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Advantages And Disadvantages Of Using Virtual Laboratory Work In Physics

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Abstract. In this paper we have considered the problem of implementation of virtual physics labs in higher education institutions, as well as their advantages and disadvantages compared to traditional laboratory practical's. The importance of supplementing real experiments with virtual ones is highlighted. It is shown that the virtual laboratory is one of the innovations having a significant impact on the modern education system. The virtual laboratory provides practical training with all the existing limitations, such as the tools and materials of practical equipment at universities.
Keywords: *Information technology, virtual laboratory, traditional experiment, advantages and disadvantages of virtual laboratory work.*

Introduction

Physics is a priority in the university educational process. Knowledge of physical phenomena and the fundamental laws that explain them not only provides a foundation for mastering applied disciplines but also develops thinking skills in future engineers. In recent years, the development of information technology has necessitated the integration of modern technologies into the educational process. Long-outdated physics laboratory equipment at many universities poses challenges to modernizing the educational process. Lecture experiments and laboratory classes are conducted using old, repeatedly repaired equipment. Key issues receiving special attention in the education system are the introduction of new technologies and comprehensive modernization. The introduction of information technology into the educational process should effectively complement existing teaching technologies or offer additional advantages over traditional forms of instruction. For example, the use of virtual labs in physics teaching makes lab work more lively and engaging, while improving the quality of education.

A virtual laboratory is a hardware and software system that allows experiments to be conducted without direct contact with a real facility, or even without one. In the former case, we are dealing with a so-called remote-access laboratory setup, which includes a real laboratory, hardware and software for controlling the setup and digitizing the obtained data, and communication tools. In the latter case, all processes are simulated using a computer [1].

1. Virtual laboratories and their impact on the development of students' skills in a scientific course

The rapid development of information and communication technologies and the resulting use of these technologies in many sectors of society, including education, has led to technological innovations to keep pace with this digital development, which has become the most noticeable feature of our time. These innovations include schools, universities, classrooms, and virtual laboratories.

Virtual laboratories are a program that represents a significant innovation in educational technology, capable of replacing and simulating real-world conditions. Students interact and participate in this reality through their senses and the use of certain assistive devices. Virtual laboratories are those that simulate real-world laboratories, allowing students to conduct multiple laboratory experiments remotely. These laboratories compensate for the lack of equipment necessary for experiments and can cover most course concepts through virtual experiments that are difficult to achieve in real life due to limited practice time and the number of labs [1].

The virtual laboratory is one of the innovations that has a great impact on the modern education system. The virtual laboratory provides hands-on learning with all the existing limitations, such as the tools and materials of practical equipment at universities [2]. There are such virtual laboratories that can be used on any device with internet access (laptops, tablets, or smartphones) [3]. Virtual laboratories have been perceived as a response to the problems faced by educational institutions struggling to offer science students the experimental learning experience they need. Organizing laboratory space requires a lot of time, cost, and compliance with

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health and safety regulations. Moreover, when students are unable to attend real laboratory classes, they may not get a second chance to practice [4]. Gaining experience in applying the scientific method through experiments, where students test hypotheses, plan experiments by setting up instruments, searching for, processing, and interpreting data, and presenting experimental results orally and in writing, is a scientific process that must be carried out for students to gain new knowledge.

2. Virtual laboratory **work in physics.**

There are many resources online offering physics lab exercises. These resources can be divided into two groups. Sites in the first group offer virtual lab exercises using animation of varying quality and style [1]. The second group of resources features videos of real experiments with either detailed or brief explanations of the experiments [2, 3]. A review of online resources offering physics lab exercises revealed that the majority of lab exercises are oriented toward the high school physics curriculum, which is insufficient for higher education institutions.

As an experiment, a virtual laboratory project on the topic "The Fundamental Equation of Rotational Dynamics" was developed and implemented jointly with the Department of Information Systems and Technologies at the Physics Department of Jizzakh State Pedagogical University (DSPU). This topic was chosen for the virtual laboratory project because the physics department has a real laboratory setup. The computerized laboratory project is divided into five sections (Figure 1):

1. Theory - a section containing theoretical information on the physical phenomena and laws being studied, which are presented in the form of hyperlinks to the text part of the printed edition of the textbook.
2. Installation. Measurement method - a section containing a description of the laboratory installation and the measurement method using photographs of the actual installation, allowing one to explain the purpose of individual installation parts and the stages of performing the laboratory work [3-7].
3. Video of the experiment - a section containing a demonstration of the entire process of performing real laboratory work.
4. The procedure for conducting the experiment is the section in which the virtual experiment is directly carried out.
5. Report - a section in which the measured values are automatically entered into the experimental data table with their subsequent computer statistical processing.

3. Virtual laboratory bench

A virtual laboratory bench is software for a personal computer that allows you to study the design and operating principles of various devices and technological installations by interacting with their realistic, interactive 3D models.

An interactive virtual model allows students to easily study phenomena invisible to the naked eye, as well as devices, mechanisms, and systems physically inaccessible to the average student, or even many experienced professionals. All models are housed in virtual environments that replicate real laboratories, workshops, and other production facilities, allowing students to move freely around them. The virtual setup contains a section with theoretical material or detailed visual animations of the phenomena, and in some cases, diagrams or drawings of the devices being studied. This makes the virtual laboratory setup an effective educational tool, both pedagogically and economically. It can be used for introductory lectures, laboratory work, for preliminary training of specialists in equipment operation, and as an alternative to on-site practical training and field trips. Add distance learning.

The stand is designed for conducting virtual laboratory work on the "Electricity and Magnetism" section of the "Physics" discipline in secondary and higher educational institutions.

Laboratory work:

- study of the temperature dependence of the resistance of conductors and semiconductors;
- determination of the time constant of a circuit containing resistance and capacitance;
- determination of the specific resistance of the conductor;
- determination of the specific charge of a particle using the magnetron method;
- study of the Hall effect in semiconductors;
- study of damped electrical oscillations;
- forced electrical oscillations in a circuit containing inductance;
- study of the resonance phenomenon in electrical circuits.

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Fig. 1. Virtual laboratory on electromagnetism

A virtual laboratory project was piloted in the Physics Department. Analysis of the virtual experiment's progress revealed that the time spent by students completing the virtual experiment was virtually identical to that spent on a real laboratory setup. However, as students gained experience implementing computer experiments, the time spent completing the virtual experiment tended to decrease [7-9] . Based on the results, conclusions were drawn about the effectiveness of the applied methodology. Remote work is not a complete substitute for laboratory research. Students do not conduct real experiments in person, but essentially observe a demonstration experiment while watching a video. They are unable to make experimental errors, analyze these errors, and, therefore, are unable to correct them. During remote experiments, students do not interact with laboratory equipment and, therefore, do not develop skills in interacting with physical instruments. At the same time, one of the most important tasks in training engineers and technologists is the development of analytical and, especially, practical skills.

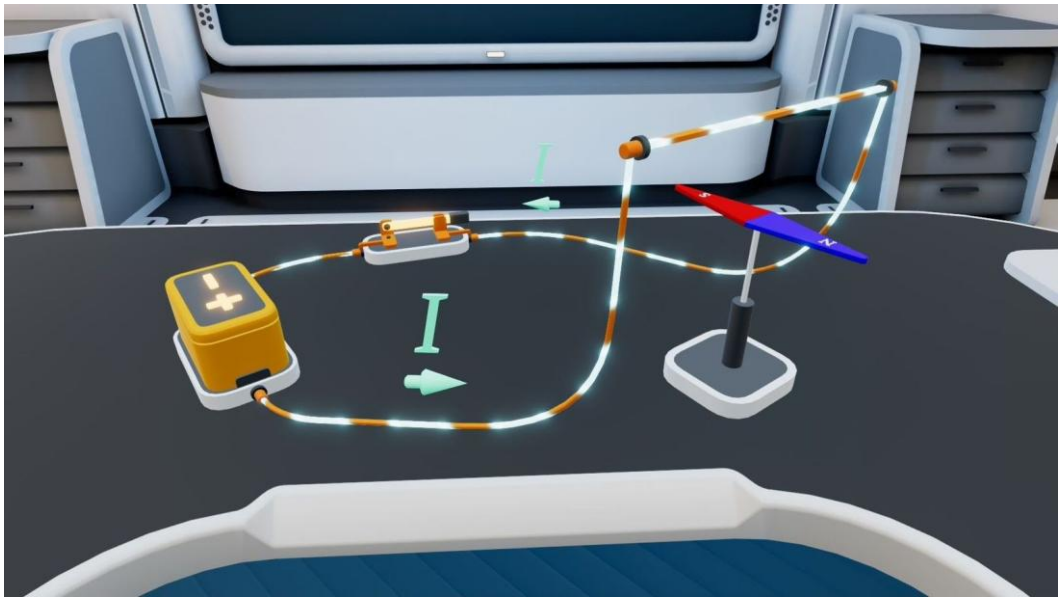

Fig. 2. Photo fragments of the virtual laboratory work

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Despite the above mentioned shortcomings, during the course of remote laboratory work, students have the opportunity to:
- obtain real or close to real experimental data and perform calculations based on the obtained data;
- independently take measurements and plot graphs based on the data obtained;
- compare the obtained values taking into account the measurement error and draw conclusions based on the analysis of the obtained data [9].

Computer animation of lab work also helps speed up the transfer of information to students and enhances their understanding. Audio accompaniment, thanks to commentary, enhances understanding of the material being studied. Video accompaniment provides a visual demonstration of the material being studied, improving its comprehension. Distance learning significantly enhances the role of students' independent learning. When completing virtual lab work, students must independently follow a specified link, find the necessary information, carefully view and listen to the course material, process the information obtained, analyze it, and draw conclusions. This helps students develop independent work skills.

Conducting virtual labs isn't a complete alternative, but it does solve certain problems. Remote labs are useful not only in emergency situations but can also be used for distance learning and for students who have long absences for valid reasons.

4. Research methodology.

The experiment involved two groups (experimental and control) of second-year students majoring in physics. The study lasted one academic year. Each group completed 12 laboratory assignments: the experimental group used a virtual laboratory, while the control group included elements of computer simulation of practical training. An important factor in group formation was the preliminary collection of information, including entrance exam results, which served as a baseline indicator for assessing, monitoring, and predicting individual student performance. The assessment plan can include a correlation between certificate grades and entrance exam results. This allows for the collection of individual data and an overall picture across groups—the average entrance exam score and baseline indicators (Table 1). The results obtained using the aforementioned assessment of the physics entrance exam in the experimental group are presented in Table 1.

The first question was about students' attitudes towards virtual learning technology, and the respondents' responses are presented in Table 1.

Table 1. Students' attitudes towards virtual learning technology and respondents' responses

Tasks	Agree		I find it difficult to answer		I disagree	
	N	%	N	%	N	%
Assignments on the LMS are presented logically and correctly	7 0	72.8	2 4	24.9	10	1 0.4
LMS assignments give me the opportunity to study the material more	68	68 .2	2 2	2 2 .2	14	1 4.7
Assignments in virtual learning mode are interactive	7 2	74.3	23	23.6	9	9 .4
Virtual learning improves my skills and understanding	6 6	66.5	2 8	29.1	10	1 0.7
The virtual learning mode is simple and clear.	69	69.3	27	27.9	8	8.6
The virtual learning mode enhances interaction between teachers and students	60	61.6	30	30 .8	1 4	1 4.5

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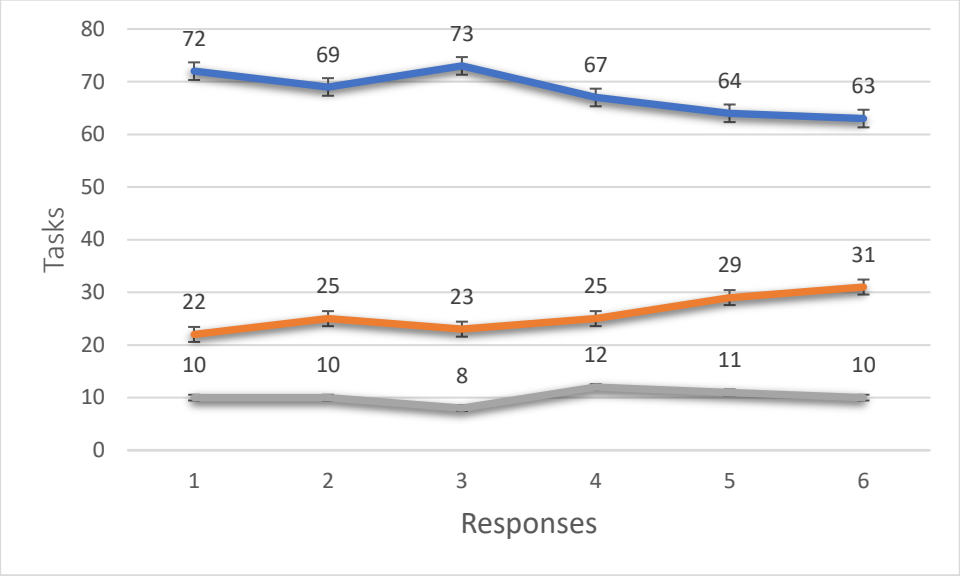

Fig. 3. Average score based on the exam results of the experimental group

It should be noted that the average score based on the exam results of the experimental group is presented in Figure 3. The second question was to identify the shortcomings and negative attitudes of students towards virtual learning technology, and the respondents' responses are presented in Table 2.

Table 2. Identification of shortcomings and negative attitudes of students towards virtual learning technology

	Agree		I find it difficult to answer		I disagree	
	N	%	N	%	N	%
When students complete interactive tasks, the teacher does not have time to provide feedback in a timely manner.	7 2	74.3	2 2	22.8	10	10.2
virtual learning .	6 9	69.3	2 5	25 .5	1 0	1 0.2
I find the virtual learning mode challenging.	7 3	74.5	23	23.4	8	8.4
Difficulty following assignment instructions in virtual learning mode	6 7	67.3	2 5	25.5	1 2	1 2.3
The virtual learning mode contributes to my social isolation	6 4	64.8	2 9	29.8	11	1 1.2
When teaching in a virtual format, I feel the need for live communication	6 3	63.7	3 1	31.3	1 0	1 0.5

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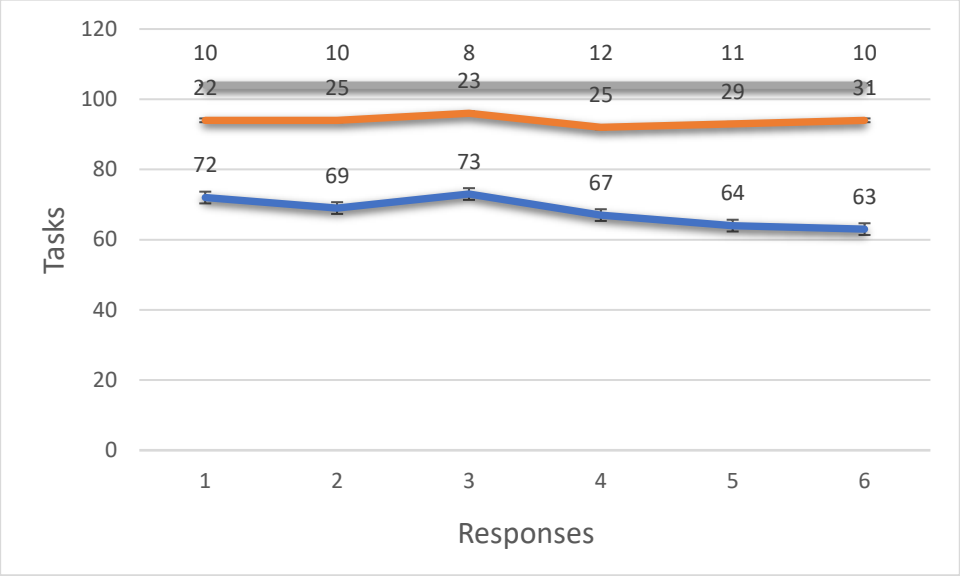

Fig. 4. Average score based on the exam results of the experimental group

Conclusion

Based on the analysis, it was proven that the use of virtual technology in lessons improves the quality of education due to the novelty of the activity. The internet has become an integral part of modern life, offering access to a vast array of additional resources that enrich lessons and extracurricular activities with a variety of ideas, interactive tasks, and spaces. Having highlighted the main advantages of using virtual technology in physics lessons, it can be seen that its use significantly increases lesson effectiveness, accelerates lesson preparation, allows the teacher to fully express their creativity, and provides clarity. Thus, it can be said that an important role of virtual technology is in enriching the content of the educational material with computer models. They are essential for students' assimilation of new material or reinforcement of existing material, making lessons more detailed and varied. While perceiving and understanding a new topic, students can observe physical phenomena presented using various models. All this makes the lesson more engaging and understandable.

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