Creation of Virtual Laboratories in Biology for 5th Class Students of Uzbekistan General Education Schools

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***Abstract*—The development of educational technology has opened new ways to improve their teaching, especially in subjects based on practical experiences. In this regard, virtual laboratories provide an immersive learning environment for students to interact with biological concepts through simulations and virtual experiences. This article provides information about virtual laboratories created in biology for 5th grade students of secondary schools in Uzbekistan. Biology textbook intended for 5th grade students of secondary schools of Uzbekistan aims to provide basic concepts and knowledge about general biology. There are 4 labs in it, and it is impossible to complete all of these labs at all times. One of the main reasons for this is that the necessary equipment for laboratory training is not distributed equally in all schools. Virtual laboratories created for the purpose of forming practical skills and enriching visual imagination of 5th grade students of Uzbekistan are presented in the form of web pages. These web pages were created using a code editing program called Visual Studio Code, and the section dedicated only to the 5th grade biology virtual labs contains 8 web pages. We believe that the process of implementing this virtual laboratory includes aligning it with national curriculum standards, training teachers to effectively use virtual tools, and increasing student engagement through interactive learning experiences.**

***Keywords*—biology, school, education, virtual laboratory, web pages, programs, online platform**

I. Introduction

In today's rapidly developing age, it is difficult to imagine our life without information technology. As in all fields, information technology has already gained its place in the field of education. The introduction of technology into education has solved a number of problems. It is known that biology, like a number of natural sciences, is one of the sciences whose research results are based on practical experiments and laboratories. They enrich the imagination of students about nature, increase their interest in science and play a decisive role in deepening their understanding. According to Paxinou *et al.* [1], technological learning tools such as videos and virtual laboratories are often included in the learning process as independent learning tools that help students acquire reliable knowledge of science and laboratory skills. The modernization of education in Uzbekistan and the provision of high-quality educational opportunities have led to the study of innovative educational tools. One such tool is the creation of virtual laboratories that offer a dynamic and active approach to teaching complex scientific concepts. According to Syahfitri *et al.* [2], Virtual laboratory is a form of simulation of a real laboratory used in educational activities or scientific research to emphasize a concept or explore concepts. Currently, there are several programs in Uzbekistan designed to create such forms of imitation, that is, virtual laboratories. But due to the presence of problems related to downloading these programs or other problems, working with these programs causes some inconvenience. The number of online platforms dedicated to virtual laboratories in the field of biology is also numerous. For example, PhET Interactive Simulations, Labster, BioMan Biology, etc. But most of them are in English, and subscribing to them is not free. Taking into account such problems, we have created an online platform for general education schools of Uzbekistan, which provides a completely free access to the subject of biology based on their native language. Our research provides information about the creation of virtual laboratories in biology for 5th grade students of this platform. In order to determine the effectiveness of this platform, we conducted a small experiment with 5th grade students at secondary school No. 21 of Taylak district of Samarkand region of Uzbekistan in the first quarter of the academic year, which took 5 weeks. In this experiment, two 5th grade students were selected, and for the first of them we organized lessons based on a traditional laboratory, and for the second—on the basis of a virtual laboratory created by us. At the end of our study, the second (virtually conducted laboratory) class recorded higher results than the first class.

II. Literature Review

To date, several scientists have conducted their research and presented relevant conclusions about the role and importance of virtual laboratories in the field of education. Among such researchers, Aliyah and Puspitasari [3] stated that inappropriate design of laboratory rooms, lack of practical schedule, limited practical tools and materials in the biology laboratory, lack of laboratory staff, limited budget, teachers' Barriers are barriers that affect the functioning of biological practices. In such times, information technologies, which are currently developing rapidly and have already taken their place in the field of education, will help. Syahfitri *et al.* [2] called virtual laboratories simulations or experiments conducted on computers to present natural phenomena that play an important role in the learning process of sciences such as physics, chemistry, and biology.

Diwakar *et al.* [4] emphasized that virtual laboratories attract students with graphic animations. Alshaikh [5] mentioned in one of his studies that the virtual laboratory is an acceptable solution for the teacher and students in terms of space and time, and it provides more flexibility. According to the research of Senechinkov [6], virtual laboratory software is virtual tools for computer implementation of the mathematical model of the studied phenomenon or device, setting parameters and visualizing the values of measured quantities, planning the experiment, obtaining includes tools for collecting and processing results. Also, virtual labs are great digital resources that help save costs and increase student productivity [7]. Korogod *et al.* [8] in one of their studies expressed the opinion that virtual laboratory work can help determine the level of success of biology teachers and each student in the updated educational program. Also, Ahmed and Hasegawa [9], Reginald [10] mentioned that virtual laboratories are convenient for teachers to evaluate students and effectively achieve educational goals. However, according to Lynch and Ghergulescu [11], Almuqbil [12], teachers should establish cooperation with field experts (programmers) in organizing and conducting virtual laboratories, and some scientific research to conduct them emphasized that they should learn from experiences. In addition, according to Khasanova and Simonova [13], educational virtual environments with rich multimedia content are virtual laboratories, which are not always available for school laboratories in real time, and allow you to see the processes. Radhamani *et al.* [14] mentioned in one of their studies that the inclusion of virtual laboratories in the educational process forms the ability of students to be independent. Also, Amankwaa *et al.* [15] in one of their scientific works, virtual laboratory demonstrations provide an opportunity to repeat the laboratory process. This, in turn, ensures further strengthening of the acquired knowledge. In their research, Nurul and Suyitno [16] concluded that virtual laboratories significantly improve student achievement in biology education, with more than 50% of high school students using them.

III. Materials and Methods

Traditional laboratory experiments have long been a cornerstone of science education, offering students hands-on opportunities to learn scientific principles, conduct experiments, and analyze results. However, logistical issues such as limited access to equipment, safety concerns, and time constraints often limit the frequency and scope of these experiments. Virtual labs address these challenges by providing a simulated environment where students can conduct experiments that mimic real-world scenarios without the constraints of physical resources or time. This study is aimed at the development of virtual laboratory modules for biology education, specifically for 5th grade students at secondary schools in Uzbekistan. Virtual labs are designed to complement the existing biology curriculum by providing interactive, hands-on experiences in a controlled online environment. The primary goal is to increase students' understanding of biology through simulation-based learning, allowing them to engage with scientific phenomena that may be difficult to demonstrate in traditional classroom settings due to time, resource, or safety constraints. The target group for virtual laboratory modules consists of 5th grade students studying in general schools in Uzbekistan, usually 10–11 years old children are at the initial stage of formal science education. Modules were developed in accordance with the biology curriculum for this class, emphasizing fundamental topics such as familiarization with laboratory equipment, observation of plant cells, and introduction to the world of fungi.

Virtual laboratories are developed using the following tools and technologies:

1) Programming languages: HTML5, JavaScript and CSS were used to develop interactive simulations, ensuring cross-platform accessibility and compatibility with different devices such as desktop computers, laptops and tablets.
2) Learning management system: A specially built online platform was used to host virtual laboratories. This platform allowed students to access simulations, complete activities and track progress. The learning management system is designed to be user-friendly and culturally relevant to the conditions of Uzbekistan.
3) Graphics and animation tools: Adobe Photoshop was used to design visual content, including realistic illustrations of organisms, biological processes, and laboratory equipment.

Virtual lab modules were developed in collaboration with biology teachers, instructional designers, and software developers. The content was focused on basic biological concepts defined in the national curriculum for 5th graders. The following topics are covered in virtual laboratories:

1) Acquaintance with laboratory equipment.
2) Getting to know the structure of a magnifying glass and a microscope.
3) Observing the onion skin cell under a microscope.
4) Getting to know the structure of yeast.

By providing an immersive, accessible, and sustainable learning experience, virtual labs empower students to explore, experiment, and innovate, resulting in a generation of scientifically literate and globally competitive individuals. Taking this into account, we have created an online platform for 5th grade students of Uzbekistan to conduct biology labs online. This platform was implemented through the Front-End field of programming in information technologies, that is, the direction of creating web pages. Web-based virtual labs have several advantages, the first of which is that they can be accessed directly from anywhere with an Internet connection. Second, no additional software downloads are required to complete these labs. It is also very convenient for distance education. Everything visible on a website, such as buttons, links, animations, etc., is created in Front-End programming. There are several editing programs in this field, and one of the most popular and convenient programs is Visual Studio Code. It is the most popular code editor due to its free, open source, ease of working with large projects, resource efficiency, and availability on Windows, macOS, and Linux (Fig. 1). There are three main branches of this code editor: HTML (hypertext markup language), CSS (Cascading style sheets) and JavaScript. It is through these networks that any type of web page can be created.

The online platform of virtual laboratories in biology that we created was also created in the Visual Studio Code

program, where each branch of this program (HTML, CSS, JavaScript) has its own tasks. For example, HTML is used to create text, images, links, and tags play an important role in this. In particular, headings using <h1></h1>, <h2></h2> tags, “Home”, “Back” buttons using <button></button> tags, and <a > link tags are used. Also, tags were used to surround each card and <img src = “” alt = “”> tags were used to place images (Fig. 2).

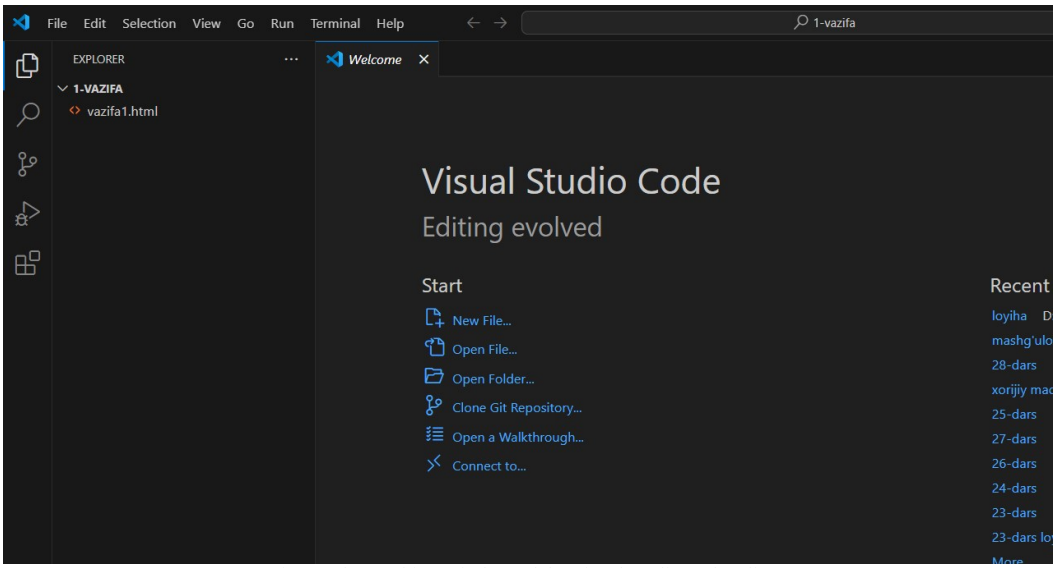

Fig. 1. The working window of the visual studio code editor.

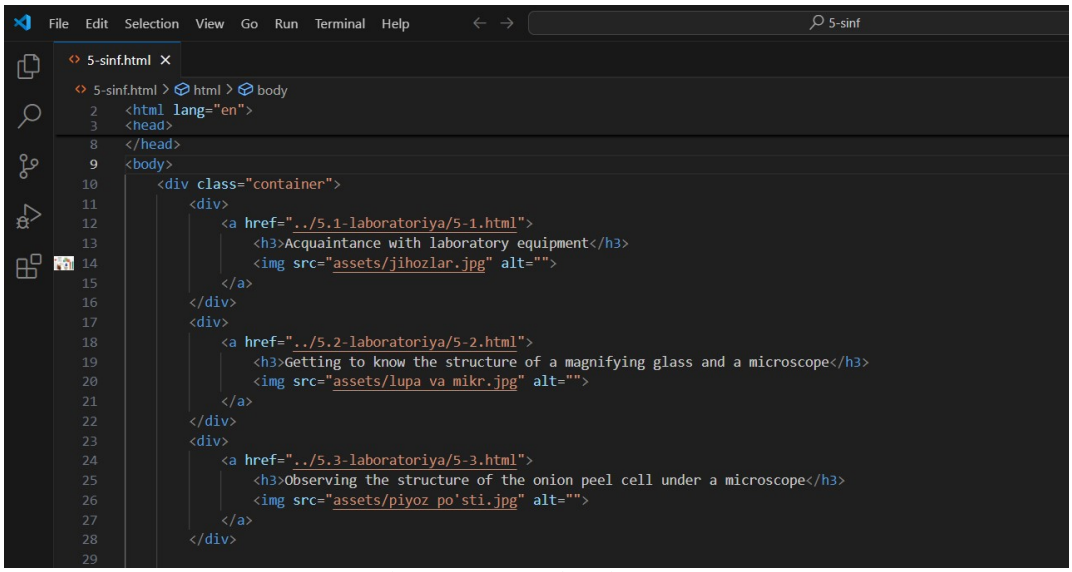

Fig. 2. Appearance of tags in HTML.

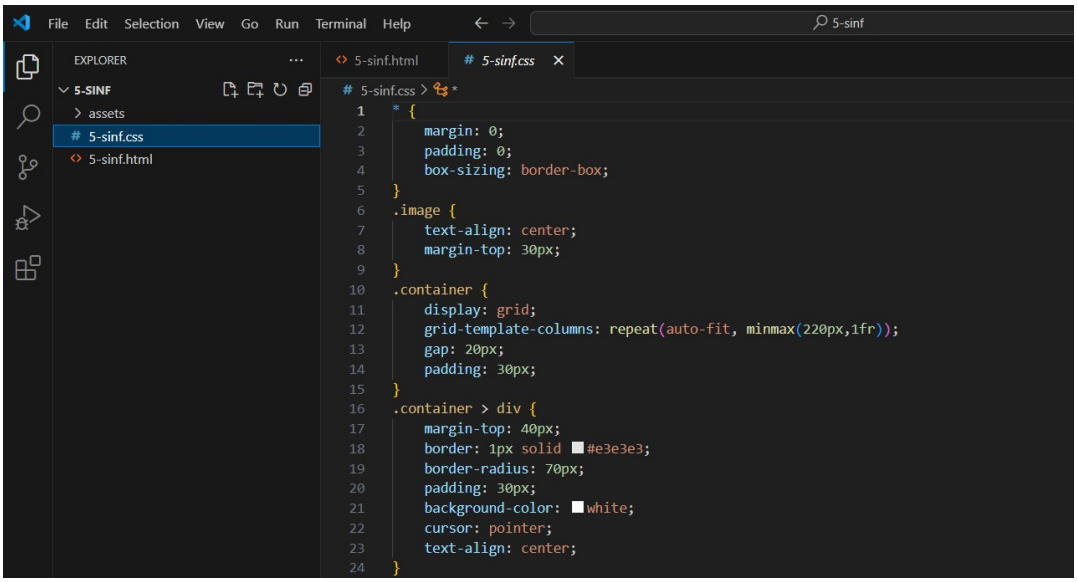

Fig. 3. A window of codes written in CSS.

Codes written in HTML and JavaScript can be styled differently using CSS. In this case, tags created in HTML are given "class" and this "class" is given an arbitrary name. The name of the same "class" is written in CSS and it is optionally given a style (Fig. 3). For example, if we create a <h1></h1> tag in HTML, we can give it a "class" as follows: <h1 class = "container" >Virtual laboratories of biology</h1>. So we named our <h1></h1> tag "container" and this tag became a selector in CSS. If we want to color the same selector, we use the "color" property. The color we want to enter as an optional type is called value. We can choose the colors according to our taste. It should also be mentioned that there are many types of "property" and "value" in CSS.

JavaScript is essential to make the things you see on our web page work. In JavaScript, variables are initially declared, and they can be activated by performing various operations on these created variables (Fig. 4).

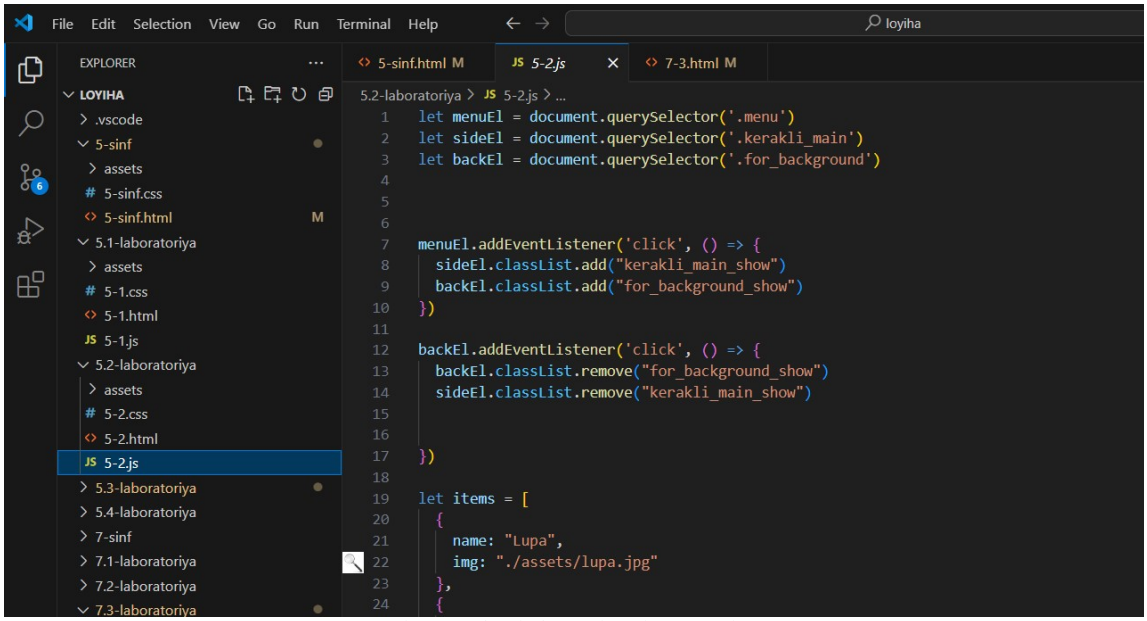

Fig. 4. Code window written in JavaScript.

After creating a virtual laboratory for 5th grade biology students using the HTML, CSS, and JavaScript of the Visual Studio Code code editing program, we used it as an experiment in the educational process to test its effectiveness. In this experiment, students of grade 5-A of secondary school No. 21 under the Department of Public Education in Taylak district of Samarkand region of Uzbekistan were selected as the experimental class, and students of grade 5-V were selected as the control class, and our experiment was conducted for 5 weeks. We spent the first 1st week of our experiment checking the school's provision of laboratory equipment and monitoring the condition of the students. We spent the next 4 weeks using the virtual laboratories we created in the experimental class (5th "A").

IV. Results

From the above considerations, it is clear that biology as a science often relies on visualization and hands-on demonstrations to explain complex biological processes. For young high school students, virtual labs offer an immersive environment in which they can learn and interact with simulated but realistic biological phenomena. This approach addresses several key educational needs: (a) Accessible learning: virtual labs provide learning experiences for all students, regardless of geographic location or school resources. This is particularly important for countries where educational resources may vary by region; (b) extended understanding: concepts such as cell structure, ecosystems, and human body functions can be difficult to understand without practical experience. Virtual labs give students the opportunity to visualize these concepts in action, help them gain a deeper understanding of biological principles; (c) safety and convenience: unlike traditional laboratories that require physical materials and equipment, virtual laboratories eliminate safety concerns and logistical problems. Students can conduct experiments and observe the results without special equipment, which makes learning more convenient and economical.

Based on the above information, an online platform of virtual laboratories in biology was created for 5th grade students. Below is the home page of this platform (Fig. 5).

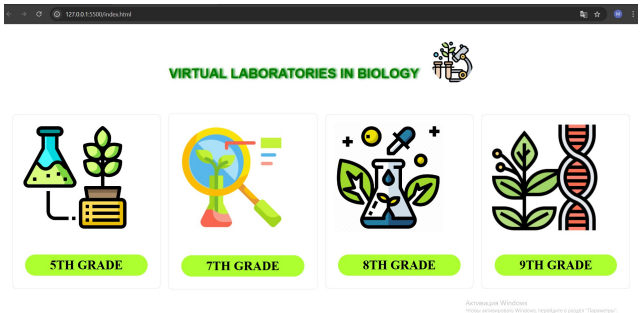

Fig. 5. Home page of the online platform of virtual laboratories created for secondary schools in biology.

If you select the card intended for 5th graders from the above home page, the page of laboratory exercises listed in the biology science book for 5th graders of Uzbekistan will open. (Fig. 6).

The topic of the 1st laboratory session is "Getting to know the laboratory equipment" and its brief explanation is given in the Table 1.

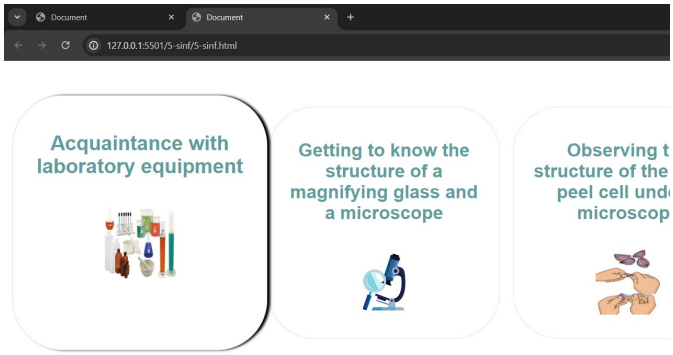

Fig. 6. Names of laboratory exercises in the 5th grade biology book.

Table 1. Laboratory exercise 1. Acquaintance with laboratory equipment

Necessary equipment:	Work progress:
1. Test tube	a glass container used to study the properties of substances
2. Pipette	helps drain the liquid.
3. Tweezers	clamp. It is used for compressing and moving the studied object.
4. Petri dish	a two-part glass container. It consists of outer larger and inner smaller vessels. It is often used to grow bacteria and fungi
5. Item glass and cover glass	used to view a living object under a microscope. A drop of water is added to the glass, the cell is placed and covered with a cover glass. Prepared micropreparations are observed under a microscope
6. Scalpel	a knife with a sharp blade. It is used for cutting living objects in the laboratory

The pedagogical value of laboratory activities is multifaceted and integral, helping students to develop deeper learning, critical thinking and skills. One of the most important processes in any laboratory training is to first get to know the laboratory equipment, to be familiar with it and to have information about it. Our above laboratory training is also dedicated to getting acquainted with the laboratory equipment, in which the students will gain an understanding of the structure and functions of the equipment. In addition, students learn to work with special equipment, perform accurate measurements and follow safety rules. However, in all regions of Uzbekistan, the necessary equipment for laboratory training in secondary schools is not distributed equally. Therefore, in order to give the students a better idea about the laboratory equipment, the online web page of this laboratory was created (Figs. 7 and 8).

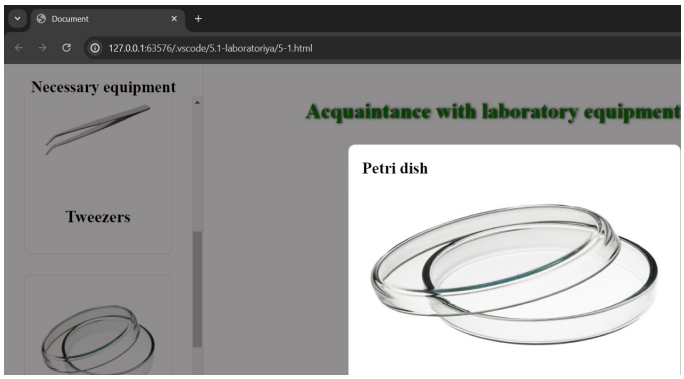

Fig. 7. Online page of 5th grade 1st laboratory exercise.

This web page is part of the 5th grade biology virtual lab web page and was created using the HTML, CSS, and JavaScript frameworks of Visual Studio Code.

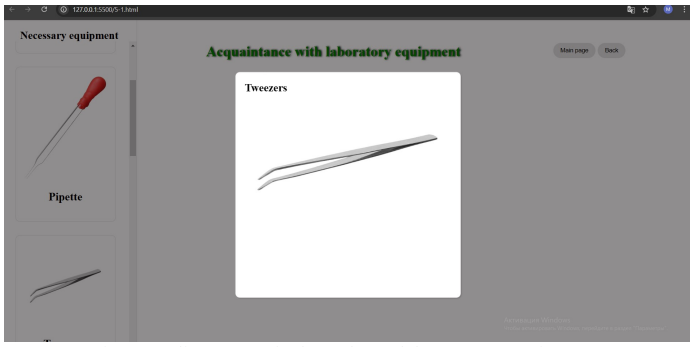

Fig. 8. Online page of 5th grade 1st laboratory exercise.

Laboratory sessions provide students with a hands-on learning experience. This gives them the opportunity to directly interact with materials, tools and experimental processes. This experiential learning helps students deepen their understanding of theoretical concepts by allowing them to directly observe phenomena, make real-time observations, and draw conclusions from empirical evidence.

The name of the 2nd laboratory exercise in the 5th grade biology book is “Getting to know the structure of the magnifying glass and microscope”, a brief description of which is given in Table 2.

Table 2. Laboratory exercise 2. Getting to know the structure of a magnifying glass and a microscope

Necessary equipment:	Work progress:
1. Magnifying glass	It is the simplest magnifying device, consisting of a convex lens on both sides. Hand magnifier magnifies the object by 2–20 times. The magnifying glass is zoomed in until the living organism under examination is clearly visible, and the structure of the object under examination is studied. For example, you can examine slices of watermelon or tomato and determine whether they consist of round cells using a magnifying glass.
2. Microscope	a) place the microscope leaving 3–4 cm space from the edge of the table. b) point the mirror at the light. When viewed through the eyepiece, the light should fall evenly. c) do not move the microscope during operation. d) place the finished product on the product table and fasten it with clamps. e) gently turn the macro screw and lower the tube. The lens should be 4–5 mm above the drug. f) look into the eyepiece with one eye, but do not close the other eye, do not blink. g) gently lift the tube using the macroscrew. Continue this process until the image is created. h) use a microscrew to sharpen the image. i) the micropreparation is first observed in a small lens, then in a large lens. j) you can remember the image seen in the microscope by drawing. Therefore, draw a picture of what you see in your notebook. k) after using the microscope, wipe it, transfer it to the small objective and place it in the mold

Participating in laboratory activities develops important practical skills that are invaluable in professional activities. Students learn how to collect, analyze, interpret, and troubleshoot data. These skills not only enhance their understanding of scientific principles, but also enrich them with the ability to apply theoretical knowledge in practice.

It is not possible to complete this laboratory. Therefore, in order to give students an idea about the structure of a

magnifying glass and a microscope, the following web page of this laboratory exercise was created (Fig. 9).

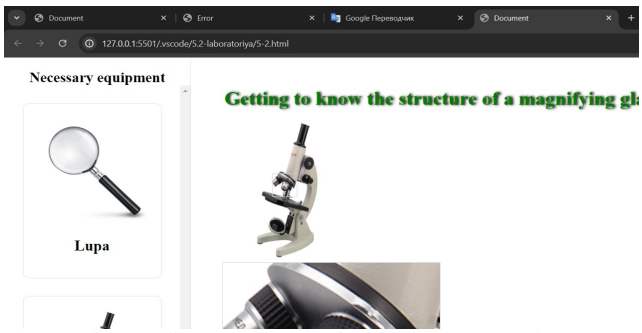

Fig. 9. Online page of 5th grade 2nd laboratory exercise.

Laboratory activities foster curiosity and encourage inquiry-based learning. Through hands-on experiments, students are encouraged to explore scientific principles, test hypotheses, and seek answers to fundamental questions. Such active participation in the learning process arouses a sense of curiosity and a desire to learn knowledge beyond the scope of established experiences. These scientific investigations develop students' minds, where students learn to form hypotheses, conduct experiments, and draw conclusions based on evidence.

The 3rd laboratory activity is called "Study of the structure of the onion peel cell under a microscope", and the procedure for this laboratory is given in the Table 3.

Table 3. Laboratory exercise 3. Microscopic study of the structure of the onion peel cell

Necessary equipment:	Work progress:
1. Item window 2. Cover window 3. Scalpel 4. Tweezers 5. Pipette 6. Microscope 7. Filter paper 8. Iodine solution 9. Onion	a) cut the onion into quarters using a scalpel. b) use a pipette to drop a drop of water on the glass of the cleaned product. c) using tweezers, remove the thin skin of the cut onion. d) place the thin onion skin flat on a drop of water in the test glass and drop a drop of iodine solution on it. e) cover with a cover glass and blot excess water on filter paper. f) observe first in the small objective of the microscope, then in the large objective. g) draw the image seen under the microscope in your notebook and write a conclusion.

The online web page of this laboratory is also broken down and shown below (Figs. 10 and 11).

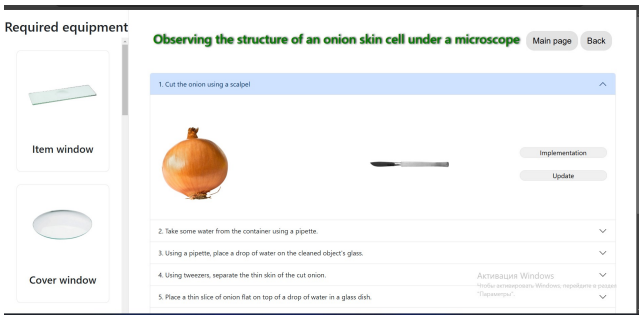

Fig. 10. Online page of 5th grade 3rd laboratory exercise.

Laboratory training has a great pedagogical value in education, especially in scientific subjects. It provides students with practical knowledge, develops practical skills, strengthens theoretical knowledge, encourages curiosity and inquiry, and prepares them for future careers. Combining theory with practice, the lab enhances the overall learning experience and equips students with the tools to excel in their academic and professional careers. Thus, it remains an integral part of effective and comprehensive education in modern times.

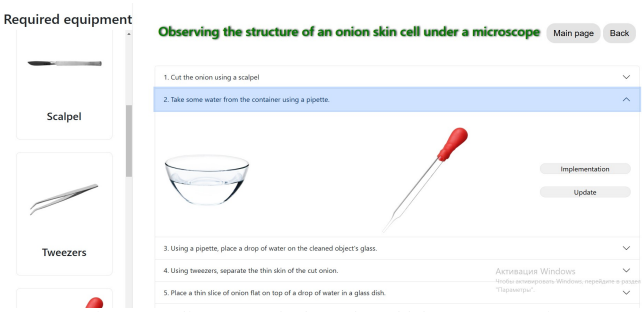

Fig. 11. Online page of 5th grade 3rd laboratory exercise.

Also, the sequence of the work process of the 4th laboratory exercise given in the 5th grade biology textbook is presented in the form of Table 4.

Table 4. Laboratory exercise 4. Getting to know the structure of yeast.

Necessary equipment:	Work progress:
1. Item window 2. Cover window 3. Pipette 4. Microscope 5. Filter paper 6. Sugar 7. Warm water 8. Yeast	a) put the yeast in the sugar water and put it in a warm place. b) use a pipette to remove the yeast from the yeast and drop it into the glass of the product. c) cover with a cover glass and blot excess water on filter paper. d) observe the yeast with a microscope. e) draw a picture of what you see under the microscope in your notebook.

An online web page for Lab 4 was also created and is presented below (Figs. 12 and 13).

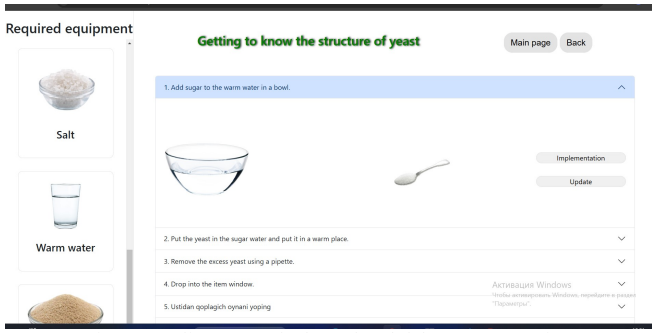

Fig. 12. Online page of 5th grade 4th laboratory exercise.

The above-mentioned virtual laboratories for 5th grade biology were conducted only in the experimental class (5-A). For this, the school's computer room, fully equipped with computers, was used. In the control class (5-V), the laboratories were conducted in the traditional way. Due to time constraints and the lack of some equipment, it was not possible to fully involve students in the laboratory process. Therefore, 3 or 4 students had the opportunity to complete the laboratory, while the rest of the students observed the students who completed the laboratory. After the study was completed, a control test was taken from the students in order to determine the students' mastery indicators. A table is presented below for comparing the results (Tables 5 and 6).

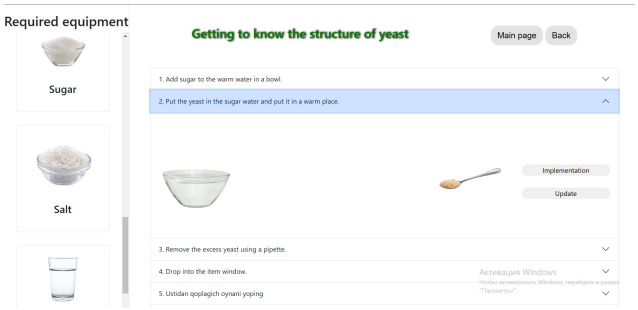

Fig. 13. Online page of 5th grade 4th laboratory exercise.

According to the results of the study, it was clear that the mastery rate in the experimental class increased by 14% compared to the pre-experimental result. In the control class, this result was 3%. This can be understood more clearly through the following Fig. 14.

Table 5. The results of the students of the experimental school before the experiment

Class	Number of students	Acquisition rate (%)
Experience class	34	61%
Control class	35	59%

Note: Results before the study was conducted in the experimental and control classes.

Table 6. Results of students from the experimental school after the experiment

Class	Number of students	Acquisition rate (%)
Experience class	34	75%
Control class	35	62%

Note: Results after the study was conducted in the experimental and control classes.

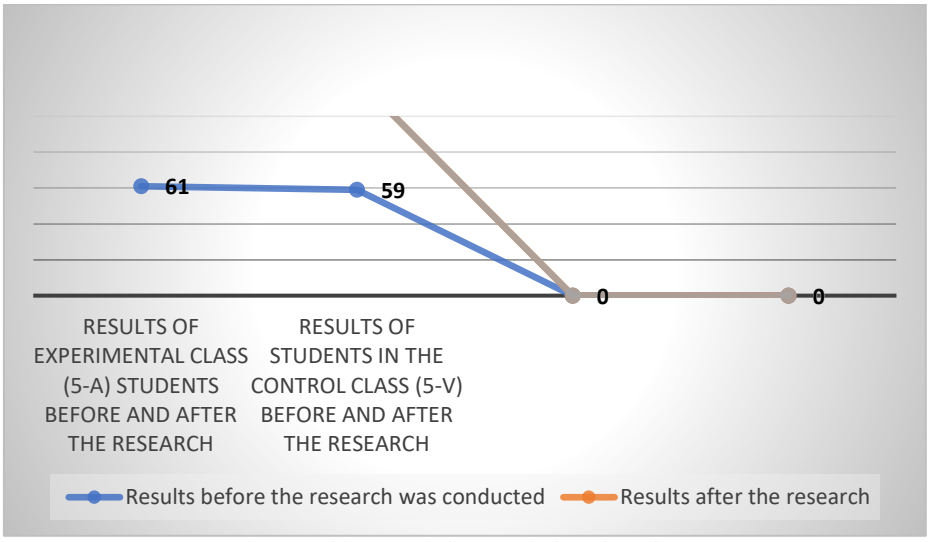

Fig. 14. Achievement indicators of 5th grade students.

V. Discussion

It's no secret that virtual laboratories also have their own disadvantages, and in some cases they can cause some inconvenience. For example, (a) lack of practical experience, i.e., lack of live communication when working with equipment and preparations; (b) the occurrence of technical problems, i.e. software errors, connection or compatibility problems; (c) learning challenges, i.e., teachers need to be competent in using the software and integrating it into the curriculum, while students need to be able to navigate and use virtual platforms effectively, need to develop new skills. According to the research of Ganji *et al.* [17], mental, physical and social injuries; economic problems; insufficient virtual teaching skills; lack of virtual infrastructure; lack of motivation was identified as the main drawback of virtual education. In addition, Son *et al.* [18] have pointed out that there are advantages of virtual laboratories in the teaching system, but there is a lot of work to be done in this area. However, despite these shortcomings, virtual laboratories created through web pages are important today. According to the research conducted by Lestari and Supahar [19], it was determined that most teachers and students need virtual laboratory tools. According to Yuniarti *et al.* [20], the virtual laboratory is a real and effective educational tool for teaching students how to plant and stain bacteria. Alshaikh [5] mentioned that the student's laboratory skills can be improved by using a virtual teaching and learning environment called "virtual laboratory". The introduction of virtual laboratories in secondary schools of Uzbekistan for both students and teachers: (a) student activity: virtual laboratories arouse the interest and curiosity of students, and cultivate passion for biology and science from a young age; (b) improved performance: hands-on learning experiences provided by virtual laboratories improve retention of scientific knowledge and improve academic performance in biology; (c) professional development: pedagogues will have the opportunity to use innovative teaching methods and technological tools, improve their professional skills and the effectiveness of teaching subjects. However, the existence of some problems prevents the sufficient implementation of virtual laboratories. For example, technological problems - some virtual laboratories are created in special programs, but not all computers can load them. In addition, the lack of technological knowledge among teachers and students can create problems in organizing virtual laboratories.

Although these problems are obvious, there are specific solutions for them. For example, it is necessary to create more types of virtual laboratories that are conducted online than those conducted using special programs. The advantage of such laboratories is that they do not require downloading any additional programs to the computer, they can simply be used on the platform via the Internet. Also, additional computer science courses can be organized in schools in order to

improve the technological knowledge of teachers and students.

Looking ahead, the development of virtual laboratories in the educational system of Uzbekistan promises further achievements: (a) integration of advanced technologies: continuous development of Virtual Reality (VR) and Augmented Reality (AR) for students can offer a more immersive and interactive learning experience; (b) extension to other disciplines: the success of virtual laboratories in biology can serve as a model for the integration of similar technologies in the teaching of other scientific disciplines, such as chemistry and physics.

VI. Conclusion

In conclusion, it can be said that the creation of virtual laboratories for students of 5th grade biological sciences in Uzbekistan represents a transformative approach to science education. By using technology to simulate real-world experiments and visualize abstract concepts, virtual labs allow students to explore the wonders of biology in a fun and accessible way. This initiative not only enriches the learning experience, but also helps to develop students into scientifically literate citizens capable of solving future problems in Uzbekistan and beyond. To assess the effectiveness of this platform, we conducted a small-scale experiment with 5th grade students from Secondary School No. 21 in Taylak district, Samarkand region, Uzbekistan, during the first quarter of the academic year, which lasted for 5 weeks. In this experiment, two groups of 5th grade students were selected. One group participated in lessons using a traditional laboratory approach, while the other group engaged in lessons based on a virtual laboratory that we developed. At the conclusion of the study, the group that used the virtual laboratory achieved better results than the group that used the traditional laboratory. While implementing virtual labs in diverse educational settings poses several challenges, many of them can be addressed through strategic planning, training, use of appropriate technologies, and adapting the educational model to ensure inclusion. By recognizing and addressing these challenges, virtual labs can be effectively integrated into diverse educational environments, improving the learning experience and outcomes for students.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

M.T. conceived and designed the study, contributed to background research and contextualization, developed the methodology, and drafted the original manuscript. N.R. collected data and performed statistical analysis, contributed to experimental design and validation experiments. Also contributed to revision and critical editing. N.A. conducted an extensive literature review, provided theoretical framework for the study, and assisted with graphical representation and data visualization. All authors had approved the final version.

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