

**A EFICÁCIA DA UTILIZAÇÃO DE OFICINAS DE LABORATÓRIO VIRTUAL NA EDUCAÇÃO ON-LINE DE ALUNOS QUE ESTUDAM A DISCIPLINA “QUÍMICA INORGÂNICA”****THE EFFECTIVENESS OF USING VIRTUAL LABORATORY WORKSHOPS IN ONLINE EDUCATION OF STUDENTS STUDYING THE DISCIPLINE “INORGANIC CHEMISTRY”****ЭФФЕКТИВНОСТЬ ПРИМЕНЕНИЯ ВИРТУАЛЬНОГО ЛАБОРАТОРНОГО ПРАКТИКУМА В ONLINE ОБУЧЕНИИ СТУДЕНТОВ ИЗУЧАЮЩИХ ДИСЦИПЛИНУ «НЕОРГАНИЧЕСКАЯ ХИМИЯ»**

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**RESUMO**

O ensino a distância já faz parte do processo educacional. Nesse sentido, surgem questionamentos quanto à sua organização e solução de problemas específicos. Incluem oficinas laboratoriais, parte integrante do processo educativo no ensino superior, uma vez que os trabalhos de laboratório permitem aos alunos adquirir conhecimentos e competências, um pré-requisito para a formação da sua competência de especialista. Os problemas de obtenção de informações educacionais durante o ensino à distância podem ser resolvidos com bastante sucesso. No entanto, a aquisição de habilidades experimentais continua sendo um problema educacional, científico e metodológico que requer uma solução. O artigo define as peculiaridades da utilização de oficinas de laboratório virtual na educação online de alunos da disciplina “Química Inorgânica”. A análise teórica das principais afirmações do problema de pesquisa foi apresentada no artigo. Os resultados do estudo experimental comprovaram que o uso da modelagem computacional e das ferramentas de um laboratório virtual no estudo das disciplinas de química aumenta o aproveitamento escolar dos alunos, independentemente do nível inicial de conhecimento. Um pré-requisito para a aquisição efetiva de habilidades pelos alunos é o uso sistemático de ferramentas de laboratório virtual. Com o uso ocasional de instrumentos de laboratório virtuais, as habilidades obtidas durante o experimento não foram aprendidas ou não foram aprendidas por um longo tempo. O uso de laboratórios virtuais proporciona treinamento independente para os alunos, aumenta a motivação para o domínio de novos materiais. Os alunos se concentram no processo experimental, não em equipamentos e ferramentas, como acontece em um laboratório real, o que pode se tornar tanto um aspecto positivo quanto negativo na aquisição de habilidades práticas de futuros engenheiros, médicos e farmacêuticos.

**Palavras-chave:** ensino à distância, laboratório virtual, oficina de laboratório virtual, oficina de laboratório à distância, alunos de química.

**ABSTRACT**

Distance learning has already become a part of the educational process. In this regard, questions appear concerning its organization and the solution of specific problems. They include laboratory workshops, which is an integral part of the educational process in higher education since laboratory works allow students to gain

knowledge and acquire skills, which is a prerequisite for the formation of their specialist competence. The problems of obtaining educational information during distance learning can be quite successfully solved. However, the acquisition of experimental skills remains an educational, scientific, and methodological problem that requires a solution. The article defines the peculiarities of using virtual laboratory workshops in the online education of students studying the discipline "Inorganic Chemistry". The theoretic analysis of the main statements of the research problem was presented in the article. The results of the experimental study have proved that the use of computer modeling and the tools of a virtual laboratory when studying chemistry disciplines increases the educational achievements of the students, regardless of the initial level of knowledge. A prerequisite for the effective acquisition of skills by students is the systematic use of virtual laboratory tools. With the occasional use of virtual laboratory instruments, the skills obtained during the experiment were not learned or were not learned for a long time. The use of virtual laboratories provides independent training for students, increases motivation to master new material. Students focus on the experimental process, not on equipment and tools, as it happens in a real laboratory, which can become both a positive and a negative aspect of acquiring practical skills of future engineers, doctors, and pharmacists.

**Keywords:** *distance learning, virtual laboratory, virtual laboratory workshop, distance laboratory workshop, chemistry students.*

## АННОТАЦИЯ

Дистанционное обучение уже стало реальностью в образовании, в связи с этим возникают вопросы его организации и решение конкретных проблем. К ним относится лабораторный практикум, который является неотъемлемой составляющей учебного процесса в высшей школе, поскольку благодаря выполнению лабораторных работ студент не только получает знания, но и приобретает умения, что является обязательным условием формирования его компетентности как специалиста. Если проблемы получения учебной информации при дистанционном обучении достаточно успешно решаются, то приобретение экспериментальных умений остается не только учебной, но и научно-методической проблемой, которая требует своего решения. В статье определены особенности применения виртуального лабораторного практикума в online обучении студентов, изучающих дисциплину «Неорганическая химия». В статье представлен теоретический анализ основных положений проблемы исследования. На основании экспериментального исследования было доказано, что применение компьютерного моделирования при изучении химических дисциплин с использованием инструментария виртуальной лаборатории приводит к повышению учебных достижений студентов вне зависимости от начального уровня знаний. Обязательным условием для эффективного получения навыков студентами является систематичность использования инструментария виртуальной лаборатории. При эпизодическом использовании инструментария виртуальной лаборатории, навыки полученные в процессе эксперимента не усваивались или усваивались не на длительный период времени. Использование виртуальных лабораторий обеспечивает самостоятельную подготовку студентов, повышает мотивацию к освоению нового материала. Студенты сосредотачивают внимание на экспериментальном процессе, а не на оборудовании и инструментах, как это происходит в реальной лаборатории, что может стать как позитивным, та и негативным аспектом в ходе приобретения навыков практической деятельности будущих инженеров, врачей, фармацевтов.

**Ключевые слова:** дистанционное обучение, виртуальная лаборатория, виртуальный лабораторный практикум, дистанционный лабораторный практикум, студенты-химики.

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## 1. INTRODUCTION:

Distance learning is interactive communication in work, providing students with the opportunity to master the studied material independently, and consulting support in the research activities. The purpose of distance learning is to provide educational services with modern information and communication technologies (ICT) in teaching certain educational or qualification levels following state educational standards (Golubeva, Kokhanovskaya, Golovneva, Fatykhova, and Terekhova, 2020). Distance learning is one of the most promising forms of education using modern ICT and

appropriate technical tools (Manning, Cohen, and DeMichiell, 2003).

New approaches are also needed in teaching natural sciences. One of these approaches is the use of ICT during the educational process. The use of ICT in teaching chemistry disciplines makes it possible to intensify the educational process, accelerate the transfer of knowledge and experience, and improve the quality of learning and education (Ardac and Akaygun, 2004). Modeling the studied processes and phenomena makes it possible to carry out computer experiments in those areas of human knowledge where real experiments are either labor-intensive or not possible at all (Lindgren,

Tscholl, Wang, and Johnson, 2016; Smetana and Bell, 2012). The use of ICT increases the information and communication competences of students. It forms the skills and abilities to use modern Internet technologies, particularly those used for distance learning and monitoring (Sergeeva et al., 2019; Nikiforov, Kokorina, Bagdasarian, Shishanova, and Beskorovaynaya, 2019).

One of the directions of using ICT in teaching chemistry disciplines is computer modeling of real-world objects, phenomena, and experiments, which are practically impossible to demonstrate, as well as the creation of simulation models (Rutten, Joolingen, and van der Veen, 2012; Trundle and Bell, 2010). However, it is important to remember that the introduction of information technologies in the educational process will be warranted only when they effectively complement the existing teaching technologies or have additional advantages over traditional education forms (Dadashev, Muskhanova, Batchaeva, and Yahyaeva, 2020; Dolzhenkov, Maltzagov, Makarova, Kamarova, and Kukhtin, 2020).

According to J.R. Brinson (2015), the main advantages of computer simulations are an intensification of the learning process; the ability to change the focus on the fragments of the model; the involvement of an unlimited number of students in the work at the same time (peer education); doing exercises at any time from any computer; reducing the cost of the experiment.

The special software: the so-called "virtual laboratories" (VL) aimed at creating and performing the imitation laboratory work. (Baran, Currie, and Kennepohl, 2004).

The issue of creating a laboratory workshop in distance learning is studied in different scientific and methodological works. In the literature, the concept of a VL is defined differently. In the simplest case, it can be a local computer with a pre-installed virtual simulator or some other program for modeling an experiment (Nico, van Joolingen, and van der Veen, 2012). A more precise definition can be found in the work (Jorda, 2013), where the term VL also includes information technology to create an interactive virtual environment, taking into account the needs of students and teachers.

According to R.K. Scheckler (2003), VL is a virtual learning environment that allows one to simulate the behavior of real-world objects in a computer environment and helps in mastering new knowledge and skills. Such a laboratory can act as

a means for researching various natural phenomena to construct their mathematical and physical models.

In H.M. Babateen's opinion (Babateen, 2011), VL is a program that allows one to simulate chemical processes on a computer, to change the conditions and parameters of their implementation. This program creates special opportunities for interactive learning. The implementation of laboratory work in a VL includes the emulation of the actions that the user should carry out in real conditions. This allows one to test one's theoretical knowledge in practice and get experimental work skills.

T. Wolf (2010) considers VL to be a software and hardware complex that allows experiments to be carried out without direct contact with a real facility or in its absence. According to D. Liu and others (2015), VL is a virtual software environment in which the possibility of researching objects' models, their populations, and derivatives, given at a certain level of detail concerning real objects, within a certain area of knowledge, is organized.

VL allows simulating objects and processes of the surrounding world and organizing computer access to real laboratory equipment (Shin, Yoon, Park, and Lee, 2000). The computer allows one to carry out experiments that are quite complex or unreal under standard conditions, to develop skills of handling hazardous substances or devices (Nicholson, Nicholson, and Valacich, 2008).

Software developers use different approaches to create VL (Figure 1).

D. Kennepohl (2001) believes that a variety of educational tasks can be solved while teaching chemistry disciplines with the help of VL, for example, familiarization with the experimental techniques and equipment before carrying out real laboratory work, as well as checking the level of preparation of the student (programs react instantly to incorrect steps); modeling experiments, which are dangerous or costly to carry out in a chemical laboratory; acquiring the skills of recording observations, compiling reports and interpreting data in a laboratory journal.

According to Y.J. Dori and J.W. Belcher (2005), the best of the software products provide the possibility of realizing the teacher's creative personality. They allow creating laboratory experiments, have a rather convenient and easy-to-use constructor of works. In that case, teachers

can correct all the shortcomings (or most of them) of the program on their own.

S. Chen (2010) believes that distance laboratory workshops of the university require the creation of a special laboratory, where the developed laboratory works are accumulated, and the methodological base is located. Links with distance learning participants are established from the laboratory. For this purpose, a separate website is created on a special university server linked to the learning management system. This site provides access to the VL server, and the schedule of students' research, consultations, and performance of tests are organized there. The use of Wi-Fi wireless data transmission technology facilitates the introduction and implementation of distance laboratory work.

The work (Dalgarno, Bishop, Adlong, and Bedgood, 2009) proposes the general structure of a VL as an interactive virtual space, which includes technological, pedagogical, and human (academic) resources for research, adapted to the needs of students and teachers in a virtual learning environment. Technical resources include virtual communication, remotely performed laboratory work, virtual simulators, an automatic assessment system, virtual computers, and software. Pedagogical resources include methodological supply, and academic resources include students and teachers.

Among the means mentioned above necessary for a distance laboratory workshop in modern higher education, the greatest difficulties, according to B.F. Woodfield (2004), are caused by the creation of remotely performed laboratory works and virtual simulators and the provision of the corresponding instruments and software products. To minimize the required time and labor costs, creating a workshop based on automated laboratory work or research facilities is the most reasonable (Pekdag, 2010). Such equipment makes it possible to accumulate experimental databases and upgrade the existing software to create a remotely performed laboratory work and virtual simulators. In the future, the developed programs and databases can be changed for the needs of different universities and transferred to other educational centers. This interchange significantly facilitates the workshop organization in universities that do not have an appropriate laboratory base. In this case, the distance workshop can contain only simulations, for the development and creation of which only the cooperation of the programmer and the teacher is required.

When creating remotely performed laboratory work and virtual simulators, it is important to consider the basic didactic rules and principles formulated based on the acquired pedagogical experience. In works (Huppert, Lomask, and Lazarowitz, 2002; Rajendran, Veilumuthu, and Divya, 2010), following the analysis of modern research, such basic and generally recognized principles are highlighted as the scientific character, consistency, systematicity, accessibility, visibility, consciousness, and activity, the connection between theory and practice, unity of the individual and collective.

The analysis of the VL peculiarities shows the possibility of observing these principles in e-learning, and in some cases, there are advantages over traditional forms of education. Thus, the requirements of scientific character, systematicity, and consistency depend mainly on the curriculum and their content and, to a lesser extent, on the form of education. The 24-hour functioning of the distance workshops servers makes it possible to access works convenient for students and ensures systematic and consistent education. The use of animation technologies makes it possible to demonstrate the course of processes with a high degree of similarity, the laboratory study associated with experimental difficulties. VL that use ideal models allows students to compare virtual measurements with a modern experiment conducted on expensive research equipment and expand the ability to explore and understand complex ideas and phenomena. Simultaneously, there is a transition to a higher degree of visualization of teaching, and students' interest and their activity in the study of educational material increases. A powerful stimulus for enhancing students' consciousness and activity is to independently test the achieved result. Such rapid self-control, which has an educational character, enables students to correct mistakes and stimulates their creative abilities, interest, and curiosity (Martinez-Jimenez, Pontes-Pedrajas, Polo, and Climent-Bellido, 2003).

Modern equipment used in scientific research, in many cases, is created with the help of computers. Measurement results, equipment condition, parameters, and results of the investigated processes are observed on the computer screen, and control commands are given with the help of the keyboard or manipulator. In this case, performing laboratory work with the help of VL does not physically differ from working with similar devices in a laboratory. In other cases, the use of multimedia demonstrations helps to visually show the course of the studied processes

and use them in practice, which is often impossible in a laboratory. Together, this facilitates the connection between theory and practice in the process of learning (Falvo, 2008).

The main feature of a students' work with VL is independence, and communication with the teacher is carried out using communication. Therefore, with the distant use of VL, there is a need for the broadest use of interactive modes, which can choose the parameters and the course of the experiment, operating modes of devices, and measurement ranges. This provides an independent study of the principles of devices operation and measurement techniques, research of statistical regularities based on the results obtained, an assessment of accuracy, the correlation between the random error of the measured value and the error of devices, the presence of noise. The configuration of VL works can be diversified, and new implementation options can be quickly created depending on the required educational level. Such approaches make it possible to make laboratory work similar to the real one and acquire the skills of research work (Tatli and Ayas, 2013). Together, this contributes to the fulfilment of the above didactic rules and principles.

The study (Logar and Ferik Savec, 2011) notes that remote performance of laboratory work is, to a certain extent, an imitation of laboratory work, despite the illusion of real execution. Therefore, to make a virtual experiment similar to real laboratory work and fully consider the principles of didactics in teaching, it is necessary to widely use all these tools that can be implemented using modern electronic technologies.

The study aims to prove the possibility of introducing VL into the distance learning process of future chemists.

Research hypothesis: the use of computer modeling when studying chemistry disciplines using the tools of a VL increases students' educational achievements, regardless of the initial level of knowledge.

According to the results of the study, it can be concluded that the aim was achieved.

## 2. MATERIALS AND METHODS:

In the study, a complex of modern methods of pedagogical research was used: theoretical (analysis, generalization, comparison, synthesis, review of scientific, educational, and methodical

literature to determine the current state of the examined problem); empirical (observation, conversation, interviewing, survey, testing); pedagogical experiment; methods of mathematical statistics.

The experiment aimed to describe the results of an experimental test of the distance learning effectiveness of the first-year students studying the discipline "Inorganic Chemistry" at the First Moscow State Medical University after I. M. Sechenov, 141 people in total. The experiment was carried out through a laboratory workshop using the ChemLab for Windows, a chemical laboratory simulation. It has several versions, one of which is adapted for use in Russian educational institutions.

The formative experiment was carried out during a real educational process. The use of ICT in teaching chemistry in the experimental group was not opposed to traditional distance learning. However, it was carried out systematically and in close combination with them, as the methodology required it of the experiment. As for organization, all conditions and content of education in the control and experimental groups were the same, except for using a simulation chemical laboratory ChemLab.

The initial and final check-ups and resorted to the element-by-element analysis of the experiment results were carried out. The effectiveness of the learning process was determined by several characteristics, such as the level of assimilation of knowledge in the field of chemistry, the pedagogical effect of experimental learning, motivation for learning. These criteria were used to evaluate the success of academic achievements and motivation.

The level of effectiveness was measured with the coefficient of knowledge assimilation ( $K_a$ ), which is the correlation of the number of correctly reproduced elements of knowledge (correct answers) and the total number of questions of the input (output) test (20 questions): level I –  $K_a \leq 0.5$ ; level II –  $0.5 \leq K_a \leq 0.7$ ; level III –  $0.7 \leq K_a \leq 0.9$ ; level IV –  $K_a \geq 0.9$ .

The results were processed with the help of methods of statistical analysis: the characteristics of the samples were compared, the reliability was determined, the significance of differences was estimated, and a correlation analysis was carried out.

The online laboratory workshop was chosen as a method that was well accepted by the majority of students, regardless of their

educational strengths. The ChemLab environment was used for its implementation, as it most closely matches the developed principles of effective chemistry teaching. The work in it makes it possible to visualize the connections between the microscopic level of data presentation, phenomena of the material world, and symbolic forms of description and study situations that develop in time. ChemLab has interface elements that allow students to adapt the process to their characteristics and allow teachers to manage the total cognitive load of students.

The didactically grounded course of actions in the educational and information environment of the virtual chemical laboratory consisted of the following stages: stage 1 – the theoretical material review; stage 2 – reflection and assimilation of knowledge during the preparation for self-control questions or solving test tasks (practical work); stage 3 – the acquisition and development of practical skills, the accumulation of professional experience using VL workshops; stage 4 – solving practical problems with the help of science-intensive specialized programs and software.

A short questionnaire survey of students after the completion of the pedagogical experiment included the following questions:

1. What is the reason for using virtual laboratory workshops in the study of chemistry?
2. Do you find useful virtual laboratory workshops in the study of chemistry? Why?
3. Would you like to continue using virtual laboratory workshops in the study of chemistry?

### 3. RESULTS AND DISCUSSIONS:

According to the results of the initial and final check-ups, we analyzed the changes in the levels of knowledge assimilation by students from the experimental and control groups (Figure 2-3).

In the experimental groups, there was a shift in the number of students from I and II levels of knowledge assimilation to III and IV levels. Accordingly, there is a decrease in the number of weak students (I and II levels of knowledge assimilation). In the control groups, the number of students with different levels of knowledge assimilation remains almost unchanged. The difference between the final and initial check-ups results for all levels does not exceed 1.5%. All the above mentioned allows us to conclude that the experimental methodology contributes to a

significant improvement in the learning process results.

Table 1 shows the coefficients of assimilation of knowledge in the field of chemistry of students from experimental and control groups.

The generally accepted indicator of the effectiveness of the learning process is  $K \geq 0.7$ . Therefore, the obtained result of the final check-up indicates a high level of knowledge assimilation in chemistry by students who were taught according to the experimental method. Table 1 shows that the pedagogical effect is 0.085 in the experimental groups and 0.014 in the control groups. The increase in knowledge, which is considered the difference in the coefficients of knowledge assimilation by students from the experimental and control groups, is positive, it is 0.065. This proves the pedagogical effectiveness of the proposed experimental method of teaching the discipline "Inorganic chemistry".

A normal distribution within both datasets makes it possible to compare the mean check-up results for both groups using the student's t-test for two independent samples. The results (Table 1) indicate a statistically significant difference between the coefficients of knowledge assimilation in the experimental groups and the control groups.

The results of the fulfillment of the tasks by students of the experimental groups were also analyzed qualitatively, basing on the changes in the assimilation of the elements of knowledge, which in the given experiment were identified as the most problematic. In comparison to the control group, the number of correct answers increased by more than 30% for the questions related to the periodic trends in the properties of chemical elements, the establishment of correspondences, "type of bond and substance", the prediction of the changes in reaction conditions, recognition of strong and weak electrolytes, writing ion-molecular and hydrolysis equations, understanding the theories of acids and bases. The answers to questions related to the temperature, pressure, and volume change have changed most of all. The number of correct answers for some of them increased by 50-65%.

Summing the obtained data up, the following was found out:

- the results of calculating the difference between the average points of the initial and final control using the t-test for two samples showed the presence of a statistically significant increase in

points for all groups of students, which indicated a significant knowledge improvement;

- the application of the online laboratory workshop allowed correcting some long-standing misconceptions. Their presence meant that for some initial test questions, the majority of students (more than 67%), who could not answer them correctly, chose the same wrong option. The results of the final testing showed that for most of the problematic tasks, the number of correct answers increased at least by 1.5-4 times;

- the most difficult tasks for students to solve were those containing interlevel transitions, which included three levels of representation of knowledge in the field of chemistry: macro-, microscopic, and symbolic. The use of computer modeling provided the best increase in knowledge for such tasks;

- independent work using the virtual chemical laboratory, ChemLab contributed to significant progress in students' ability to work with equations and graphs. The increase in points for such tasks during the final testing turned out to be higher than the increase in points for other tasks based on figurative or verbal representation;

- the results of testing the effectiveness of using the virtual chemical laboratory ChemLab to study various topics showed that in all groups, the number of learned elements of knowledge increased significantly: it almost doubled in the control groups and increased by 2.4-2.8 times in the experimental ones. The level of assimilation of elements of knowledge by students from the experimental groups exceeded the level in the control groups by 22-25%.

- when performing laboratory work using the ChemLab, students learned how to algorithmize the sequence of actions during laboratory work; to develop appropriate instructional materials; to carry out methodological processing and analysis of specific sections of the educational course independently; to find the necessary didactic material; to master the techniques and methods of chemical experiment and modern educational technologies; to plan study time; to model fragments of classes.

As a result, the comparative analysis of the findings of the initial and final testing of students from the control and experimental groups before and after the experimental form of education indicates that a statistically significant increase in the results was obtained. Therefore, the use of VL workshops in distance learning increased students' educational achievements, and the size

of the effect did not depend on the initial level of knowledge of the respondents.

Students' behavior observation during the online practical work made it possible to conclude the need for organizational changes to ensure favorable conditions for working with the ChemLab. For this purpose, it is necessary to minimize the impact of insufficient preparation of students in ICT by organizing educational classes in small groups. At least one student has the best basic chemical and computer training. These students can also help the group members in online co-working.

A survey of students about their evaluation of the importance of using VL during practical work in chemistry showed that an important difference in students' motivation was the desire to study not for the sake of erudition but practical works (76% of respondents). 83,5% of respondents noted the usefulness of VL workshops since this method provided them with the opportunity to master such activity, which is close to professional. Formulating their attitude to working with a VL, the overwhelming majority of students from the experimental group (92,5% of respondents) spoke in favor of continuing such educational activities.

The experiment carried out within the study showed that using VL in the learning process, even for independent work, creates a more favorable situation for the manifestation of individual motivation of the students. There is a transition to real personal motives. The use of VL provides students with adequate information about their progress in learning, maintains their competence and self-confidence, hence stimulates intrinsic motivation. The students themselves control the cognitive process. They feel responsible for their behavior and consider the reasons for their success to be not any external factors but their diligence. The survey conducted at the final stage of the experiment showed that most respondents believe that such work stimulates the desire to study the proposed educational material in more detail.

Let us discuss the capabilities of the VL ChemLab in more detail.

ChemLab is designed to demonstrate laboratory experiments and check the quality of students' preparation for their independent implementation.

The main window of ChemLab is a graphical drawing depicting a part of a chemical laboratory, which allows students to feel like they are in a real chemical laboratory.

The user is provided with: a pH-meter, an analytical balance, a titration burette, an electric oven, a thermometer. Openable drawers contain chemical reagents; on the shelves, there is a large range of titrimetry indicators. The program is controlled by choosing commands from the main menu and using hyperlinks. In the main menu of the program, one can specify the name of the laboratory work to be performed, choose the equipment, and design the workshop. So, during titration, it is possible to visualize the titration curve (Figure 5), the appearance of points on which is synchronized with the addition of titrant drops.

The laboratory is equipped with an additional room containing several gas cylinders and equipment necessary for working with them. The program has a section with videos of experiments (the clips are of low quality, but the reactions are interesting).

The program can be used in two modes. The first is a self-study mode for students, which provides them with demonstrations and reference materials. It can be used for the laboratory works, namely, for the familiarization with the purpose, the necessary reagents and equipment, safety precautions, and work procedures; for the performing interactive experiments, laboratory and practical work in a virtual environment; and finally, for the self-control with the help of tests.

The second mode is the mode of the lesson. It allows broadcasting the content of the educational program and reference materials; to demonstrate all the components of the work, namely the purpose, reagents and equipment, safety rules, the procedure for working in a VL; to develop experiments, practical laboratory work in the created environment; to do test tasks.

The advantage of the program is the ability to use both standard models and models created by the user. One can develop new works using the tools of Lab Wizard to build a graphical interface for performing a particular operation. Using Lab Wizard allows one to set a sequence of actions step by step and create a personalized laboratory.

During the working process, instructive materials for conducting practical exercises were prepared and tested to make it easier for students to master the method of conducting imitation laboratory experiments. There are two stages of student work. The first one is to get acquainted with the interface and the main functions of the program, and the second one is to perform ready-made laboratory work.

Also, students had the opportunity to change the conditions of the experiment and to draw appropriate conclusions. Students compared the results obtained with those displayed on the screen independently, corrected their mistakes, and reported completing tasks, and the teacher commented and corrected the answers.

For a more detailed study of key or specific issues during interactive learning, the teacher conducted consultations that complemented the material and drew students' attention to the key elements of the course.

The research results by different authors confirm the conclusions of the conducted experiment about the effectiveness of the use of VL in the learning process of future specialists. Generalized data on the effectiveness of the use of VL and information about the effects that caused the work with them are given in Table 2.

#### 4. CONCLUSION:

In the article, we analyzed the problems of creating a distance laboratory workshop and discussed the requirements for remotely performed laboratory work. We also determined the ways of using a distance laboratory workshop in distance learning.

Literary sources review and the analysis of the results of our experimental research led to the following conclusions:

- VL software can be effectively used as an auxiliary tool for distance learning;

The use of a virtual chemical experiment allows students with a significant amount of knowledge. It develops their intellectual and creative abilities, acquiring new knowledge independently and working with various sources of information. Convenient software and sufficient computer literacy allow students to participate actively in the virtual work and to reduce the time for laboratory work;

- *the use of VL makes it possible to meet the following goals in the learning process of chemistry students: providing students with the possibility of self-preparation; increasing motivation to master new material; students focus on the experimental process, not on equipment and tools, as they do in a real laboratory;*

- the use of VL workshops is cost-effective since no materials are wasted, students work safely, and the exploitation of tools is more technological;



The experimental research results confirmed the hypothesis that the use of computer modeling when studying chemistry disciplines using the tools of a VL increases students' educational achievements, regardless of the initial level of knowledge.

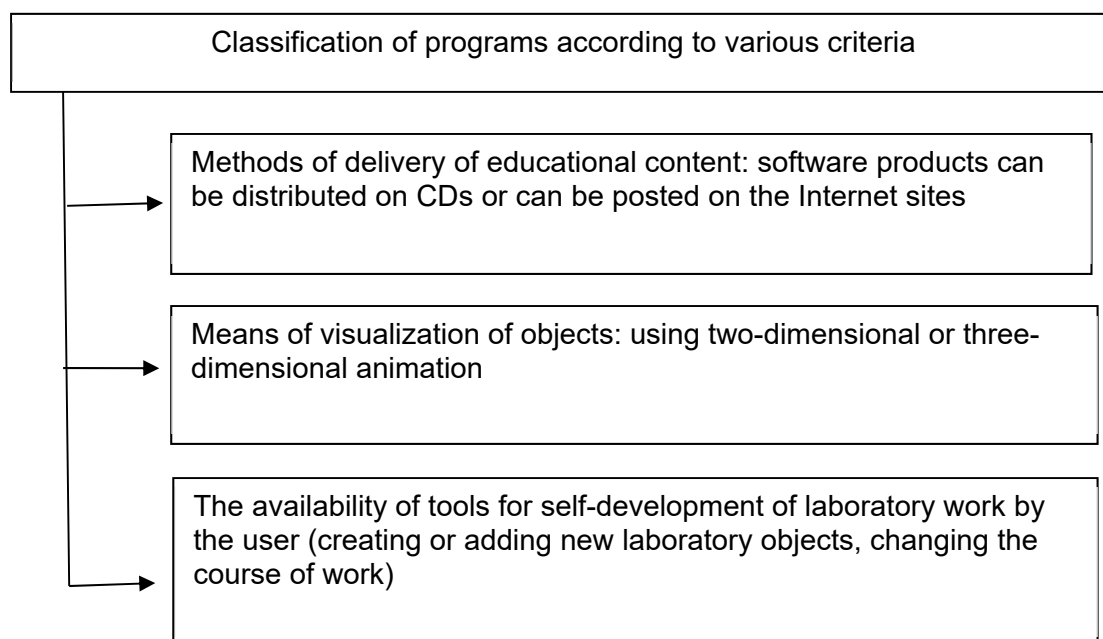
In general, there is no doubt that using computer technology in teaching chemical disciplines is relevant. The effectiveness of the learning process increases significantly if they are used not occasionally but systematically during the whole course.

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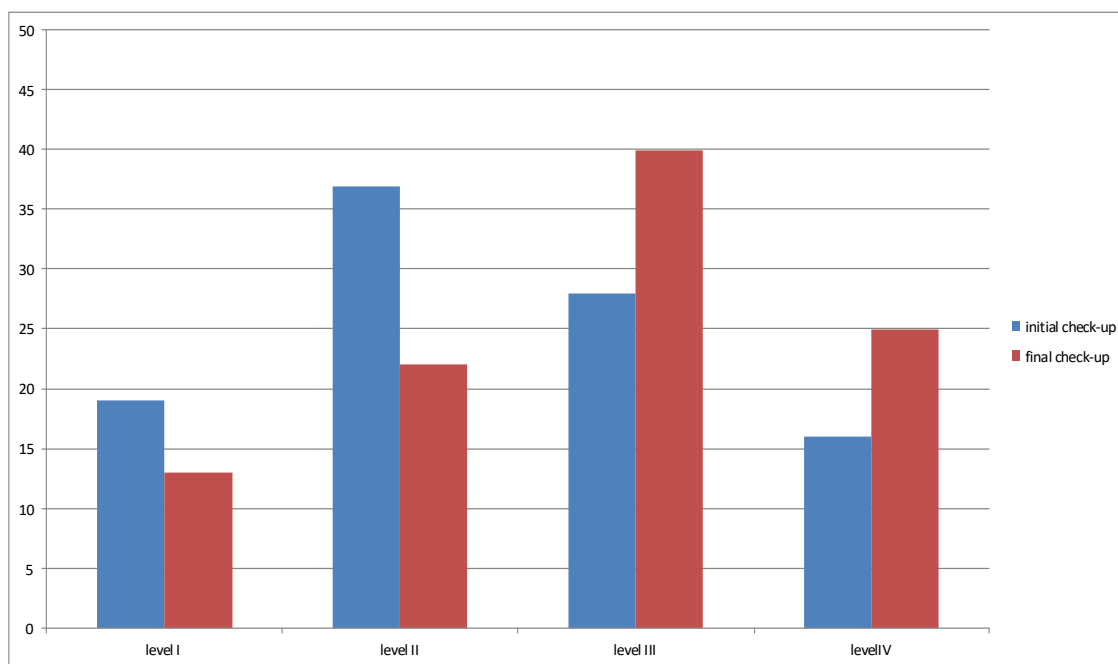
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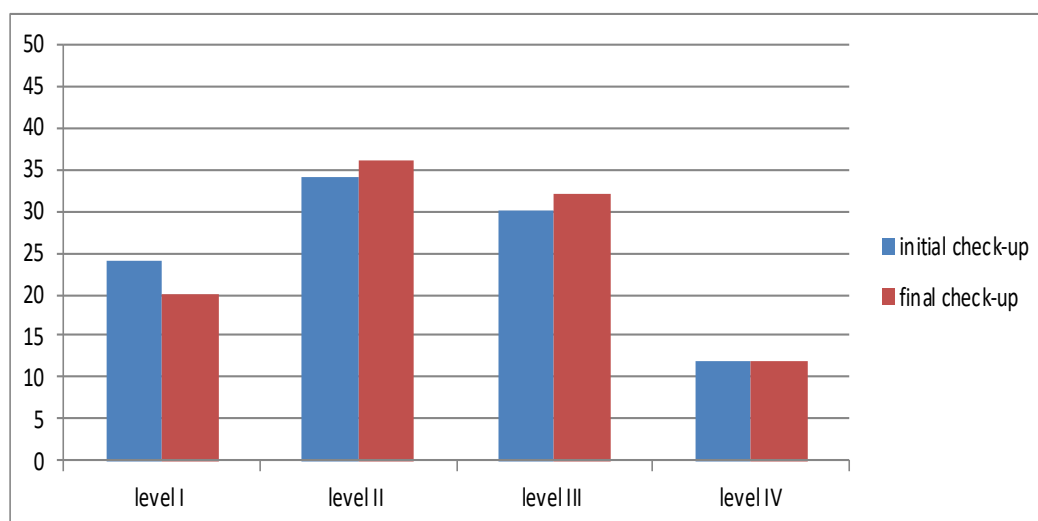
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**Figure 1.** Main approaches to VL creation. Source: Compiled by the authors based on literature (Hofstein and Lunetta, 2004)



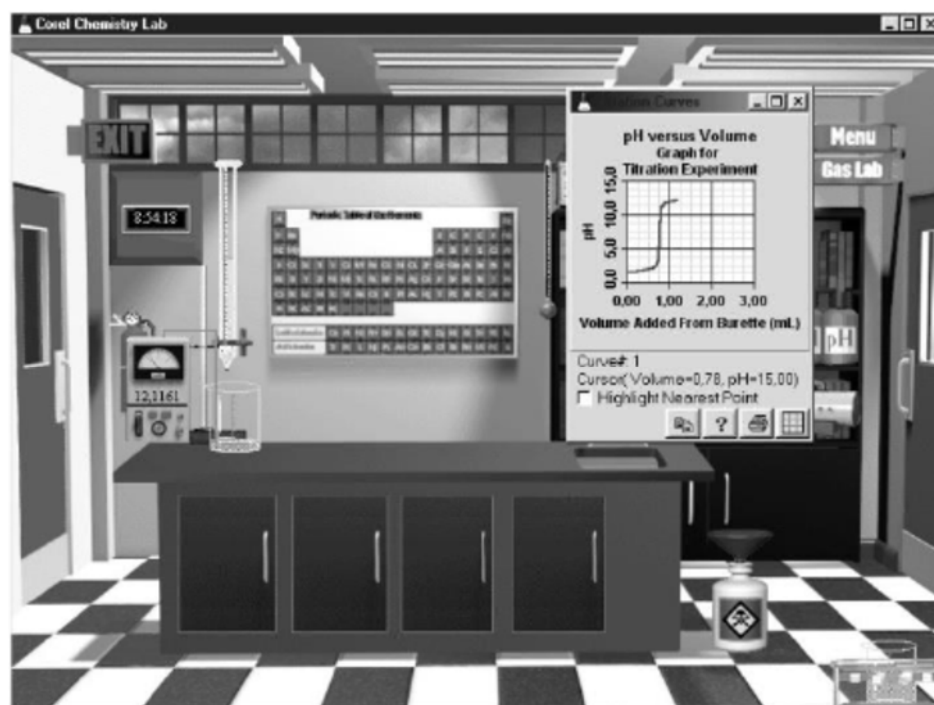
**Figure 2.** Dynamics of the levels of knowledge assimilation by students from the experimental group during experimental learning.



**Figure 3.** Dynamics of the levels of knowledge assimilation by students from the control group during experimental learning



**Figure 4.** Corel ChemLab 1.0 the main application window



**Figure 5.** Corel ChemLab 1.0 software window during acid-base titration (the titration curve is on the right)

**Table 1.** Results of the pedagogical experiment

Number of students	Number of correctly reproduced elements of knowledge		coefficient of knowledge assimilation, Ka (mean and standard deviation)		Results of student's t-test for the final check-up		Pedagogical effect	
	Initial check-up	Final check-up	Initial check-up	Final check-up	t	Significance (2-sided)	Quantitative	Qualitative
Experimental group								
67	1013	1127	0.756± 0.010	0.841± 0.012	0.0567	0.001	0.085	+
Control group								
74	1128	1149	0.762± 0.010	0.776± 0.010	0.0627	0.001	0.014	+

**Table 2.** Generalized data on the effectiveness of the use of VL in teaching chemistry disciplines

The purpose of using VL	Sampling	Data collection tool	Findings	Reference
To evaluate the effectiveness of Vlab-Chem in learning chemistry disciplines	100 students and 14 teachers from the Faculty of Chemistry	Two achievement tests	Increases students' achievements. Teachers and students think that using Vlab-Chem is beneficial for planning, learning instructions, and education.	(Kozma, Russell, and 2000) Chin, Marx,
To analyze the consequences of the use of VL by students before performing real laboratory works	88 students from the Faculty of Chemistry	Achievement test	Increases students' achievements and their sense of mastery during the classes. Students feel more relaxed, less tired, and understand new material more easily.	(Grob, 2002)
To analyze the impact of virtual works on students in comparison with real works	72 first-year students who studied the basic course of general chemistry	Questionnaire for the assessment of laboratory work; achievement test	Increases students' achievements. The work takes less time (VL takes 24 minutes, while real laboratory work takes 36 minutes). Students favor VL and consider the experiments using software to be easier and clearer.	(Bruck, Towns, and Bretz, 2010)
To evaluate the effectiveness of VL developed to study the phase condition of water	70 students from the Faculty of Chemistry	Experimental tool, equipment recognition test, questionnaire	Students with a high level of spatial skills receive the highest level of conceptual learning.	(DeKorver and Towns, 2016)
To analyze virtual learning environments in dimensions of cognitive learning, skills, and attitudes	78 students from the Faculty of Chemistry	Interviews, observations, and working papers	Virtual environments increase productivity and lead to a higher learning level; students use VL programs and think that they are attractive and	(Galloway and Bretz, 2015)

To research into the impact of virtual chemistry laboratories on student success and attitudes towards learning	341 students	Achievement tests, observation	enjoyable. The VL software (Winberg and Berg, 2007) positively affects the success and the motivation of students and makes it easier for students to understand the studied concepts. VL is an alternative to a real laboratory when experiments cannot be carried out in reality for some reason.
To evaluate the impact of VL software on college students	464 students from 26 colleges	Achievement tests, observation	Students who use (Josephsen and Kristensen, 2006) laboratory software answers to questions related to experimental methods more precisely, and they tend to use this software in learning chemistry (55%) (89% versus 26%). Due to the software, students can focus on the experimental process and understand the experiment fully.