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The impact of virtual laboratories on the interest and competence of vocational training students

Вплив віртуальних лабораторій на інтерес і компетентність студентів при фаховій підготовці

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Abstract

This article explores the use of virtual laboratories to enhance student interest and professional competence in higher education. It discusses the didactic potential of virtual laboratories, their types, and their advantages in the educational context. The study emphasizes the innovative nature of virtual laboratory work and its contribution to skill development and scientific research. A questionnaire was conducted to assess the impact of virtual laboratories on students' knowledge and skills. The results demonstrate that virtual laboratories effectively increase motivation, foster professional skills, and promote student engagement in scientific work. The research concludes that integrating virtual laboratories into higher education curricula is

Анотація

У цій статті досліджується використання віртуальних лабораторій для підвищення інтересу студентів і професійної компетентності у вищій освіті. Розглядається дидактичний потенціал віртуальних лабораторій, їх види та переваги в освітньому контексті. Дослідження підкреслює інноваційний характер віртуальної лабораторної роботи та її внесок у розвиток навичок і наукові дослідження. Для оцінки впливу віртуальних лабораторій на знання та вміння студентів було проведено анкетування. Результати демонструють, що віртуальні лабораторії ефективно підвищують мотивацію, формують професійні навички та сприяють залученню студентів до наукової

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crucial for preparing future professionals in an increasingly digital world.

Keywords: virtual laboratories, future specialists in biology, chemistry, physics, virtual laboratory works, formation of professional skills, scientific work of students.

роботи. У дослідженні зроблено висновок, що інтеграція віртуальних лабораторій у навчальні програми вищої освіти має вирішальне значення для підготовки майбутніх професіоналів у все більш цифровому світі.

Ключові слова: віртуальні лабораторії, майбутні фахівці з біології, хімії, фізики, віртуальні лабораторні роботи, формування професійних навичок, наукова робота студентів.

Introduction

The rapid digitalization of education has transformed traditional approaches to higher education, demanding the integration of innovative technologies into the learning process. In this context, virtual laboratories emerge as a promising tool to improve the quality of education and foster student interest in professional training. These laboratories offer a safe and accessible environment for experimentation, allowing students to develop practical skills and gain a deeper understanding of theoretical concepts. Despite their potential, the effective implementation of virtual laboratories in higher education presents challenges that require comprehensive research.

Thanks to the software environment, direct participation in a certain experiment involves the use of virtual laboratories, which contribute to the assimilation of students' knowledge at a more conscious and deep level, allow modeling of processes, facilitate their flow, which is impossible in normal laboratory conditions, ensure the creation of safe conditions for working with dangerous devices or substances, allow you to save resources and time and ensure productive work in a remote format (Budnyk et al., 2022). In the laboratory environment, the virtualization of the educational process of the higher school also contributes to the humanization of research, as it makes it possible to replace living experimental animals with their computer models during the experiment, which fully corresponds to modern approaches to coexistence with them and the paradigms of humane treatment of animals.

The use of virtual laboratories deserves attention as an important element of worldview changes due to the spread of digitalization processes that have taken place in modern society (Hnatiuk et al., 2023).

This article aims to explore the role of virtual laboratories in professional training and their impact on student interest and competence. To achieve this goal, we will analyze the didactic possibilities of virtual laboratories, examine their different types and advantages, and evaluate their effectiveness in training professionals. Furthermore, we will present the results of a questionnaire designed to measure the impact of virtual laboratories on student learning. Through this research, we hope to contribute to the understanding of how virtual laboratories can improve the quality of higher education and prepare students for the challenges of today's workforce.

In the following sections, we will explore in detail the relevant literature on virtual laboratories, the methodology employed in this study, the results obtained and their discussion, and finally, the conclusions and future lines of research.

Literature Review

Researchers have repeatedly addressed the issue of organizing the educational process using virtual laboratories.

Scientists have proven that the use of virtual laboratories makes it possible to significantly improve the quality of the educational process. N. Ilkevych (2021) turned to STAR (Software Tools for Academics and Researchers) – a program of the Massachusetts Institute of Technology, WolframDemonstrationsProject, TheChemCollective, and VirtualLabs. Proved that virtual laboratories have a significant set of materials and relevant information for preparing presentations, reports, remote and independent work, as well as for understanding complex biochemical phenomena and processes based on knowledge measurements. This

problem is analyzed by O. Panikhidina (2015) and proves that conducting practical classes based on a virtual laboratory contributes to the activation of independent and mental activity of students of higher education and shows that the issue of constant use of virtual laboratories is most acute in higher education, where it is necessary to more widely apply classes using educational electronic materials. Completion of practical tasks, after which the answer is checked by computer and in the process of which the student acquires practical skills, is an example of the promising use of information and educational virtual laboratories in a complex with other means of learning. The relevance of implementing a virtual laboratory for modeling processes in cyber security and the information industry is substantiated. It has been practically proven that virtual laboratories "make it possible to create different interactive models based on the same module". O. Lemeshko, O. Yeremenko, M. Yevdokymenko, & Ye. Kuzminykh (2020) developed this topic of distance learning conditions for students and noted that the problem of organizing laboratory and practical work is gaining special importance in the field of cyber security. The characteristics of the existing cyber security virtual laboratories are provided, and the content of the Cybersecurity Virtual Laboratory, CVLab – a cyber security virtual laboratory that provides high-quality continuous training in a distance format for future specialists in this field, is disclosed.

A group of scientists, in particular, V. Hnatiuk, I. Upatova, O. Dekhtiariova, & N. Kuruts (2023), investigated the possibilities of using virtual laboratories and the possibilities of modeling experimental studies during the training of specialists in biological disciplines, showed the effectiveness of virtual laboratories and simulation of experimental studies in the educational process, which increases the possibilities of studying in the field of biological sciences and training of higher education seekers. Scientists have characterized such concepts as "online laboratories", "biology online", "virtual laboratory", "virtual laboratory practicum", and "online experiment". The following programs were analyzed: Labster, LabInApp Virtual Labs, VirtualLab, BioDigital Human, etc., which are actively used for training specialists in European institutions of higher education. The possibilities of virtual laboratories in the study of various biological concepts through interactive simulations are shown, and their practical advantages for education are noted, taking into account the progressive impact of digitalization on society. Important results are also due to A. Herráez (2022) provided and defined valuable guidelines for the selection, implementation, and design of methods for using virtual laboratories and other simulations of experimental environments.

A. Mahaffey (2018) is considering implementing a virtual laboratory for nurses and exercise specialists – medical students. Ways of using face-to-face teaching and student discussions, which play a crucial role for students in the learning process, are revealed. Thus, the teaching methodology proposed by the scientist combines virtual laboratories, e-learning, didactic instruction, and tactile learning during the development of educational program courses to engage students of higher educational institutions, increasing the content of educational process materials and simultaneously preparing students for licensing exams and CAT tests. We note the works of B. Shambare, & C. Simuja (2022), who systematically reviewed scientific literature and revealed innovative ways of using virtual laboratories for educational purposes while teaching and conducting scientific-practical experiments, they focused on determining the theoretical aspects of using digital tools.

It is worth emphasizing the current thoughts of the author team under the leadership of T. Delgado et al. (2021), who showed how creative online laboratories allow students to gain valuable scientific experience, created a course of a virtual laboratory of cell biology, where the methods of cellular and molecular biology, which are worth considering in detail apply to the study of cells.

R. Wolski, & P. Jagodziński (2019) proved that the development of interfaces was facilitated by the rapid development of information and communication technologies, which are available to a wide range of users due to a low price and enable the recognition of user movements and gestures. The content of natural user interfaces that are commonly used in electronic devices and game consoles (tablets, smartphones) is revealed. The researchers described the application of Microsoft's Kinect sensor to detect user gestures and movements and demonstrated its use in teaching chemistry by developing a virtual chemical laboratory based on the hand motion system. The movements and gestures of the user of the virtual chemistry laboratory were analyzed to determine how they increase the effectiveness of chemistry education: applying their experience in situations, understanding information, remembering information, and solving problems. The research of scientists S. Maulidah, & E. Prima (2018) is aimed at the analysis of a virtual laboratory for the study of sounds and waves to use educational technologies in physics. In the study, the authors used a descriptive method with methodological triangulation as a research design. The influence of the virtual

laboratory and the positive results both in the environment of scientific laboratories and in the cognitive aspect are shown.

The use and necessity of introducing virtual laboratories into the educational process of a higher school was considered by O. Semenikhina, & V. Shamonia (2011). In particular, the attention is focused on conducting laboratory physical practicums using the EVB environment, the negative and positive sides of the laboratory physical practicum are highlighted in the virtual space.

So, the analysis of scientific research shows that an effective means of creating virtual laboratories is the use of information and computer technologies in the learning process in educational institutions in general, as well as in institutions of higher education.

Scientists have proven that the use of virtual laboratories makes it possible to significantly improve the quality of the educational process, the relevance of the implementation of a virtual laboratory for modeling processes in cyber security and the information industry is substantiated, given the characteristics of such concepts as "online laboratories", "biology online", "virtual laboratory", "virtual laboratory practicum", "online experiment", analyzed the programs: Labster, LabInApp Virtual Labs, VirtualLab, BioDigital Human, etc., which are actively used for the training of specialists in European institutions of higher education, the possibilities of virtual laboratories in studying various biological concepts through interactive simulations, combined virtual laboratories, e-learning, didactic instruction, tactile learning during the development of educational program courses, described the application of the Kinect sensor from Microsoft for the purpose of detecting gestures and movements of the user and showed its use in teaching chemistry by developing a chemical virtual laboratory based on system of hand movements. The research of scientists is directed to the analysis of a virtual laboratory for the study of sounds and waves to use educational technologies in physics, and attention is focused on conducting laboratory physics workshops using the EVB environment in a virtual space.

The study of the processes of virtualization of education, the problems of creating a virtually oriented educational environment, and the development trends of the initial experiment system, which develops by the requirements of the synergistic paradigm, allowed us to identify several contradictions, namely:

- Between the trend of virtualization of society and the education system, which at this stage is noticeably developing and leads a person away from objective reality, and the need for every student to use educational achievements in the real, objectively existing world;
- Between society's demands for education, which is oriented towards the transition to an innovative model and prepares a person for life in the knowledge society, and the traditional approach to the learning process, which does not fully ensure the full development of the personality, suitable for life and professional activity in the modern information society;
- Between the rapid development of information and communication technologies with their widespread introduction in education, in the system of the educational experiment as a fundamental science that studies real objects, phenomena, laws, and regularities and examples of their practical use;
- Between the need for the simultaneous use of real experiments and virtual educational content in the education system and the lack of a scientifically based methodology for their interrelated and mutually conditioned implementation in the learning process.

The outlined problems require the substantiation of theoretical foundations that will ensure the integration of its virtual and real components by the requirements of the modern synergistic paradigm of education, which determined the relevance of the topic of the article.

Methodology

To achieve the goal, a set of complementary research methods was used:

- ***Theoretical*** – study of pedagogical experience, analysis of methodical, philosophical, pedagogical, psychological literature, methodical materials, and program documents of a higher school, on the problem of using virtual laboratories to increase the interest of students during their professional training in institutions of higher education; methods of systematic, retrospective analysis to compare different views on the problem studied by scientists from different countries; the comparative research method made it possible to trace the positive dynamics of sufficient and high levels of formation of

professional competences of future specialists, regarding the use of virtual laboratories during the application of experimental teaching methods in higher education; system analysis and modeling during the development of the advantages of using virtual laboratories to increase the interest of students in their professional training in institutions of higher education;

- ***Empirical*** – prognostic methods (expert assessments), diagnostic methods (questionnaires, interviews), observational methods (observation, self-assessment, self-observation) to identify the level of readiness of future specialists to use virtual laboratories, experimental (conducting a pedagogical experiment) to determine and check the level of readiness future specialists to use virtual laboratories;
- ***Methods of mathematical statistics*** – to analyze the obtained results based on the establishment of quantitative indicators and confirmation of their probability of assessment of the phenomenon under study.

To check and assess the quality of knowledge of students who have completed the study of specialized disciplines in biology, chemistry, and physics, a questionnaire was conducted.

For research and experimental work, quantitatively appropriate experimental groups were selected – control (32 respondents) and experimental groups (33 respondents). During the formative experiment, the research hypothesis was tested that the introduction of virtual laboratories to conduct research and quality education, the use of programs, projects, and electronic resources are necessary for the design of digital narratives in the educational process of future specialists, will contribute to increasing the levels of professional competence formation among students.

During the experiment, it was necessary to solve the following tasks:

- Experimentally confirm the expediency of implementing virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources of future specialists;
- Experimentally check the effectiveness of the implementation of virtual laboratories in higher educational institutions;
- To identify the growth dynamics of indicators of the formation of professional competence among future specialists regarding the implementation of virtual laboratories, the use of programs, projects, and electronic resources.

The comparative research method made it possible to trace the positive dynamics of sufficient and high levels of formation of professional competencies of future specialists regarding the use of virtual laboratories during the application of experimental teaching methods in higher education. Using Pearson's $\chi 2$ test, the results of the experiment were processed, and the effectiveness of the developed method was evaluated.

Having analyzed the effectiveness of the formative experiment, we can state that the future specialists who participated in the research and were part of the experimental groups mastered the methodology of using virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources.

As a result of the experiment, it was proven that the use of virtual laboratories during the study of professional disciplines ensures mutual connection, increases motivation to study, ensures the formation of professional skills of a future competitive specialist, the integrity of individual components of the educational process, promotes the involvement of students in scientific work.

So, the course of the experimental formative research and comparative analysis of the levels of development of the professional competence of future specialists regarding the design and implementation of virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources according to the criterion characteristics of the control and experimental groups before and after the experiment confirmed the effectiveness and the need for a methodology for designing and implementing virtual laboratories for conducting research and quality education, using programs, projects, and electronic resources.

We used the following virtual laboratories: Virtu. Lab; All-fizika.com; Physics Simulations; Mozaik.

Research relies heavily on the accuracy and reliability of the data. In the framework of research work, the quality of data collection and analysis not only adds weight to the research but also contributes to the formation of sound conclusions, which is the key to academic success.

The following digital data collection tools were useful in the study:

- Google Forms – a simple tool for creating surveys that allows you to collect data from respondents, create different types of questions, and collect answers in spreadsheets.
- SurveyMonkey – a modern survey tool that offers a wide range of customization options and analytical tools for analyzing the collected data.
- JSTOR, Google Scholar, and other academic search engines provide access to scholarly articles, books, and other academic resources that may be useful for literature review and theoretical data collection.
- Zotero or Mendeley – bibliography management programs that help organize research materials, store references, and format bibliographies and citations according to different citation styles.
- Microsoft Excel or Google Sheets – spreadsheets are useful for organizing and analyzing collected data when working with quantitative data.
- SPSS, R, or Python for more advanced data analysis, statistical analysis, and processing of volumes of data.

The experiment was conducted at Central Ukrainian National Technical University, Oleksandr Dovzhenko Hlukhiv National Pedagogical University, and Sumy State University. The conduct of the experiment is permitted by the scientific councils of the universities to not violate ethical considerations in institutions of higher education.

Results and Discussion

1. Meaningful filling of the main research concepts.

The transformation of several traditional approaches to higher education was influenced by the active digitalization of education in the world. In particular, in addition to the introduction of various interactive technologies, the use of Internet space, and the involvement of myriad technical innovations, researchers began to pay great attention to the peculiarities of the forms of demonstration and implementation of various scientific biological phenomena and objects of application of specialized software tools. In the educational space, accordingly, the concepts: of "virtual laboratory", "virtual laboratory practicum", "online-experiment", "biology-online", and "online laboratories" began to be actively used (Hnatiuk et al., 2023).

Modern scientists interpret the concept of "virtual laboratory" in different ways:

- A kind of virtual educational environment that helps students of higher education acquire new skills and knowledge and helps to simulate the behavior of real-world objects in the digital computer space (Pererva, 2019).
- A kind of computer program that facilitates the implementation of modeling on computer processes (Shuliak et al., 2022).
- A computer platform or program that provides an opportunity for higher education students, interested individuals, and scientists to experiment, provides an opportunity to perform experiments in the biological sciences and for virtual simulation, provides an opportunity to observe and study phenomena that occur in real laboratories (Hnatiuk et al., 2023);
- A software virtual environment in which the possibility of researching the behavior of object models and their derivative sets, specified about real objects with a certain level of detail, is organized within the limits of a certain field of knowledge (Kuchai et al., 2022);
- A virtual learning environment that helps in mastering new knowledge and skills allows you to simulate the behavior of real-world objects in a computer environment and serves as a research apparatus for various natural phenomena with the possibility of building their mathematical models (Semenikhina & Shamonia, 2011).

2. The main didactic possibilities of virtual laboratories are to increase the interest of students in professional training.

By the didactic capabilities of virtual laboratories, we understand the possible forms of interaction of subjects with remote resources or remote subjects with each other, which are provided in the process of educational activity by the technology of computer communication of subjects during the implementation of a certain pedagogical task.

We attribute the following positions to the didactic capabilities of virtual laboratories:

- The use of a virtual environment contributes to the development of skills in fields where the real implementation of research can have a dangerous effect on the researcher, requires the presence of complex equipment, time consumption, significant material costs, and significant monetary costs;
- The use of innovative virtual learning technologies in higher education provides an opportunity to receive quality education in the process of production activity – wide access to educational resources at the place of residence;
- The possibility of using audio-visual materials, animation, and hypertext led to new fundamental approaches to the construction of the content of laboratory work, its structure, and methodology;
- To promote the improvement of the level of skills, knowledge, and abilities thanks to the individualization of the educational process, the student can work at a pace that satisfies him and stop at the moments that are most important for him in professional growth;
- Thanks to computer modeling, students can simulate the consequences of proposed or adopted decisions, create models of objects and phenomena related to future professional activity;
- The use of virtual laboratories frees students of higher education from routine operations when performing laboratory work;
- The student's creative thinking develops in the process of experimentation, and the ability to make prompt and independent decisions develops;
- Increasing the student's interest in the subject is facilitated by the independent solution of tasks, and the use of virtual laboratory tasks contributes to the formation of more conscious knowledge, the practice of skills and abilities;

The use of virtual laboratory works in the training of specialists allows us to use various technologies, which we attribute to the didactic capabilities of virtual laboratories: virtual reality (VR), computer simulation, and augmented reality (AR), to create real biological experiments and their simulations. Users interact with these technologies with virtual objects, organisms, samples, and systems and, with interest, study their behavior and properties (Plakhotnik et al., 2023).

Active learning in higher education is facilitated by virtual laboratories. Students can conduct research independently, actively solve problems, and experiment, which supports and forms their active role in the educational process and their own career growth, help students develop skills, and gain practical experience needed for work in laboratories during professional activities (Voron, 2018). Students of higher education can easily analyze data, perform experiments with interest, successfully solve problems that arise during tasks, and make observations. Such a scientific approach develops in future specialists the skills necessary for performing laboratory work: systematicity, accuracy, and analytical skills. It is valuable that virtual laboratories can be accessed and operated at any time using a computer or the Internet from anywhere (Delgado et al., 2021). This empowers students from all over the world to learn, regardless of access to physical laboratories and where they live.

When working with students, each virtual laboratory can be used by the teacher for a visual demonstration and can be used by the students to familiarize themselves with the examples during independent work, which are given in the course materials. The possibility for their pre-planned, systematic use is provided by the integration of virtual laboratories into the combined learning management system. The plan of the thematic study of each section provides for both extracurricular and classroom work and provides for the activities of teachers and students, which is built using the elements of problem-based learning and the use of a combined learning management system.

Types of virtual laboratories and their advantages in the educational space of a higher school. Today, there are a large number of virtual laboratories. For high-quality conducting of experiments, there are the following types of virtual laboratories:

- Virtual laboratories that allow conducting experiments using augmented or virtual reality;
- Virtual laboratories working based on digital measuring technologies;
- Virtual laboratories that facilitate laboratory work using traditional equipment (Hnatiuk et al., 2023).

According to the type of robotics training, the following types of virtual laboratories are distinguished:

- Software that can be used to simulate laboratory experiments and tasks;
- Classroom laboratory installation with remote access – remote laboratories.

According to the level of functioning of virtual laboratories and user management:

- Software for visualization of experiments with the setting of certain parameters of its passage, which allows you to see the changes taking place, depending on the parameters that are set, and to change the parameters of the course of the experiments (for example, VirtuLab, the web address of the site www.virtulab.net, developer of virtual laboratory "VirtuLab").
- Software consisting of modules, with the help of which simulation of a separate class of experiments takes place with the establishment of the choice of tools for their implementation and various parameters of their course (for example, Interactive Simulations, the web address of the site http://phet.colorado.edu., developer University of Colorado);
- Software that includes complex systems, the basis of which is a powerful mathematical apparatus for simulating the work of a chemical laboratory. Programs of this group can be divided into two subgroups: programs for modeling a class of phenomena and programs for modeling phenomena of a different nature. The exclusivity of the programs of this group is that the user has the opportunity to add simulation experiments by setting the parameters of their passage.

The use of virtual laboratories in the educational process of a higher school has important advantages that contribute to the enrichment of the educational experience of both students of higher education and teachers.

We list the most important of them:

- Enabling research and experiments without real health risks (Shkuropat & Hasiuk, 2018).;
- The opportunity to repeat this or that experiment several times in an educational institution and at home, realizing independent learning in this way;
- Allows conducting experiments without the need for laboratory premises and physical materials, which helps to save money and time;
- Provide an opportunity to conduct research and experiment without fear of damaging expensive devices or making a mistake;
- Provide the ability to manipulate objects and parameters and interactivity, which contributes to the formation of better motivation to study among students of higher education (Hnatiuk et al., 2023);
- There is no need to purchase expensive equipment for various types of laboratory work on robotics, computer equipment and software, consumables;
- Safety when working with servo drives, when working with high voltage;
- Provide an opportunity to simulate many processes that take place in real robotics classes;
- Versatile and detailed visualization on a personal computer;
- Provide the possibility of using the virtual laboratory complex in distance learning in the absence of the possibility of working with the classroom equipment;
- With the help of simulation of virtual reality processes, computer control allows you to conduct many studies of the necessary determination of desired results, various input parameters;
- Provide an opportunity to organize competitive activities between students of the higher school;
- Provide an opportunity to acquire knowledge with elements of self-control and self-learning when using an effective virtual learning tool while not replacing the teacher in the educational process;
- Combine the advantages of a good textbook with the capabilities of a computer, which is provided by a combination of audio and video information, text and graphic information, clarity, and the ability to store large amounts of information;
- Enable independent assembly of schemes, monitoring of processes, and calculation of their parameters;
- Ensure the implementation of students' practical skills in the conditions of a virtual laboratory, confirmation of the validity of the studied laws, and visual illustration;
- Ensure complete safety of the practical skills performed;

- Performing virtual practical skills during the class eliminates the time barrier between practical and theoretical classes, which contributes to the quality of learning, increasing efficiency, and activating the cognitive independent activity of students;
- Provide an opportunity for individual performance of skills to develop student's technical acumen, independence, and responsibility;
- Provide ample opportunities when conducting classes on instrumental diagnostics and laboratory diagnostics, which allows you to use them in certain, methodically justified situations as a supplement to real conditions;
- Ensure that in problematic and non-standard situations, students acquire subjective experience during practical classes, where the student performs practical skills on the created virtual installation, which helps during the manipulation and prepares for the examination, after which a computer check of the answer is carried out;
- The use of various free resources, a convenient graphical interface, conducting laboratory and practical work with a wide range of initial data.

The value of virtual laboratories lies in meaningful content. High reliability of virtual experiments, color palette, excellent navigation, and fast loading are auxiliary elements of mastering and acquiring knowledge. Virtual laboratories, with the help of special tools, allow you to create high-quality conditions for conducting instrumental and laboratory research, establish connections between objects, place them in the right way next to each other, allow you to create different interactive models based on the same module (Kozmenko et al., 2022).

The main goal of creating virtual laboratories is to ensure the possibility of high-quality training of a specialist to understand the essence and the complete perception of the researched object and to strive for a comprehensive visualization of the researched processes. Virtual laboratories allow you to simulate the processes and objects of the surrounding world, organize access to real laboratory equipment, and contribute to increasing interactivity, clarity, and the formation of creative and cognitive activity of students of higher education.

3. The content and innovativeness of virtual laboratory work in the environment of a higher school.

Digital technologies are transforming the educational industry and penetrating all areas of human activity. Carrying out laboratory work – contributes to increasing the interest of students in professional training and is an important part of studying professional disciplines, helps students of higher education acquire practical skills, thanks to the illustration of theoretical material, and contributes to better provision of professional concepts. Virtual laboratory work in the environment of a higher school increases the level of curiosity and interest among students, forms a positive attitude toward science, and affects motivation (Yurchenko & Khvorostina, 2016).

Virtual laboratory work is an information system that interactively simulates a real technical object using computer visualization tools and satisfies its essential properties for studying the material. When conducting virtual experiments, students interact with interactive models, and not just with technological processes and equipment, which creates the effect of the student's presence near the installation or device during the work.

The introduction of virtual laboratory work into the educational process takes place in two directions:

- Virtual laboratory work is created based on a simulation program that can visualize processes that are invisible in real installations or devices or are too fast, which fully reproduces the sequence, process, and functioning;
- Virtual laboratory work is carried out on the most modern, real devices and installations that may not be available in the laboratories of higher educational institutions. Therefore, in this case, the task of the computer program is to create the effect of the presence of the student near a real installation or device during virtual laboratory work.

New platforms have appeared that provide the opportunity to study freely at a convenient time. This is important because robotics classes open up new opportunities for students with the help of a virtual laboratory, the use of simulators, and other computer-based simulators. At the same time, the most important addition will be the use of real designers if the material and technical base of the educational institution allows it.

4. The content of the possibilities of using virtual laboratories in the educational space.

Design and programming are today the main components of educational robotics. Today, in the educational space, there are many systems of automated calculation and design that are used in robotics. The choice of tool, the age of the students, the competence of the teacher, and the goals of the classes often depend on the robot management platform. Several tools for LEGO robotic sets are actively used during the class, which is taken into account when preparing project documentation: Studio 2.0, Ldraw, and LEGO Digital Designer.

The easiest for quick and easy learning is LEGO Digital Designer, a program that easily allows you to create robots that simulate the real process of making a model. The future specialist will be able to fully master the program and understand how it works in a few lectures.

The program restores the sequence of creating a robotic device after creating a model, that is, instructions for creating a robotic physical device.

LEGO Digital Designer allows you to teach students of the educational space to assemble models from memory, allowing you to prepare for classes at home without owning a robot, significantly reducing the wear and tear of real parts.

There are many programs for "animating" simulators (robots). With such a modern approach to education, it will be effective to use virtual laboratories for working with robotic devices, namely simulators, where you can perform complex actions and simple actions. Each simulator has graphic and physical parts, and the potential depends on the complexity of the robot models implemented in the simulator.

Let's consider the graphical interface of the program, the main task of which is visualization of the environment and objects. The physical part allows you to create a virtual space. Virtual static and dynamic space can be added to virtual space, and laws of interaction of space and bodies can be set. Interaction with the body is constantly calculated by the program. By calculating the interaction of the environment and bodies, the program extends the behavior of the virtual model to the physical reality.

The most famous simulators in this category are the Virtual Robotics Toolkit simulators. This is a space where you can place a model of a robotic device from developer Lego Digital Design for a virtual simulation and how to work with the real one. Virtual machine creation is completely true, and the virtual machine creation program can be transferred without changes to a real computer. The simulator consists of game rooms equipped with models of interaction with the environment, which allows you to use all areas of robotics.

The advantages of the program include:

– There are educational videos;
– Importing models from LEGO Digital Designer;
– There are basic simulations (polygons);
– EV3G programming.
– Simulators Robot Virtual Worlds – LEGO 4.

The program allows you to use the same programs as for physical robots, is great for homework, and creates a fantastic 3D world of LEGO robots. The developers of this environment are currently providing detailed information on the methods of its implementation in the learning process. An introductory program is offered to learn real programming. A useful virtual environment is available for LEGO graphics systems for developing RobotC text environments through the NXT emulator.

The advantages of the program are:

– Suitable for robotic sets VEX, NXT, Tetrix & Lego;
– There is an opportunity for landfills to import items;
– There are training grounds for competitions and basic training grounds;
– The creation of its own landfills is foreseen.

It should be noted separately the robot programming environment with the interactive mode of simulation TRICK Studio, where you can create a program for the widely used Lego Mindstorms EV3 controller, and not just a program for the TRICK controller.

Developers have developed a simple, convenient, good, free robotics simulator – Open Roberta Lab to promote robotics. Microbit, WeDo 2.0, Lego Mindstorm, and other platforms can be programmed in the program. The platforms have a simulation environment that allows a user without special technical skills to start programming. It is possible to upload your own 2D polygons.

Let's note the virtual laboratory for Vex robots.

The VEXcode VR platform is convenient and allows you to easily master robots and information technologies. Users of the educational space from anywhere can code virtual objects or programs using the block algorithm. Virtual reality VEXcode is based on one of the software interfaces of the robotic platform VEX 123GO, IQ, V. There are different playing fields in this simulator, which allow you to practice different algorithms.

To accelerate education, we can use ready-made program templates or various videos. In the robotic device, we need to have a handle that can change color. This is necessary to teach how to make graphical elements of robotic virtual devices. The teacher will have the opportunity to give various tasks to practice simple movements and to offer creative tasks to increase interest and increase the level of knowledge of future specialists.

Virtual laboratory from Vex. VEX VR is perfect for remote learning and has several advantages:

- VEX VR virtual reality code enables script block-based programs that teach students to code using a virtual robot coding environment. This allows students to have comfortable transitions after mastering the basics of programming;
- Checking the correctness of the program is carried out in real-time on the physical simulation of the robotic device;
- It is possible to send the program created by students in the project file format to the teacher to check the task without a designer;
- A virtual robotic device does not require space for storage or regular maintenance, allows replacing expensive equipment in an educational institution;
- Virtual space allows students to focus completely on programming tasks.

VEX VR can be run as a web resource on most other devices in all popular browsers. The VEX VR robotic device is equipped with many physical functions, controls, and sensors.

VEX VR has only one pre-configured robot. This eliminates the need to configure a predetermined project template or robots (Luchko et al., 2024).

A large number of virtual laboratories are available to Internet users. The most suitable among virtual laboratories for use in teaching physics, biology, biochemistry, medicine, etc., is based on the following requirements: intuitive interface, no registration, and free use on any computer.

5. Programs, projects, and resources are necessary for virtual laboratories to conduct research and quality education.

For virtual laboratories, there are programs and projects, resources for conducting research, and quality education. Let's consider the most important of them.

Software Tools for Academics and Researchers (STAR) is a program for the development of virtual laboratories of the Massachusetts Institute of Technology for conducting research and teaching. Program website: http://star.mit.edu. Star Biochem's 3D protein molecule visualizer is the most convenient to use – it allows you to visualize any molecules contained in the protein database and also has detailed and flexible settings. Computer animation and its capabilities allow students of higher education to form a visual image of complex natural compounds and their spatial structure. Computer modeling of the structure of such molecules allows you to see the molecule from different angles; it is already one of the tools for their study,

it is possible to highlight individual regions in the structure of the molecule by color or to present them on a larger scale for a more detailed description. With the participation of molecules that cannot be seen or complexes, it helps in understanding biochemical processes. The program also allows you to present the structures of complex proteins and elements of various structures (secondary, tertiary, quaternary).

Wolfram Demonstrations Project http://demonstrations.wolfram.com/ is an important project for virtual laboratories. It is dedicated to a visual demonstration of the concepts of modern technology and science.

The project includes about a hundred visualizations of processes in the field of biochemistry and laboratory work. The materials presented in this project enable students to effectively prepare for laboratory work and are a supplement to the lecture course:

- The work Some Peptide Properties provides an opportunity to investigate the dependence of the properties of physicochemical peptides on their primary structure, which is very difficult to do within the limits of traditional laboratory practices. Students can feel like real researchers and have the opportunity to independently set any amino acid sequence while performing this work;
- Works Double Helix and DNA Base Pairing illustrate the structures of DNA and their principles, Vitamin Explorer – contains the necessary information about vitamins, including molar masses, physical and chemical characteristics, alternative names, three-dimensional and two-dimensional structural schemes;
- The work Synergism and Antagonism helps to visualize the phenomena of antagonism and synergism that appear in the process of simultaneous use of drugs or other biologically active compounds, two antimicrobial agents, etc.;
- The work Glycolysis presents a simplified description of the sequence of reactions, glycolysis, where glucose is converted to pyruvate. Data from these works can be used in the professional training of specialists during the preparation of presentations by students, in multimedia lectures, etc.;
- A large number of works (Light-Dependent Reactions in Photosynthesis, Michaelis-Menten Enzyme Kinetics and the Steady-State Approximation, Saturation Binding of Ligands to Proteins Oxygen, Transport by Hemoglobin and Myoglobin and others) in a simplified form for understanding phenomena and biochemical processes have to illustrate rather complex processes.

The Chem Collective is a virtual laboratory: http://www.chemcollective.org/vlab/vlab.php. The peculiarity of this laboratory is that the freedom of action of the user is provided for, that there are no tasks. Thus, the student independently investigates the reaction between polynucleotide chains of DNA in the work Predicting DNA Concentration. Using the available dishes and reagents, students need to prepare a DNA solution of a certain concentration and explain the processes that occur in this process.

Virtual labs resource https://www.vlab.co.in is important for many technical and scientific disciplines and provides remote access to laboratories. Graduate students have the opportunity to use various tools during their studies, including additional animated demonstrations, web resources, video lectures, and self-assessment tools. Interesting laboratory works in bioorganic chemistry and biochemistry: Detection of Adulteration in Milk, Isoelectric Precipitation of Proteins: Casein from Milk, Estimation of Blood Glucose by Glucose Oxidase Method, Estimation of Iodine Value of Fats and Oils, Estimation of Saponification Value of Fats/Oils, Qualitative Analysis of Carbohydrates, Qualitative Analysis of Amino Acid, Agarose Gel Electrophoresis (AGE), Quantitative Estimation of Amino Acids by Ninhydrin (Ilkevych, 2021).

6. An experiment to discuss the limitations of the study

To check and assess the quality of knowledge of students who have completed the study of specialized disciplines in biology, chemistry, and physics, a questionnaire was conducted.

For research and experimental work, quantitatively appropriate experimental groups were selected – control (32 respondents) and experimental groups (33 respondents). During the formative experiment, the research hypothesis was tested that the introduction of virtual laboratories to conduct research and quality education, the use of programs, projects, and electronic resources are necessary for the design of digital narratives in the educational process of future specialists, will contribute to increasing the levels of professional competence formation among students.

During the experiment, it was necessary to solve the following tasks:

- Experimentally confirm the expediency of implementing virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources of future specialists;
- Experimentally check the effectiveness of the implementation of virtual laboratories in higher educational institutions;
- To identify the growth dynamics of indicators of the formation of professional competence among future specialists regarding the implementation of virtual laboratories, the use of programs, projects, and electronic resources.

To find out the level of professional competence of future specialists regarding the implementation of virtual laboratories, the use of programs, projects, and electronic resources, the most significant professional competencies were determined at the beginning of the study by the method of expert evaluation: the ability to apply the digital approach to the implementation of virtual laboratories in practical activities; innovativeness; initiative; adaptability; reporting; solving problems; self-motivation, orientation to the final result; continuous learning and self-development; decision-making; teamwork; manifestation of professional honesty and ethics; cooperation; communication skills; support of interpersonal relations; planning and prioritization.

The analysis of the survey results at the ascertainment stage indicates low results. Few respondents from the total number of respondents have a high or sufficient level of formation of professional competencies regarding the use of virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources. This suggests that methodological recommendations for the training of future specialists and educational programs in higher education are not sufficiently focused on the formation of professional competencies of future specialists regarding the use of virtual laboratories to conduct research and quality education, use programs, projects, electronic resources, and therefore this aspect of the educational process needs correction and improvement. The conducted experiment on the implementation of virtual laboratories in the educational process to conduct research and quality education, use programs, projects, electronic resources in education, and further professional activities provided that in the experimental groups of the higher school, students were taught according to the developed methodical system with the constant implementation of virtual laboratories to conduct research and quality education, use programs, projects, electronic resources, while in the control groups the educational process took place in compliance with the typical conditions of traditional education.

According to the author's methodology, the integration of virtual laboratories, programs, projects, and electronic resources into the educational process was carried out, as well as the measurement of the state of formation of professional competencies of future specialists regarding the use of virtual laboratories; generalization was carried out, statistical results were drawn up. As a result, positive dynamics of the formation of professional competencies of future specialists were recorded. The comparative research method made it possible to trace the positive dynamics of sufficient and high levels of formation of professional competencies of future specialists regarding the use of virtual laboratories during the application of experimental teaching methods in higher education. Using Pearson's $\chi 2$ test, the results of the experiment were processed, and the effectiveness of the developed method was evaluated.

The formative experiment and its course combined a cycle of organizational and advisory events (consultations, briefings, seminars, round tables, etc.).

The practical implementation of the implementation of virtual laboratories to conduct research and quality education and use programs, projects, and electronic resources during the formative experiment took place within the framework of the study of professional disciplines.

The implementation of the implementation of virtual laboratories in the educational process of future specialists to conduct research and quality training, use programs, projects, and electronics, as shown by experimental research, where information and communication and professional technologies are combined, creates conditions for the practical implementation of the principles of creative, humanistic, interactive, democratic, person-oriented education.

The art of using virtual laboratories, programs, projects, and electronic resources deepens the assimilation of knowledge, contributes to the improvement of creative skills, the development of scientific and research skills in students, the clear presentation of thoughts in various forms, since the multichannel information influence, the emotional component of the introduction of virtual laboratories into the educational process

of a higher school improves professional competence and allows you to learn the educational material in a high-quality way.

The digital approach of implementing virtual laboratories allowed the respondents, based on the transformed and learned experience, to conclude that the educational activity of each person involves tests in which he, with the help of the latest educational technologies, solves numerous situations, gains life experience that affects further the professional destiny of a person.

Having analyzed the effectiveness of the formative experiment, we can state that the future specialists who participated in the research and were part of the experimental groups mastered the methodology of using virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources.

We present the distribution of future specialists according to the levels of formation of professional competence regarding the design and implementation of virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources according to criterion characteristics before and after the formative experiment.

Before the experiment, the following indicators of digital competence were found in the experimental group:

– At a ***low level*** – 58% of respondents;
– At a ***sufficient level*** – 40% of respondents;
– At a ***high level*** – 2% of respondents.

After the experiment, the level of professional competence regarding the design and implementation of virtual laboratories to conduct research and quality education, use programs, projects, and electronic resources according to the criterion characteristics was:

– At a ***low level*** – 9% of respondents;
– At a ***sufficient level*** – 72% of respondents;
– At a ***high level*** – 19% of respondents.

As a result of the experiment, it was proven that the use of virtual laboratories during the study of professional disciplines ensures mutual connection, increases motivation to study, ensures the formation of professional skills of a future competitive specialist, the integrity of individual components of the educational process, promotes the involvement of students in scientific work.

So, the course of the experimental formative research and comparative analysis of the levels of development of the professional competence of future specialists regarding the design and implementation of virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources according to the criterion characteristics of the control and experimental groups before and after the experiment confirmed the effectiveness and the need for a methodology for designing and implementing virtual laboratories for conducting research and quality education, using programs, projects, and electronic resources.

The process of informatization of education requires the formation of new methodological systems of education focused on the formation of knowledge, abilities, and skills necessary for successful self-realization and the creation of a new information and educational environment, the use of which provides the necessary conditions for student learning. In this regard, determining the prospects of using a virtual educational environment in the process of teaching various subjects, in particular computer science, their role and place in the organization of the educational process, and the methodological principles of their application is an urgent problem of the theory and methodology of teaching various subjects using modern information and communication technologies in education.

The practical significance of the obtained research results is that the formulated theoretical conclusions are aimed at improving the virtual educational environment, increasing the completeness and objectivity of expert research, and the effectiveness of the functioning of the Impact of virtual laboratories on the interest and competence of students in professional training.

The content and results of the study can be used by those who have obtained a bachelor's degree in full-time, correspondence, and distance education, scientific and pedagogical workers of higher education institutions for modeling the forms and methods of working with future specialists of information technologies, for compiling methods for diagnosing the process of creative self-realization of students.

Conclusions

The content of the main research concepts is revealed. The main didactic possibilities of virtual laboratories for increasing the interest of students in professional training are shown.

The types of virtual laboratories are named, and their advantages in the educational space of a higher school are shown. The content is substantiated, and the innovativeness of virtual laboratory work in the environment of a higher school is emphasized. The directions in which the introduction of virtual laboratory work into the educational process takes place are shown. The possibilities of using virtual laboratories in the educational space are described. The programs, projects, and resources necessary for virtual laboratories to conduct research and quality education are revealed.

To check and assess the quality of knowledge of students who have completed the study of specialized disciplines in biology, chemistry, and physics, a questionnaire was conducted.

Quantitatively appropriate experimental groups – control and experimental groups – were selected for research and experimental work. During the formative experiment, the research hypothesis was tested that the introduction of virtual laboratories to conduct research and quality education, the use of programs, projects, and electronic resources are necessary for the design of digital narratives in the educational process of future specialists, will contribute to increasing the levels of professional competence formation among students.

Having analyzed the effectiveness of the formative experiment, we can state that the future specialists who participated in the research and were part of the experimental groups mastered the methodology of using virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources.

As a result of the experiment, it was proven that the use of virtual laboratories during the study of professional disciplines ensures mutual connection, increases the motivation to study, ensures the formation of professional skills of the future competitive specialist, the integrity of individual components of the educational process, promotes the involvement of students in scientific work.

So, the course of the experimental formative research and comparative analysis of the levels of development of the professional competence of future specialists regarding the design and implementation of virtual laboratories to conduct research and quality training, use programs, projects, and electronic resources according to the criterion characteristics of the control and experimental groups before and after the experiment confirmed the effectiveness and the need for a methodology for designing and implementing virtual laboratories for conducting research and quality education, using programs, projects, and electronic resources.

Prospects for further scientific research in this area are the research of the information needs of various subjects to determine the order and mechanisms of virtual laboratories for the interest and competence of students in accessing information using the latest information technologies. Undoubtedly, the development of the latter determines the interest of scientists of the information spectrum in the creation and use of databases, electronic libraries, access to electronic carriers of personal information, demarcation of access to electronic carriers of open information and information with limited access, etc.

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