboratories in teaching mechanical movement in grade VII, the researcher found that the use of simulations allows for a better understanding of physical concepts that students cannot perceive, as well as the development of their knowledge and skills. Grade VII students have some difficulty in understanding the concept of force in the teaching of physics. Students do not understand many issues related to force generation, direction, and Newton's first law. Not enough pedagogical research has been conducted to solve the mentioned problem. In the conducted study, the possibilities of using simulations in the teaching of force in grade VII were shown.

2. Material and methods

In order to test our proposed lesson model, we conducted a pedagogical experiment in the Educational Complex No. 132-134 located in Baku. The pedagogical experiment consisted of 3 stages: confirmation, search and formation. In the first stage of the research, we examined the documents, lesson plans, physics textbooks and methodical materials for the VII grade, checked the students' computer skills, and analyzed the problems that arise during the use of computer technology in physics classes. Scientific studies show that one of the main problems in the application of modern technologies is the lack of computer skills of students and teachers. In most cases, teachers talk about the effect of carts on each other when explaining the concept of inertia and force from physics. Students cannot understand how the phenomenon of inertia is created. In such situations, the teacher's pedagogical skills, training methods should be aimed at solving the problem. At this stage, the problem of the research, the state of scientific-methodological and psychological-pedagogical literature and the teacher's readiness for the implementation of these processes were also investigated (Sharifov, 2020). When explaining a lesson in physics, the teacher in most cases uses demonstration experiments. Such experiments require a certain amount of time. Sometimes the teacher does not demonstrate the practice, thinking that it may be dangerous for the students. This deficiency in the teaching of the subject creates difficulties in mastering the subject. To test students' knowledge of the phenomenon of force and inertia, we gave them the following study.

Research 1. What causes the change in the speed of the object?

Equipment: two identical cars, a small bag filled with sand, a thin elastic board, scissors, thread, plasticine.

Research progress:

I stage: 1. Place the car on the table and it stays put. 2. Move it by pushing it.

Discuss the result: 1. What is the reason for the car to remain calm ? 2. What should be done to move the cart?

II stage: 3. Place the bag full of sand in front of the cart that you moved and watch what happens (a). Discuss the result: Why did only the speed of the cart change when the cart collided with the bag full of sand?

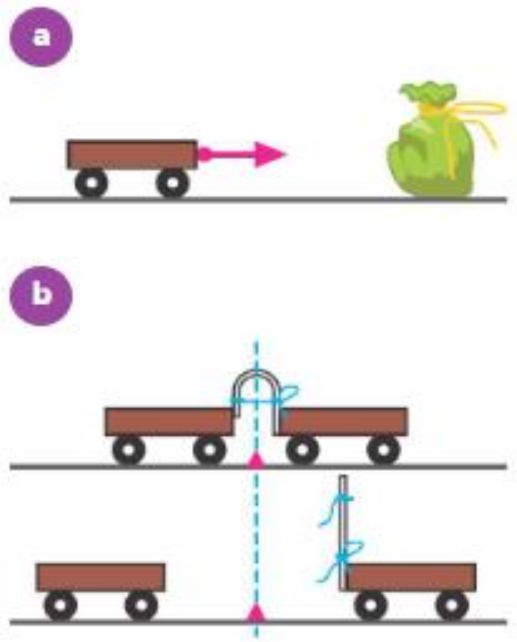

Fig. 1. Research on cars

III stage: 4. Attach an elastic board to one of the carts and tie it with a thread. 5. Place the second cart opposite the first cart, touching the board. Put a plasticine mark in the middle of the distance between the carts. Cut the handle and watch what happens (b). Discuss the result: 1. Why did the board that opened when the handle was cut move both the carts? 2. What was the reason for the speed change in the carts? In the second stage of the research, simulations were used to explain the concept of force in the teaching of physics in grade VII. To conduct a pedagogical experiment, we divided the students into control and experimental groups with 34 people in each group. The main purpose of using simulations in teaching the topic is to ensure cooperation between students by creating interest in them. In order to assess the students' knowledge and skills, they were given three simple, three relatively simple, two relatively complex and two complex tasks on the topic, then the results of the assessment were analyzed. The level of difficulty of the tasks is taken as an assessment criterion for conducting an assessment. Students in the experimental group were shown a virtual laboratory work "Forces and Motion: Basics" through Phet simulations.

Whenever there is a net force, the cart on the Net Force screen will accelerate. If more pullers are added after the motion is started, students may have to run some tests to understand that the motionwas already happening. This might be a great teaching moment around "An object at rest stays at restand an object in motion stays in motion unless acted upon by an external force." Students may have some difficulty understanding why adding mass in the frictionless environment doesn't change the motion. In order to determine the effect of the use of simulations on mastering the subject during the pedagogical experiment, test tasks were given to VII grade students in both the control and experimental groups (Table 1). Gunawan et. al note that the use of virtual laboratories together with oral interpretation affects the development of students' knowledge and forms creativity in them (Gunawan *et. al.*, 2018).

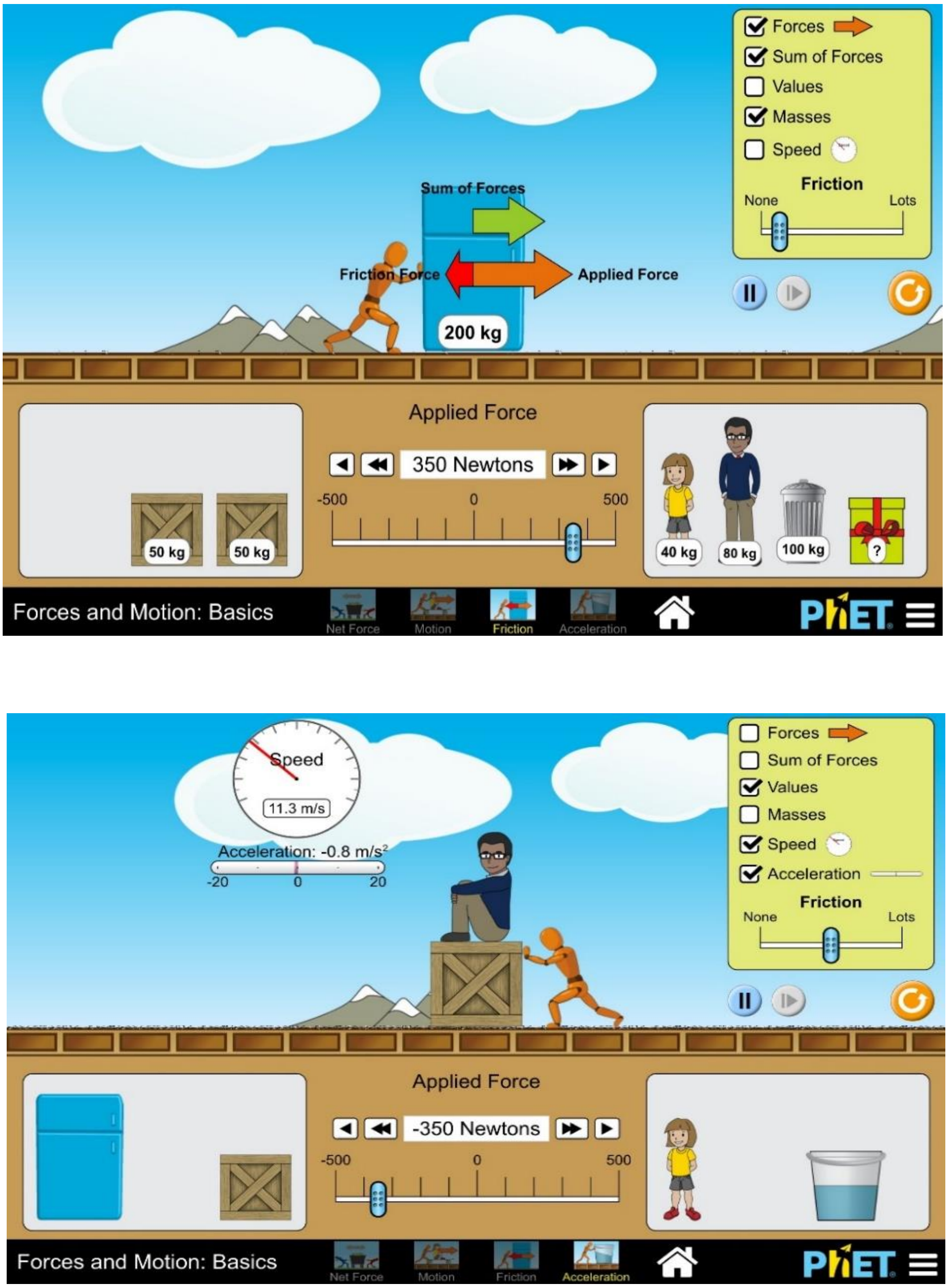

Fig. 2. Virtual lab for “Forces and Motion: Basics”
https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html

Table 1. Questions asked to control and experiment groups

Boy ☐ Girl ☐
1. What makes objects move?
A) objects move by themselves
B) divine force
C) other objects that affect objects
D) speed of objects
E) shape of objects
2. What physical quantity is equal to the product of the mass of the body and the momentum given to it by the compensating force?
A) speed B) work C) displacement D) substituting force E) momentum
3. What device is used to measure force?
A) ruler B) stopwatch C) dynamometer D) speedometer E) accelerometer
4. Two forces act on the object in the horizontal direction: F_1 = 2N to the left, F_2 = 6 N to the right. Determine the magnitude and direction of the displacement force.
A) in 4 N, F_1 direction D) in 6 N, F_1 direction
B) in 10 N, F_2 direction E) in 8 N, F_2 direction
C) in 4 N, F_2 direction
5. How does the momentum change when the substituting force acting on the object increases 4 times ?
A) decreases 4 times C) increases 2 times
B) increases 4 times D) decreases 2 times E) does not change
6. To calculate the price of the substituting force acting on the object, it is enough to know the prices of what quantities ?
A) momentum and density of the object D) volume and speed of the object
B) mass and velocity of the object E) mass and momentum of the object
C) mass and volume of the object
7. If the object was not affected by other objects, how would it move ?
A) oscillatory motion
B) vibratory motion
C) circular motion
D) rectilinear motion
E) rotatory motion
8. With what momentum will an object with a mass of 64 kg move under the action of a force of 192 N ?
A) 5 N B) 2 N C) 3 N D) 7 N E) 9 N
9. An object with a mass of 2 kg moves rectilinear uniformly at a speed of 20 m/sec. Calculate the substituting force acting on the object.
A) 20 N B) 40 N C) 10 N D) 0 E) 80 N
10. How is Newton's first law expressed ?
A) There are calculation systems in which objects exist only at stillness.
B) If the object is not affected by other objects, it maintains its state of stillness.
C) There are calculation systems in which the object retains its state of stillness when the force does not act on it.
D) There are calculation systems in which, when the force does not act on the object or the substituent force is zero, it retains its state of stillness or rectilinear uniform motion.
E) When other objects affect an object, it moves only rectilinear uniformly.

In order to determine the effect of the use of simulations on mastering the subject during the pedagogical experiment, test tasks were given to VII grade students in both the control and experimental groups (Table 1). Jackson stated that creativityis a fundamental characteristic of human being which is the center of prosperity, productivity and prosperity of a nation (Jackson, 2006).

3. Results and discussion

VII grade students gave the following answers to the questions related to the study:
I stage. What is the reason why the cart is standing still? What needs to be done to move the cart?

– When we impact the cart with our hands, it gets a certain speed.
– We have to push the cart.

II stage. Why did only the speed of the cart change when the cart collided with a sand bag?

– Because the sandbag is in stillness.
– Since the cart in motion acts on the sandbag with a certain force.

III stage. Why did the opening board move both of the carts when the handle was cut? For what reason did the speed change occur in the carts?

– When cutting the handle, each of the carts moves to the opposite side at the same speed.
– The carts act on the elastic board with the same force.

Table 2. Independent t-test results of control and experimental group students' responses

Test	Groups	N	Mean	SD	T-value	P-value	Remark
Pretest	Experimental group	34	37.56	6.36	-0.037	0.970	No Significant
	Control group	34	37.62	6.66			
Posttest	Experimental group	34	79.65	10.65	2.294	0.025	Significant
	Control group	34	73.00	13.11			

The results of the research show that although the students have certain knowledge and skills related to the creation of force, they have difficulty understanding issues related to the direction of force and the interaction between objects. Simulations were widely used in different stages of the physics lesson in the experimental group (Figure 2). Then, students in the control and experimental groups answered the tasks in Table 1. Student's independent t-test results are shown in Table 2. The results show that there is no significant difference between the results of the control and experimental groups. However, while the average indicator in the control group is 78% ± 12.6%, in the experimental group this indicator is 94% ± 7% (Figure 3). The analysis of the test results shows that the knowledge level of students studying in both control and experimental groups is approximately the same. Based on Table 1, we can say that according to the results of the t-test (p = 0.28), the control and experimental groups have approximately the same theoretical knowledge. Pedagogical research and analysis are also reflected in the articles of scientists conducting research on the impact of virtual laboratories in teaching physics on the development of students.

In Figure 4, the answers given by the students on the assessment of the level of knowledge of the students on strength were analyzed, the final results were analyzed.

The first question is about the reason for the creation of the movement of objects. Apparently, this question is simple, so in both the control and experiment groups, 92% of students answered this question correctly. The question requires students to differentiate the underlying cause that drives objects.

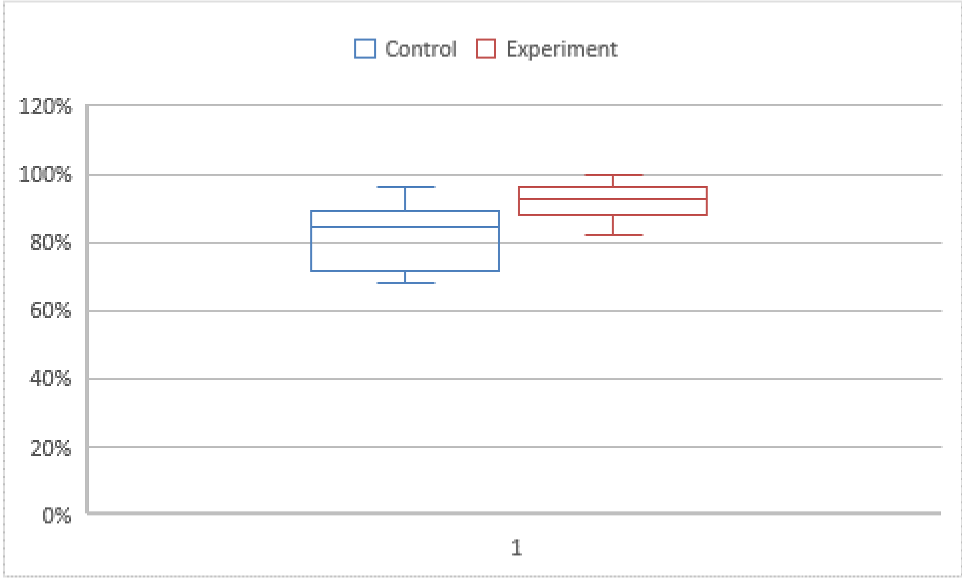

Fig. 3. Average indicators of test results of control and experimental groups

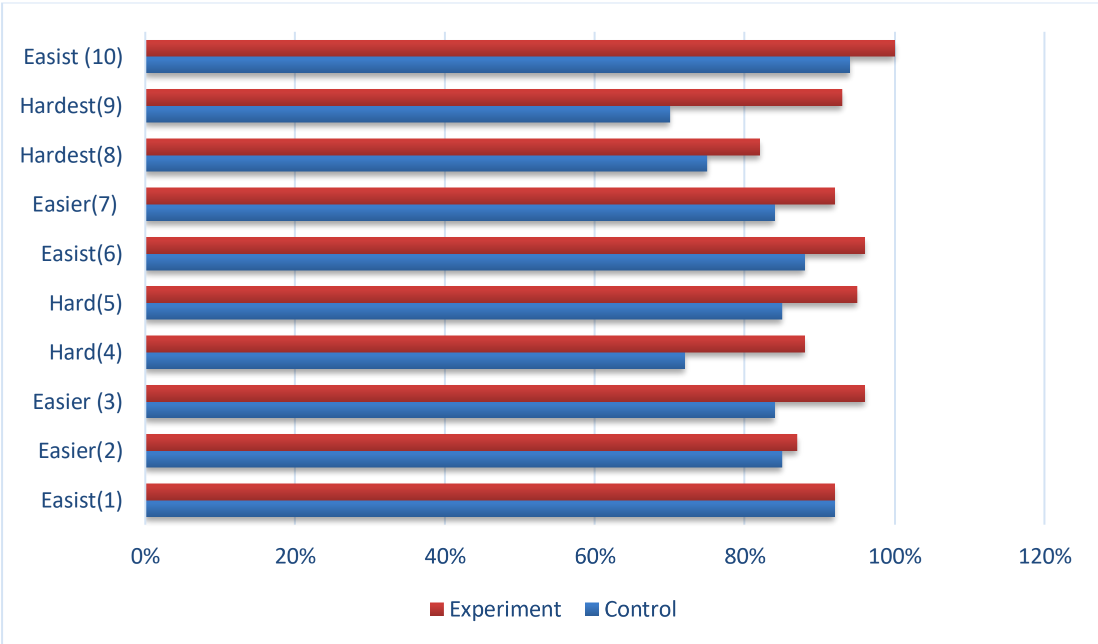

Fig. 4. The difference between experimental and control groups' responses to tests

Because the second question is relatively simple, 87% of the students in the experiment group and 85% of the students in the control group answered it correctly.

In the third question, the device for measuring force is asked by students. Apparently, the control group answered this question by 84%, and the experiment group- by 96%. Some of the students confuse the device used to measure speed with the device used to measure force.

To the fourth question, which was considered relatively difficult, requiring drawing and calculation, the control group answered correctly by 72%, and the experiment group- by 88%. The study shows that most of the students in the control group find it difficult to determine the direction of the substitutive force even if they do the calculations correctly. However, students in the experimental group, who visually saw the direction of the force with simulations, were able to determine the direction of the force without difficulty. From here it can be concluded that virtual laboratories help students to master the subject better.

The fifth question is a mid-level qualitative type question that requires calculation. 85% of the students in the control group and 95% of the students in the experimental group answered this question correctly.

Since the sixth question is a simple question, 88% of students answered this question correctly in the theoretical group and 96% in the experimental group. The results show that students know the formula for the substituent force.

The seventh question requires students to determine the difference between the state of stillness and motion of objects. 84% of the students in the control group and 92% of the students in the experimental group answered this question correctly.

The eighth question is the one that requires calculation from students. Although students know the formula of the substituent force, in some cases they receive an incorrect answer, since they make an error in the calculations. Some students, on the other hand, do the calculation incorrectly, as they do not write the formula correctly. Therefore, the indicators are 75% in the control group and 82% in the experimental group.

The ninth question is a difficult-type question that requires deep reflection and a critical approach from students. The study shows that most students tried to make a calculation without carefully reading the question. In the control group, the indicator of students was 70%, and in the experiment group-93%.

The tenth question concerns Newton's first law. This question, considered simple, was answered correctly by the vast majority of students. 96% of students in the control group and 100% in the experimental group answered this question correctly.

The results of pedagogical studies and observations show that the use of virtual laboratory work has a positive effect on the level of knowledge and skills of students. Simulations increase students' interest in physics and create great enthusiasm for the subject. Students learn to solve problems independently with the help of virtual laboratories. Thus, their research skills begin to develop. Students can visually see the knowledge they have learned in theory through simulations. The teaching of the lesson provides a better understanding of the subject by developing attention, vision, critical and creative thinking in students (Gunawan *et al*., 2019).

Statistical analysis of students' responses to tests was carried out (Figure 3,4). Test tasks were given to students in both theoretical and experimental groups. The main purpose of the survey is to determine whether there is a significant difference between the groups. A 96% confidence level ($\alpha = 0.07$) was used for all comparisons throughout the course. The mean scores of the test were 78% ± 12,6% for the control group and 94 % ± 7% for the experimental group.

As can be seen from Figure 5, students in control and experimental groups answered questions No. 2,3,4,6,7,10 with a slight margin (2-8%). Such a small difference between the groups is due to the fact that the students in both selected groups have a high level of knowledge. Such a result was expected. Notable differences were observed between the answers to the 5th (10%) and 9th (13%) questions. This is explained by the positive effect of the use of virtual laboratories in teaching physics on the assimilation indicator of students.

4. Conclusion

The ability of students in the experimental group to perform calculations more efficiently, to correctly answer questions of a qualitative type, to practically draw a picture, to show the direction of the force, to be able to explain the opposite effects between objects proved that virtual laboratories have a positive effect on the development of students. The use of simulations further develops their logical and creative thinking.

In conclusion of pedagogical practice, we identified a number of advantages of using virtual laboratory work in teaching physics:

1. The use of simulations in teaching physics develops students' logical, critical and creative thinking;
2. Even students who have no interest in physics are interested in this subject;
3. It provides for the study of topics not only theoretically, but visually;
4. It allows you to contribute to the time by demonstrating physical experiences in the classroom in a shorter time;
5. Simulations are safer as they are displayed via a computer;
6. It allows you to conduct physical experiments with greater accuracy even without expensive devices and equipment;
7. With the help of simulations, it is possible to simultaneously demonstrate various experiments, at any time interfere with the course of the experiment and make changes.

Studies show that the use of Phet simulations also develops students' knowledge and skills in computer use, ensures their better mastery of the subject, and increases motivation. Although virtual laboratories cannot replace real laboratories, they can easily eliminate the gaps that may arise in the teaching process in cases of force majeure occurring in the world.

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