



Development of Physics Learning Software Complex Using Leap Motion

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Abstract. The purpose of this article was to talk about the developed software product. Also, the article reflects the issue of relevance and technological capabilities of the IT world in the direction of virtual educational software. The work also raises the issue of gamification and the industry of serious games. Various analogs of applications and studies in the field of use and evaluation of the practical benefits of such programs are discussed. This article describes the development of a software package for virtual physics laboratories for studying a school physics course. In the course of work on the application, the Unity game engine was used to model 3Ds Max 3D objects. Laboratory works corresponds to the school physics course and fully implements the necessary functionality. Each of the laboratory work of the complex is described in detail and reflected in the form of screenshots. It also describes how to use the Leap Motion controller.

Keywords: virtual reality, leap motion, physics.

1 Introduction

The increase in the number of smart devices has given rise to the entertainment-education. Children are no longer interested in the traditional way of learning, which implies receiving information from a teacher and then consolidating knowledge using practical tasks. Current students are from the Generation Z, the first truly digital generation of people. The peculiarity of this generation is that “technologies of the future” for them are technologies with which they are familiar from their birth. Therefore, for them a completely different approach in all types of activities, including education is required. Thus, any educational material must meet the requirements of today, and the main consumers of this market are representatives of the Generation Z.

The most suitable way of presenting educational resources is a format that can compete with entertainment. One of the most popular and sought-after solutions are interactive applications similar to computer games. The main reason educational programs are more and more like games is the need to present material in a more accessible form.

The information that is gained during certain activity is better understood by a person without any additional action required.

As a result of the increasing number of such applications, the entire field has emerged – serious games. They are created mainly not for entertainment, but for other spheres like education, military affairs, scientific research, medicine, engineering and etc.

The high indicators of the effectiveness of the game approach prove its usefulness and relevance. So even those areas, where traditionally gamification has not been used at all, have started to consider it as one of the possible implementations. Psychologists, neuroscientists, teachers are also increasingly convinced of the effectiveness of the game approach, not only to improve education, but also to improve cognitive and perceptual skills [1].

It turns out that serious games have ceased to be a transitional element, but have grown into a separate industry with their own rules, goals, and capabilities.

In this project the software complex to study physics in secondary educational institutions is described. This virtual laboratory is developed in the International Information Technology University (Almaty, Kazakhstan). It allows users implementing virtually five different laboratory works on mechanics and electrostatics sections. The interaction with the application is supported by the Leap Motion controller, which helps to imitate real laboratory work execution. The virtual implementation of labs with application of the Leap Motion controller provides the game approach to study physics.

2 Related work

As already mentioned, the game approach is widely used in a variety of industries and fields. Another technological revolution also contributed to this. It brought us to the condition, when every sphere of our life is digitalized. Education is an integral part of the modern world, so technology has leaked here too. Many different approaches are implemented and used within educational process [2], and serious games are among them.

Thus, Papanastasiou et al. have analyzed the introduction of serious games in the educational process of primary and secondary schools. The result of their work was the confirmation of the effectiveness of such a decision, especially considering the needs of the current generation, which is used to communicate, express themselves, and study the world around them through smart devices, social networks and technologies [3].

Huang et al. in their paper presented a 3D game, where the characters are controlled using gestures, which are captured by the Leap Motion controller. Since the built-in set of gestures is quite small, the authors created their own ones. The result is a project that is a game with a new non-ordinary way of managing characters [4].

Another example of introducing games into the learning process is the development of the virtual mathematical class [4]. It is based on the use of Oculus Rift and Leap Motion. Within the virtual space a user is given different tasks on objects calculations or domino-based logic game. It helps children to acquire counting skills in the interesting unusual way, which increases creativity. With the Leap Motion kids use their own

hands as a controlling device, which also allows creating friendly and comfort atmosphere within the virtual media.

Usually the most important part during every educational process is practice. So the authors in [6] propose the idea that even the simplest practical exercise allows increasing the understanding of an underlying subject. Thus, they made an analysis of existing Mixed Reality tools and approaches, and studied the ways of manipulation within AR and VR. The authors also try to define the most suitable and useful spheres for application of the Leap Motion, which is a great tool for human-computer interaction, because it does not require any other special devices or equipment.

Chen et al. in [7] present the research on the way that primary school students interact with a drawing app using the Leap Motion. They concluded that it is a great tool to improve the manipulations within the virtual space, but it requires practicing with it before using it.

Another example of using new technologies in education is presented in the work [8]. The author states that children often lose the interest in studying, because many different entertainment apps and attractive TV shows have emerged recently. At this situation education seems boring and not interesting for them. And one of the possible solutions to make it interesting for kids is development and application of the special software that can bring a game into the educational process. The author presents such a virtual laboratory named “Fascinating reality”. It is used during physics classes in a secondary school, and augmented reality and Leap Motion are the way of interacting with the application.

3 Implementation

The implementation of the virtual physical laboratory developed is a platform that consists of several labs. In order to provide logical integration within it, the certain common rules were formulated. They describe the UI, user-app interaction, and functional structure. From the software development point of view, it can be defined as a unified approach for the development of a class model and other resources.

Thus, for all the laboratory works included into the application the common template for the laboratory scene was developed (see Fig. 1). Such requirements for the user interface as attractiveness, responsiveness and clarity were taken into consideration. The attractiveness of the interface implies a comfortable combination of colors, convenient size of interactive elements. The responsiveness is the speed of response of the system to user actions. It also includes the information content of the system. For example, the user must know, where he is at any given time inside the application, which makes him/her feel comfortable. The clarity of the system is a characteristic that allows the user to perceive information unambiguously, thereby improving and simplifying his/her interaction with the program.

According to the developed template it can be noticed that the common scene has the following elements:

1. Menu button;
2. Help button with description;

3. Common view on the lab equipment;
4. Panel with instruction to complete the lab.

Such an approach of designing the common UI for all the labs within the virtual laboratory provides certain kind of comfort for a user during the interaction with the application.

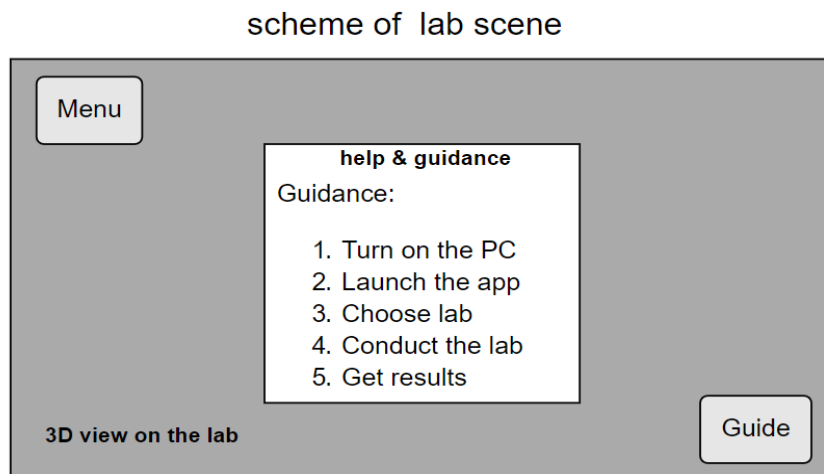


Fig. 1. Common UI for the laboratory scenes

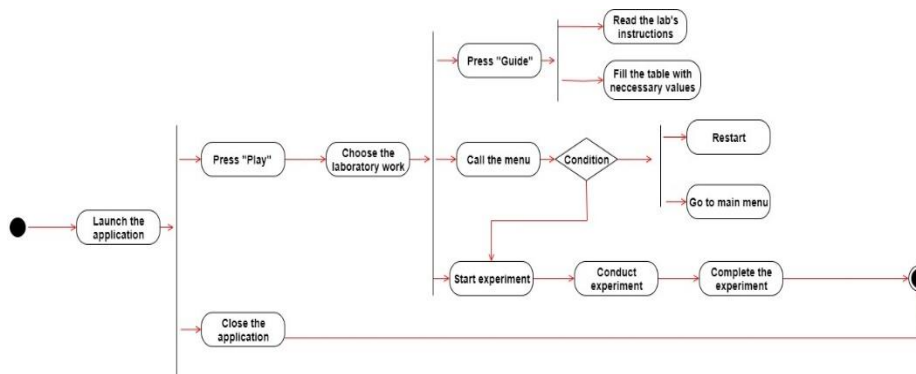


Fig. 2. Activity diagram of the application

There is an activity diagram (see Fig. 2), that displays the logical links between action within the application. A user after application is launched can choose to continue or to cancel the program. In case of pressing "Play" the user needs to select one of the laboratory works. Within the laboratory work a student can conduct an experiment, find guidance for it or press the menu button, which leads to following options: restart, continue, back to menu.

According to the functional structure of the software each lab should meet the common requirements. Consequently, each laboratory work includes the following components:

1. Theory;
2. Installation of the equipment;
3. Testing before and after an experiment;
4. Conduction of the experiment, getting results;

3.1 Tools

The C# programming language was used to develop the application; however, initially Unity supports working in C#, UnityScript, and .NET languages [9].

For the correct work of the application, the object must interact with other objects in a certain predefined way. This behavior is recorded in a script, which is placed then on this object using drag & drop. Initially, Unity had a built-in text editor that allowed writing, modifying, and editing code. Since the version 2018.1, it has become possible to use Visual Studio for Unity Community, and the text editors Notepad, Sublime Text, and Visual Studio.

In the current project the Visual Studio was applied, since this environment allows writing code quickly and accurately, easily switching between classes, and effectively finding and fixing problems.

Unity 3D game engine is the kernel, on which the presented application works. It has several advantages compared to its analogs: simple interface, large selection of various plug-ins and libraries, well-developed physics, high-quality graphics [10]. Thereby, Unity allows creating realistic objects based on their physical settings, as well as the interaction between them. The ability to configure a variety of properties of each element of any scene is another advantage of this platform.

Leap Motion controller is a device with two infrared cameras and three infrared sensors [11]. They allow tracking the movements and positions of the hands in space above the device itself. The controller is equipped with a module to integrate with Unity, which makes it easier to work with it inside applications created on this engine.

3.2 Development of the virtual laboratory work #1

The aim of the lab “Dependence of the body flight distance on the throw angle” is to make students understand the relationship between these two quantities. In the course of work, students study the theoretical basis of the body motion, which is thrown at an angle to the horizon and also experimentally establish the dependence of the body flight distance on the throw angle. Conduction of the experiment requires setting the ballistic pistol’s angle, which can be done after putting of the ball into defined place. After starting the ball, students need to measure the length and enter this data into the table. This project has the following classes: FireManager, OnTableDropDesktop. The user interface is shown in Figure 3, which also displays accessible laboratory equipment’s controllers. By changing the slider’s position users can set the throw angle.



Fig. 3. The dependence of the body flight distance on the throw angle

3.3 Development of the virtual laboratory work #2

The aim of the laboratory work “Determination of the moment of inertia of a ball” is to calculate and experimentally establish the moment of inertia of the body. During the work, students interact with three objects – balls of various diameters and masses. Also, other elements of the equipment are a tripod, an arc-shaped tray, and a measuring ruler. To implement the experiment, students must alternately place the balls in the tray after recording their masses and the height of the tripod. After starting the ball, students need to determine the place of its fall, measure it and also add this data to the table. Then students must calculate the moment of inertia – J of the ball according to the following formula:

$$J = \frac{mR^2(4hH-l^2)}{l^2} \quad (1)$$

where m is the mass of the ball, R is the radius of the ball, h is the height of the ball above the tray, H is the height of the tray above the table, l is the distance that the ball flew when falling from H . This project has the class `AttachController`. The user interface is presented in Figure 4 and consists of experiment’s equipment and also user’s hands as controllers. A user needs to put the balls of different weight and diameter into arc-shaped tray and then observe the place of their grounding.

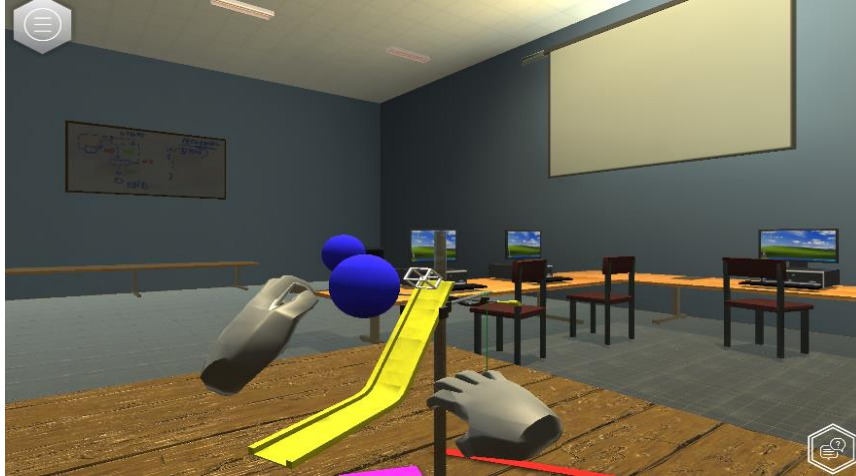


Fig. 4. Determination of the moment of inertia of a ball

3.4 Development of the virtual laboratory work #3

The aim of the lab “The study of Ohm's law for a circuit part” is to experimentally establish the dependence of the current strength on voltage and resistance. To perform this work, students must install the equipment in accordance with the scheme shown in Figure 5. After completing the work, students must enter the data into the appropriate table. This project has the following classes: AttachedController, ColliderScript, ManagerLab. In Figure 6 there is the laboratory equipment installation. A user needs to put all the devices into right places, according to the scheme. After the proper installation the user will see values of relation U/R .

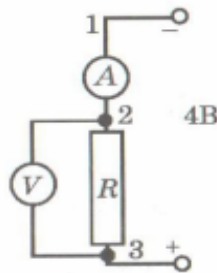


Fig. 5. Chain scheme for “The study of Ohm's law for a circuit part” lab



Fig. 6. The study of Ohm's law for a circuit part

3.5 Development of the virtual laboratory work #4

The aim of the lab “Study of series-parallel connecting conductors” is to study the operation of electrical circuits with a mixed connection of current consumers. To do this, students must assemble a circuit that corresponds to the circuit shown in Figure 7.

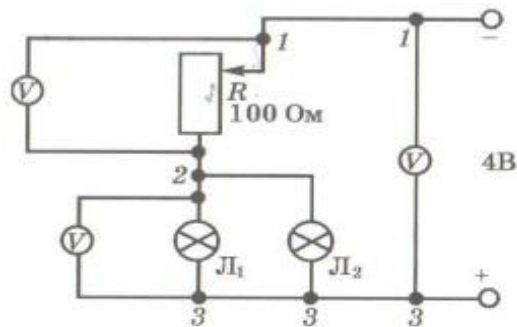


Fig. 7. Chain scheme for “Study of series-parallel connecting conductors”

Then students should observe the installation: by changing the position of the slider of the rheostat, determine the change in the brightness of the lamps, as well as indicators on voltmeters. This project has the following classes: BulbCalculation, BuldParticleController, RheostatMoving. The user interface is presented in Figure 8. There are all the devices that are necessary for the experiment. A user needs to change rheostat's

position and check how it changes brightness of the bulbs. The user then needs to find out what is the dependency between position of rheostat and voltage value.



Fig.8. Study of series-parallel connecting conductors

3.6 Development of the virtual laboratory work #5

The main aim for students in “Determination of EMF of a current source and its internal resistance” lab is to learn how to determine the internal resistance of the current source and EMF. By changing the position of the rheostat slider, students can observe how the numerical indicators on the ammeter and voltmeter change, as well as the change in the brightness of the lamp. Then, experimentally, through Ohm's law, students need to find EMF and internal resistance. This project has the following classes: ArrowController, BulbCalculation, BuldParticleController. The equipment is set according to the required order on the scheme in Figure 9. The complete installation and user interface are presented in the Figure 10. Also, as in the previous laboratory work the user needs to change position of the rheostat in order to track changes of voltage's value and brightness of the bulb.

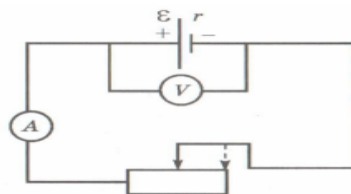


Fig. 9. Scheme of the installation for “Determination of EMF of a current source and its internal resistance”

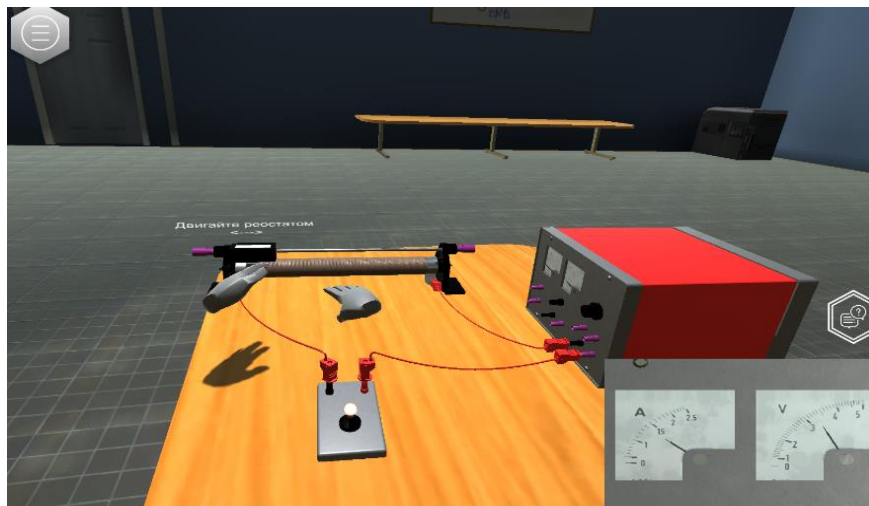


Fig. 10. Determination of EMF of a current source and its internal resistance

4 Evaluation and Conclusion

Contemporary pupils are intensively involved in information technologies and different smart devices from birth. It led to the necessity of new educational materials created specifically using computer games, multimedia resources and etc. As a result, the amount of these methods increased and created a new subdivision like serious games.

Today many schools are equipped with computer classes. However, despite the wide dissemination of this approach among the study of the humanities, such as language, art, and history, the technical sciences are mostly left overboard. The reason is a complex implementation. But from a perspective view, it is much more useful for pupils, because many of them have some problems with understanding, for example, of physical phenomena, which can be hard to imagine. Partially this problem is solved by conduction laboratory works and practical lessons with real equipment. And there is another problem – many installations on physical experiments can be very expensive for a school, or the amount of equipment does not provide every student with enough time for its conduction. From this side, virtual laboratory works grant pupils with unlimited 365/7/24 access and place. In order to approve the effectiveness of virtual laboratory works the following survey was conducted.

During the first half of the 2019-2020 academic year pupils of one 9th grade class of the Republican Physics and Mathematical School (Almaty, Kazakhstan) had been using the developed application within physics lessons for execution of the laboratory works. After that they participated in the survey. Twenty-four pupils took part in the research.

The first stage of the survey was conducted in September, when the academic year just started. Its main goal was to clarify, whether or not the pupils used similar applications earlier. The common answer was “No” and meant that they did not use similar

applications on lessons before. But about 20% used corresponding programs on their own.

During the second stage of the survey in December, the pupils were asked the question “Is the application “Virtual laboratory” effective as an additional and convenient source of knowledge in the physics study?”. And more than 80% of respondents answered positively, the corresponding graph is shown in Figure 11. So this survey demonstrated the explicit use of virtual physical laboratory works and allows getting deeper knowledge and understanding of the educational material.

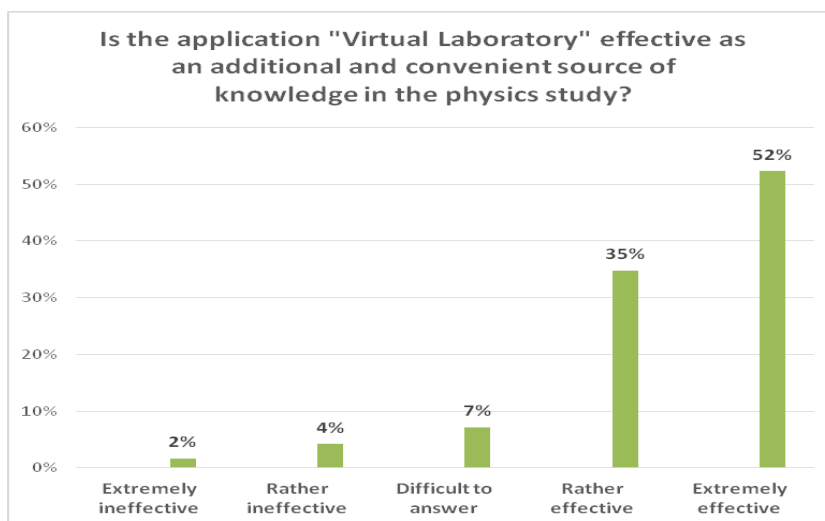


Fig. 11. Graph on research about effectiveness of the virtual laboratories

Thus, the main result of this research is the set of virtual laboratory works. It has 5 different labs, based on the real school program of physics course of Kazakhstani high schools. Each of the labs has its own equipment that close to the real and the interaction between students and all the devices is provided by Leap Motion controller features. It allows making contact with laboratory installation very similar to the real environment. Such type of the work helps to achieve deeper understanding of material without any probable hazard.

The main conclusion that can be drawn is that educational processes in virtual space are really underrated and must be improved and spread as wide as possible. However, conducted analysis and new findings made by cross-sectional specialists show the enormous potential of this industry.

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