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EFFECT OF A VIRTUAL PHYSICS LABORATORY ON STUDENTS' ACHIEVEMENT IN LYCEUM

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Abstract- This paper deals with the effectiveness of a virtual lab in obtaining in-depth scientific knowledge and excellent practice skills on a mechanical motion at the lyceum for seventh-grade students. Pedagogical experiments were carried out at the Baku European Lyceum. Based on a p-value of 0.41, the statistical and data analysis results from the SPSS program revealed no statistically significant difference between the means of the two groups. This value indicates that both groups initially have a similar conceptual understanding of mechanics concepts. However, the main differences were observed in responses to complex test tasks. As a result, it was determined that a virtual lab enabled lyceum students to improve their critical thinking and creative abilities and solve complex mechanical motion physics tasks.

Keywords: Lyceum, Mechanical Motion, Virtual Laboratory, PhET.

1. INTRODUCTION

The role of new technology in the classroom is a primary concern for pedagogical researchers. As a result, the physics teacher may not be presented with accurate, conventional, and useful physics teaching technology and traditional laboratory equipment in some cases. Due to a lack of physics tools, physics teaching appears to be impossible. Computers now offer numerous opportunities to assist in the physics classroom teaching process. One of the most crucial usages of computers is in virtual laboratories. Computer simulations, such as virtual labs and their applications, were developed to increase student engagement and create an environment that cannot be replicated in a traditional lab or classroom [1]. The student was first introduced to the virtual physiology laboratory. Virtual laboratories have evolved into valuable resources for teachers and students at all levels of education, from primary school to high school. Many academic papers have been written about the virtual laboratory.

Several recent papers have focused on investigating virtual labs [2-14]. The data have shown that using virtual labs in the study for some physics concepts increased learners' creative potential, problem-solving skills, and comprehension. Finkelstein et al. carried out pedagogical experiments at the Colorado University to investigate the efficacy of replacing traditional laboratory equipment with computer simulations when studying direct currents [15].

The study's goal was to see if the simulations could replace the original equipment effectively. Based on the static data, the researchers could claim that simulations can effectively replace traditional laboratory equipment, with the average score for the experimental group - 0.593 and the control group - 0.476 showing a significant difference between the two groups ($p<0.001$).

At the Maryland University, Steinberg conducted a research study on air resistance [12]. This study included three classes, each of which used tutorials. Two classes used computer-based simulations with tutorials, while the third used paper-and-pencil activities.

Regarding the effectiveness of virtual labs on creativity based on gender differences in physics learning, Gunawan et al. discovered that male students are more creative than female students [16]. Serungke et al. researched the role of virtual labs in PBL model lessons [17].

Many recent studies have demonstrated the benefits of a virtual laboratory for robotic applications [18-20]. Several studies have suggested that virtual laboratory physics teaching of electromagnetism could be beneficial [21-24]. Overall, researchers discovered that this type of laboratory was effective among University students.

The preceding section provided a summary of the literature on virtual laboratories. However, no previous research has examined any pedagogical experiments involving virtual laboratories in specialized schools or lyceums. The primary role of the virtual lab in the teaching of mechanical motion at the lyceum remains unexplored. As a result, this paper investigates the impact of the virtual laboratory on the physics teaching method based on virtual laboratory among seventh-grade students at the lyceum.

2. MATERIALS AND METHODS

The investigation was conducted at the Baku European Lyceum during the 2019-2020 academic school year. The pedagogical experiment has consisted of three stages: confirmation, search, and formation.

The analysis of normative documents in the field of lyceum education, the design of lesson structure, and the ability of VII grade-students to conduct research, their ICT skill, and the problems that arose from the implementation of computer technology in physics teaching were carried out in the first stage of the study. Furthermore, the state of scientific-methodical and psychological-pedagogical literature and the teacher's readiness to implement these processes have been investigated. One of the main issues that arise during the physics teaching process in the VII grade of the lyceum is a thorough understanding of the main essence of mechanical motion and the role of various forces in that motion.

Physics teachers who can master the ability to conduct practical mechanics experiments play a critical role in the resolution of this process. However, in some cases, for security reasons, the physics teacher does not want to take the risk of researching this topic. As a result, it was decided to select virtual practices on these topics.

The availability of exceptional talent in lyceum students, their knowledge and skills in the teaching process, their research activities, and teachers' preparation for completing this task was investigated. As a result, the research problem, goals, and objectives were formed. The goal of the first stage was to identify the organizing issues that arose during students' laboratory work in physics teaching and the physics teacher's readiness to solve these issues. Purposeful discussions with physics teachers and students were held for this purpose. Students were asked the following mechanical motion-related questions:

- Question 1: How would the object's speed change if it moved under constant force?
- Question 2: What does an object's inertia imply?
- Question 3: What exactly is an inertial reference frame?
- Question 4: In what cases can the force vector acting on an object and the acceleration vector caused by that force be in the opposite direction?

A model of the organization processes of doing activities with a virtual laboratory in physics teaching was prepared at the second stage of the research, and a research hypothesis was developed. Following that, a strategy was devised. It was provided with the necessary resources and specific teaching tools for the physics teacher to design and organize student activities through a virtual laboratory. Sixty-one seventh-grade students who participated in pedagogical experiments were split into the control group (N=30) and the experimental group (N=31).

The lecture presentations practise problems, homework assignments, and quizzes/tests were all given to the groups. The Conceptual Physics textbook and teacher resources were used for some of the materials in both classes. The following timeline was the same for both groups and was consistent for each topic [25]. Mechanical motion took about two weeks to complete and was typically started using the 7E model.

In different stages of the 7E model lesson, the experimental group completed activities that required using PhET interactive simulations. The exercises given to the experimental group are created by the teacher and are based on some of the teacher resource materials available on the PhET website (Figure 1) [26].

The various activities were assigned to both classes on the same day of instruction. Both groups' activities typically took one class period. During the organization of a physics lesson on mechanical motion topics, experimental group students were shown a PhET simulation titled "Forces and motion basics" (Figure 1) prepared by Colorado University [26].

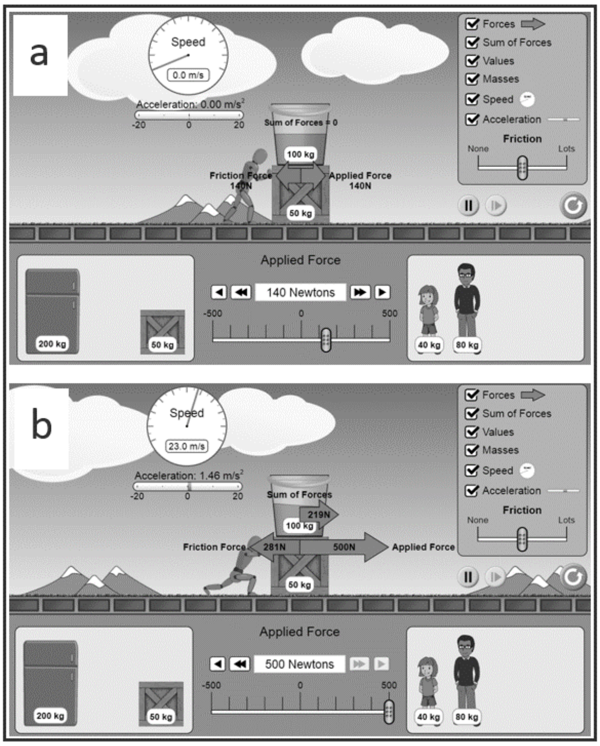

Figure 1. Virtual laboratory for the topic of mechanical motion [26]

The net force and its components can be found and calculated using this virtual laboratory. Furthermore, the reasons for the emergence of uniform rectilinear motion and accelerated, decelerated motions, as well as in-depth knowledge and skills, can be fully comprehended. A student can use this virtual lab to investigate the similarities and differences between static and sliding friction.

This investigation aimed to see how virtual simulations affected student understanding of mechanical motion by testing their conceptual knowledge of kinematics and Newton's laws. Before completing the course, most students have only a basic knowledge of mechanics concepts. In order to assess their understanding of forces and motion concepts, both classes were given test tasks consisting of ten questions. The pre-test and post-test consisted of three easiest, three easier, two harder, and two most difficult tests. It should be noted that the content of the pre-test and post-test is the same; however, the digits have been changed. Therefore, this article presents only the test (Figure 2) given to the experimental group.

Following the test administration, the data were analyzed using the SPSS program. The data were compared using a two-tailed t-test statistical analysis. This test aims to see a significant difference between the two groups on the topic mentioned above. A confidence level of 95% (α = 0.05) was used throughout the survey for all comparisons.

Male □ Female □

1. How would the object do if it was not affected by the objects/
A) Wave motion B) Constant deceleration C) Uniform circular motion
D) Constant deceleration E) Constant acceleration

2. The two opposite forces F_1=25 N and F_2=17 N were applied to the object. Calculate the module of the net force.
A) 8 N B) 42 N C) 21 N D) 4 N E) 10 N

3. Which quantity value is considered to be enough to calculate the net force affected an object?
A) acceleration and density B) mass and speed C) mass and volume
D) volume and speed E) mass and acceleration

4. In which case, the car-related computing system can be considered inertial?
The car:
A) turns into the street at right angle B) goes at constant accelera highway
C) goes at constant deceleration on horizontal highway D) straight-line uniform mo horizontal highway
E) goes up a mountain

5. What forces cannot be a net force of 7 N and 12 N, applied to an object?
A) 9 N B) 6 N C) 4 N D) 14 N E) 13 N

6. The object gained acceleration of 2 m/s² under the force of 100 N. By which forces would this object gain 0.4 m/s²?
A) 10 N B) 20 N C) 50 N D) 40 N E) 80 N

7. The object under the force of 78 N on a road of 50 m increased its speed from 5 m/s to 8 m/s. Calculate the mass of the object.
A) 150 kg B) 200 kg C) 175 kg D) 125 kg E) 100 kg

8. What is Newton's third law?
A) measure of inertia of bodies
B) a physical quantity that is characterized as the inertia of a mass
C) the acceleration of an object is directly proportional to the force acting on it and is inversely proportional to its mass
D) any mutual forces, by which of them the two objects acts on each other, are equal in value, and are opposite due to the direction
E) the conservation of speed of object without any impacts of objects on it

9. The two objects with mass m_1=m and m_2=2m moves in the circles with R_1=R and R_2=2R at a constant speed. Compare the net forces affecting them.
A) $F_2=2F_1$ B) $F_2=4F_1$ C) $F_2=F_1$ D) $F_1=2F_2$ E) $F_1=4F_2$

10. What expression does the force act on an object moving in uniform circular motion determined (R-radius, m-mass, T-period)?
A) $\frac{4\pi^2}{T}mr$ B) $\frac{4\pi^2}{T^2}mr^2$ C) $4\pi^2T^2mr$ D) $\frac{4\pi^2}{T^2}mr$ E) $4\pi^2Tmr$

Figure 2. The test given to the experimental group

3. RESULTS

During the Discussion in the first stage of pedagogical experiments, each seventh-grade student is asked to answer some mechanical motion-related questions, and the majority of them respond as follows:

- Question 1: How would the object's speed change if it moved under constant force?
• Answer 1: The speed also remains constant because of the constant force.
• Answer 2: It will rise in a parabolic fashion.
- Question 2: What does an object's inertia imply?
• Answer 1: An object is changing mass.
• Answer 2: The speed's dependence on the force acting on it.
- Question 3: What exactly is an inertial reference frame?
• Answer 1: It is nothing more than a system that moves at a constant speed.
• Answer 2: The system is only in a state of rest.
- Question 4: In what cases can the force vector acting on an object and the acceleration vector caused by that force be in the opposite direction?
• Answer 1: At a high rate of speed.
• Answer 2: In a slowed motion.
• Answer 3: In smooth motions.

Analyzing the students' responses has shown that despite understanding mechanical motion, they lack sufficient scientific and practical skills regarding the angles between the vectors of forces affecting the moving object and its velocity or acceleration. Even if they understand Newton's laws, they cannot fully comprehend the practical benefits that resulted from the application of those laws.

The simulator (Figure 1) was shown to students in the experimental group at all stages of the 7E model lesson. The test tasks were introduced to both groups to assess the adoption level of knowledge about the essence of the mechanical motion topic (Figure 2).

Following the post-test, a statistical analysis was performed. As a result, a two-tailed test was used (Figure 3) A 95% confidence level ($\alpha = 0.05$) was used throughout the study for all comparisons. Also, all errors expressed here represent uncertainty in the means. The mean scores were 55.7 ± 35.1 for the control group and 69 ± 35.9 for the experimental group. A t-test result (p=0.41) indicates that the experimental and control groups have similar conceptual knowledge after virtual simulations.

The p-value (0.41) obtained from independent t-test results for the control and experimental group students via the SPSS program shows no significant difference between the two groups. However, there is a significant difference between the control and experimental groups (Figure 3).

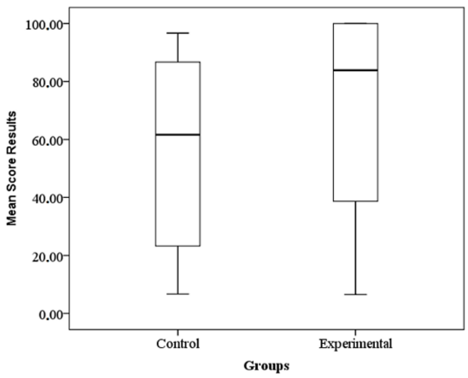

Figure 3. Mean test scores, in percentages, for both control and experimental groups

Besides, considering that the interquartile range for both groups is approximately the same, the upper median for the experimental group is equal upper whisker for the control group. Furthermore, even though the minimums for both groups are the same, the minimum level of 75% of correct responses of experimental group students became higher than that of one of the control group students.

Figure 4 depicts the result distinctions derived from the test answer analysis. The first question is a series of straightforward questions. Students in the control group answered 93.3% of the correct answer, while students in the experimental group answered 100% correctly. However, there was a significant difference in response to the second question: 60% of control group students and 96.8% of experimental group students.

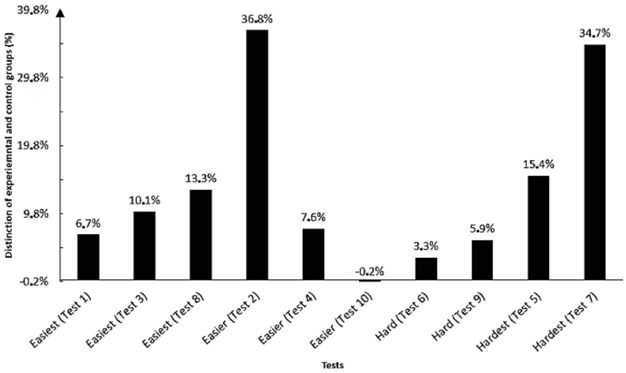

Figure 4. Subtraction of experimental and control groups success for each test

When looking at the answers to the third and fourth questions, there is only a slight difference between these groups. The fifth question was posed to the students as a difficult one. Students must be able to calculate net forces to answer this question. As a result, 23.3% of students in the control group and 38.7% of the experimental group correctly answered this difficult question. The sixth question was designed to be relatively complex. Students in the control group answered 96.7%, while students in the experimental group answered 100%.

Looking at the seventh test task, we can see a series of difficult questions. The percentage of correct answers given by students in the control group was 23.3%, while the rate of correct answers in the experimental group was 58.1%. The eighth question is one of the most valuable questions on the test. Students in the experimental group responded 100%, while those in the control group responded 86.7%. Students grasped the essence of Newton's third law by answering this question. The experimental class's performance on this question is closely related to their virtual practice performance.

When we look at question No. 9, one of the more difficult ones, we can see that it is about the centripetal force acting on it while moving around the circle. The relatively tricky question was answered correctly by 16.7% of the control group and 22.6% of the experimental group.

The tenth question in the test assignments is relatively simple. So, 6.5% of the experimental group and 6.7% of the control group responded to this question. Both groups' answering unsatisfactory to this question was assumed their inability to comprehend the relationship between the forces in uniform circular and linear motion and the essence of the movement on the circle entirely.

4. DISCUSSION

The pedagogical experiments confirmed that virtual mechanical motion experiments positively affect students. It is universally acknowledged that lyceum students obsess over specific talents. In this regard, Azerbaijan Education Law paragraph No. 1.0.33 states [27]: Lyceum is an educational institution that provides educational services to talented students at the general and complete secondary levels.

As a result, students who wish to study at this institution must take different admission exams. Our investigations revealed that approximately more than half of the students in both groups correctly answered these tests. This fact was expectable. The main effect of the virtual laboratory can be seen in practice issues for solving complex physics tasks.

Although the solution for tests 1, 3, and 8 is considered easy, these tests aim to assess students' abilities to obtain Newton's laws, as shown in Figures 2, 3, and 4. We can evaluate the answers to these questions as a student understands the difference between static and sliding frictions and how they affect net force. Correct answers provided by students in the control group may be related to theoretical knowledge.

Even though tests 2, 4, and 10 were considered relatively simple, the experimental group's number of answers for test 2 was 36.8% higher than the control group's. This significant difference may be attributed to students' understanding of the force module. However, due to a lack of scientific and practical knowledge about the force in a uniform circular motion, both student groups received the lowest scores (≈7%) in test 10.

Tests 5, 6, 7, and 9 demonstrate a significant influence of the virtual laboratory on students' solutions to complex questions. It can be concluded that the study of uniform accelerated and decelerated motion using the virtual lab resulted in the students answering these tests efficiently. Tests 6 and 7, for example, can be solved using only Newton's second law formulas. A correct answer to these questions by students from the experimental group, on the other hand, demonstrates that they can comprehensively describe the essence and content of the problem in their imagination.

Furthermore, the virtual lab depicted in Figure 1 was assigned to students as homework. The differential approach was thus used to explain and apply mechanical motion. Taking into consideration the following factors as the main benefits of using the virtual laboratory, they can be used in a different stage of physics lesson based on the 7E model:

- the ability to display very accurate physics experiments that cannot be measured with simple laboratory tools and not require complicated and expensive equipment;
- is helpful for the students and teachers to learn and prepare laboratory experiments anywhere at any time;
- the ability to record all results electronically, helping them analyze at the end and share the results with other participants;
- provides a simultaneous and comparative analysis of various laboratory studies.

5. CONCLUSION

A detailed examination of the difference between the pre-test and post-test results revealed that there appears to be an impact, but it is not significant at the 5% level. This fact could imply that the effect is genuine. Nonetheless, the sample size of one class in each group was insufficient to provide statistical study power, a common problem in educational research. Furthermore, it should be noted that, despite statistical data analyses showing no significant difference between experimental and control groups and taking into account each test result, it could be concluded that the impact of virtual labs on mechanical motion teaching among seventh-grade students in lyceum is satisfactory. It was discovered that a virtual lab enables the student to monitor the initial data of the research in this type of lab, change various operations, and monitor the results without the supervision's participation. Integrating these virtual labs into physics lessons will be more relevant and appropriate.

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