IEEE Catalog Number
Part number: CFP21S92-ART
ISBN: 978-1-6654-1854-6

ACIT

2021 11th International Conference on

Advanced Computer Information Technologies

Deggendorf, GERMANY, 15-17 September 2021

IEEE Germany Section

WEST UKRAINIAN NATIONAL UNIVERSITY

DEGGENDORF INSTITUTE OF TECHNOLOGY DIT

Jihočeská univerzita v Českých Budějovicích
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IEEE GERMANY SECTION / COMMUNICATIONS SOCIETY GERMAN CHAPTER (COM19)

2021 11th International Conference on

ADVANCED COMPUTER INFORMATION TECHNOLOGIES ACIT'2021

Conference Proceedings

Deggendorf, Germany
September 15-17, 2021

2021 11th International Conference on Advanced Computer Information Technologies

ACIT'2021

Organized by:

West Ukrainian National University, Ukraine
Deggendorf Institute of Technology, Germany
University of South Bohemia, Czech Republic
IEEE Germany Section / Communications Society German Chapter (COM19)

IEEE Catalog Numbers
ISBN: 978-1-6654-1854-6
Part Number: CFP21S92-ART

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Dear scientists, participants of the 11th International Conference "Advanced Computer Information Technologies" ACIT'2021!

The development of civilization causes a rapid changes of the technogenic sphere, which leaves a special mark in the economic, cultural, scientific progress of mankind. The accumulation of knowledge and experience, the flow of new ideas and inventions disclose new opportunities for the society, although they pose new threats. Mastering huge layers of information for millennia, people seek to extract useful information, find optimal solutions and build effective models. It is also worth noting that among the criteria for the successful existence of companies of the third millennium there is the one based on the collection and processing of environmental data and its monitoring.

Today, computer technology with the organization of intelligent computing is flourishing. New software products are rapidly emerging, using such modern technologies and types of tasks, the application of which allows to achieve a significant economic effect. Computer data processing and information mining are now becoming an integral part of the concept of electronic data warehouses and intelligent computing technologies. The time of intellectual economy has come and the main source of well-being of any state is the development of the scientific sphere.

The dynamics of intellectual development in any country is an important factor in increasing the competitiveness of the economy, increasing living standards, improving the quality of technological and environmental safety. These above-mentioned problems and directions of IT development are the subject of scientific discussions within the eleventh International Conference "Advanced Computer Information Technologies". The 11th International Conference "Advanced Computer Information Technologies" ACIT'2021 has combined all participants from 44 countries: Angola, Austria, Bulgaria, Cameroon, Canada, Congo, Côte d'Ivoire, Cyprus, Czech Republic, Egypt, England, Estonia, Finland , France, Germany, Ghana, Hong Kong, India, Indonesia, Italy, Jordan, Kazakhstan, Latvia, Libya, Lithuania, Luxembourg, Moldova, Nigeria, Norway, Pakistan, Poland, Portugal, Romania, Russia, Saudi Arabia, Slovakia, South Africa, Spain, Taiwan, Tunisia, Tunisia, Ukraine, USA, Uzbekistan.

This year ACIT'2021 is organized by the Faculty of Computer Information Technologies (West Ukrainian National University, Ukraine), Institute of Applied Informatics (Deggendorf Institute of Technology, Germany), Institute of Applied Informatics (University of South Bohemia, Czech Republic) and IEEE Germany Section / Communications Society German Chapter (COM19). We express our sincere gratitude to the partners for the opportunity to organize this conference together.

Experience has shown that the ACIT'2021 International Conference on Advanced Computer Information Technologies enables scientists from various universities and representatives of IT product companies to establish contacts quickly and enter into cooperation agreements.

I am convinced that there will be a lot of discussions during the conference, new ideas and approaches to solving current problems will be appeared. I hope that such cooperation will be deepened and improved, gaining new meaning. This meeting of the scientific elite representatives will be a solid foundation for in-depth cooperation and integration of Ukraine into the world scientific community.

Greeting the international scientific community, I would like to wish you good health, creative inspiration in conquering new heights of computer science, tireless search, interesting discoveries and realization of ideas.

Sincerely yours,

Andrii Krysovatyi
Rector of West Ukrainian National University

Message from ACIT'2021 Co-Chairmen

Dear participants of the "2021 11th International Conference on Advanced Computer Information Technologies" ACIT'2021! It is a great pleasure for us to greet all of you at the conference this year again.

The first annual All-Ukrainian School-Workshop for Young Scientists and Students "Advanced Computer Information Technologies" was held in May 2011. It was organized by the Faculty of Computer Information Technologies (Ternopil National Economic University, Ukraine), the Association of Computer Information Technologies Specialists and the Council of Young Scientists of TNEU. In 2017, the 7th ACIT'2017 has firstly became International Conference.

The 8th International Conference ACIT'2018 has been organized by the Faculty of Computer Information Technologies (Ternopil National Economic University, Ukraine), Institute of Applied Informatics (University of South Bohemia, Czech Republic) and Institute of Applied Informatics (Deggendorf Institute of Technology, Germany). Participants from twelve countries took part in the Conference.

Last year, ACIT'2020 is made possible through collaboration of Faculty of Computer Information Technologies (Ternopil National Economic University, Ukraine), Institute of Applied Informatics (Deggendorf Institute of Technology, Germany), Institute of Applied Informatics (University of South Bohemia, Czech Republic) and IEEE Germany Section/Communications Society German Chapter (COM19). ACIT'2020 was host by our partner – Institute of Applied Informatics of Deggendorf Institute of Technology. Scientists from 53 different countries submitted the applications for participation in the 10th International Conference ACIT'2020. Participants represented more than 200 universities. Due to emergency circumstances, the ACIT'2020 conference was taken in virtual mode.

This year, the 2021 11th International Conference ACIT'2021 is organized by the same professional and reliable team from Ukraine, Czech Republic and Germany. Technical support is offered by IEEE Germany Section. Scientists from 44 different countries submitted the applications for participation in the 11th International Conference ACIT'2021. We would like to sincerely thank to all of the reviewers of 321 submitted papers. Their names are listed in the conference proceedings. Almost second of submitted papers has been rejected. In totally 164 articles has been accepted. Unfortunately, the COVID-19 pandemic does not allow us to meet this year in Germany at Deggendorf Institute of Technology. But, we hope that the spirit of ACIT'2021 International Conference will be present during online plenary and sectional meetings, and our physical absence will not prevent a high level of scientific discussions.

Dear participants! We wish you to have productive discussions and hope that the conference will give you good inspiration for further developments in the field of Advanced Computer and Information Technologies!

Best regards,

Mykola Dyvak, Wolfgang Dorner, Libor Dostalek.

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Virtual Laboratories for Engineering Education

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***Abstract*— The analysis of existing virtual laboratories for engineering education is carried out. It is shown that virtual laboratories are an effective alternative to real laboratories. Users can get access to such laboratories at any time and from any place. Typically, virtual labs are cheaper than real ones. Such laboratories allow users to change operating parameters over a wide range while carrying out experiments, to conduct virtual experiments with hazardous substances or such that are practically impossible to carry out in real conditions or require significant financial resources. At the same time, the disadvantages of virtual laboratories are reviewed. In addition, an analysis of current trends in the development of virtual laboratories for engineering education is presented. Conclusions are made that blended learning can serve as a promising one.**

Keywords—virtual laboratory, e-learning, engineering education, virtual experiments

I. Introduction

One of the modern trends in world development is the formation of an information society. In this context, e-learning becomes an assistant in the formation such a society, enabling a variety of universities to meet global challenges and the level of technology development. Recently, e-learning has become an integral part of the educational process in many higher educational institutions. The use of e-learning makes it possible to improve the quality of education through the use of electronic teaching aids and distance educational technologies.

In most countries, education reforms based on the introduction of e-learning technologies has been elevated to the rank of public policy. In the United States of America the transition from teaching in classrooms and libraries to teaching via the Internet using electronic libraries is in progress. European Union recognizes e-learning as a tool for building a dynamic competitive knowledge-based economy. and creating a lifelong learning space.

Public interest in e-learning has increased so much that classical educational institutions began to consider the inclusion of online courses in their programs as a mandatory component. A lot of researches have been carried out investigating the issues related to online and blended learning [1-6].

Many leading universities provide free online courses - the British Open University (OpenLearn project), Stanford and Berkeley Universities, University of California, Massachusetts Institute of Technology and many others.

Various theoretical and practical online courses are becoming more and more popular among the learners. One of the most striking examples is the Coursera project [7], created in 2011, which originally combined the open resources of three world universities in the United States and in less than a year became the best educational website of 2012 according to Time magazine.

It is already undeniable that e-learning has grown in popularity since the launch of Coursera. At the same time, the quality of online courses is also growing, technologies are constantly being improved, offering various applications and platforms that promote creation of a universal virtual environment, convenient both for use and for perception of the material.

E-learning, like any innovation, meets with a different attitude in society and especially in the education system itself. The most critical attitude towards e-learning is on the part of teachers who fear that the development of e-learning resources will oust them from the education system and deprive them of their jobs.

At the same time, the number of e-learning supporters is growing with the development of information and communication technologies. E-learning is a serious challenge to modern universities and the traditional education system. In the context of the rapid development of society, science and technologies that have made electronic resources accessible to everyone and have changed the nature of communication, modern online education contains enormous potential for the implementation of completely new level of education. At the same time, e-learning is unlikely to be able to completely replace the traditional one, it will only expand educational opportunities for society, create additional comfortable conditions for personal development and advanced training.

One of the trends in e-learning technologies is the development of virtual laboratories. Virtual laboratories can be used to train specialists in any field, but they are especially relevant for future engineers, since the practical component in engineering education is one of the most important.

A virtual laboratory is a software and hardware complex that allows experiments to be carried out without direct contact with a real installation or in the complete absence of it. In the first case, we are dealing with a so-called laboratory installation with remote access, which includes a real laboratory, software and hardware for managing the installation and digitizing the data obtained, as well as

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communication tools. In the second case, all processes are modeled using a computer.

The aim of the paper is to analyze the current status of virtual laboratories, review the existing ones, consider advantages and disadvantages of implementing virtual experiments as well as outline the current trends in electronic resources development.

II. Benefits of Virtual Laboratories

Traditional student's activities in real laboratories are known to be an effective way to get needed skills. Such classes allow students to acquire practical knowledge, see real installations and devices, and feel like they are in a real environment. However, real laboratory facilities are quite expensive. In addition, the continuous development of science and technologies requires the replacement of outdated equipment. Not all universities can afford to purchase expensive laboratory facilities and often replace outdated ones. In addition, outdated equipment can be unsafe from a safety standpoint. The way out in this situation can be the use of virtual laboratories. Virtual laboratories are more affordable compared to real ones. Students can conduct experiments, process experimental data, conduct research in such virtual laboratories anytime and anywhere. The use of virtual laboratories allows learners to develop critical thinking [8]. The conduction of virtual experiments is facilitated by inquiry-based learning [9].

One of the important advantages of virtual laboratories over traditional ones is that such electronic resources can be shared by several universities [10].

Virtual laboratories are easy to install, set up and maintain. At the same time, universities have the opportunity to significantly reduce their costs, which are spent on servicing real installations.

Virtual laboratories are indispensable in cases where experiments are difficult or impossible to carry out in real conditions. In addition, such laboratories represent a good alternative to real installations in terms of the safety.

III. Limitations of Virtual Laboratories

Along with the advantages of using virtual laboratories, some disadvantages should be noted. First, it is often impossible to completely replace a real experiment with a computer one. When using virtual laboratories, students do not acquire the skills to work with real equipment. In addition, students do not have the opportunity to feel like they are in a real laboratory. In the future, when they find themselves in a real production environment, they may experience confusion and uncertainty.

When carrying out experiments in a real laboratory, students also acquire skills for safe work, which will be very important in their future professional activities. When working in a virtual environment, such skills are often not acquired.

Often, when developing virtual laboratory software, too many simplifying assumptions are made, which can distort students' perception of the studied processes or the studied processes can be presented in a simplified form.

IV. Review of Existing Virtual Laboratories for Engineering Education

It is known that in order for students studying in engineering specialties to acquire the appropriate professional competencies, it is necessary to spend a lot of time in laboratories and acquire practical skills. The use of virtual laboratories as an alternative to real laboratories can facilitate the acquisition of relevant competencies.

As noted above, many universities cannot afford to buy expensive laboratory equipment or expensive software resources. Therefore, the use of virtual laboratories available as open source software is of undoubted interest. In recent years, a significant number of virtual laboratories have been developed by various companies, which are presented on the Internet as free information resources. Students can access to these virtual labs from anywhere in the world and at any time. In addition, students often have access to cutting-edge technologies. This is especially true for universities with modest budgets that cannot afford to purchase laboratory facilities that meet the latest technological advances.

One of the widely represented electronic resources is the collection of virtual chemistry laboratories [11]. Teachers can use this educational resource for both group work with students and individual work. When conducting experiments in virtual chemical laboratories, students have access to hundreds of different reagents, which is almost impossible to achieve in real laboratories. This collection also contains related didactic materials, tutorials and concept tests on stoichiometry, thermochemistry, acid-base chemistry, electrochemistry, analytical chemistry, etc. Students and teachers can use interactive simulations from this collection to visualize difficult-to-understand phenomena and concepts. The virtual labs from this collection can be used both online and offline. This collection can be a great help in training students in chemical engineering, bioengineering, and some other fields.

Another open source is Open Source Physics [12]. This resource contains hundreds of virtual laboratories in physics, computer modeling and some other areas. Students have the opportunity to conduct experiments in such subject areas as Astronomy, Electricity and Magnetism, General Physics, Oscillations and Waves, Quantum Physics, Classical Mechanics, Fluid Mechanics, Optics etc. This open source is undoubtedly an excellent electronic resource, and can be used to train undergraduates in electrical engineering, thermal engineering, mechanical engineering etc.

One of the characteristic features of virtual laboratories is their interactivity. Virtual laboratories offered by the BioInteractive resource [13] are an environment in which students can not only participate in carrying out experiments, but also conduct self-assessment of acquired knowledge by answering test questions presented on this resource. This resource may be of interest to students studying in bioengineering.

For students studying in the field of electrical engineering, the Virtual Electronic Machine Laboratory [14] may be of undoubted interest. Learners are given the opportunity to change various parameters when conducting virtual experiments and analyze the influence of certain parameters on the final results.

Another electronic resource is Multimedia Educational Resource for Learning and Online Teaching (MERLOT) [15]. The MERLOT system provides online access to learning and support materials and content creation tools led by an international community of educators, learners and researches. Learning exercises in MERLOT can be sorted by disciplines. Access to some materials requires assignments while others are of open access type. The screen shot of one of the virtual lab (Bacteria Sampling Using Various Disposable Lab Equipment) available is presented in Fig. 1.

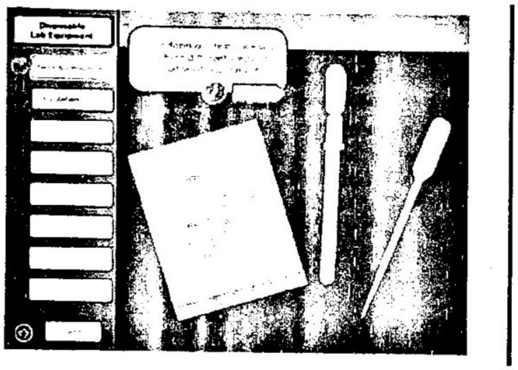


Fig. 1. Bacteria sampling using different disposable lab equipment [https://virtuallab.nmsu.edu/equip.php]

Let's take a closer look at subject-oriented virtual laboratories developed to deepen knowledge and acquire practical skills in disciplines such as thermodynamics and heat transfer.

For the virtual laboratory stands described in [16], which are analogs of real laboratory installations, mathematical models of simulated processes of thermodynamics, heat engineering, heat and mass transfer are used. Such modeling provides clarity of the studied processes and allows learners to analyze them in an unlimited range of conditions.

Learners can observe visual animation effects (boiling, burning, evaporation, etc) while conducting experiments. Control of laboratory stands (start, stop, pause, change of the operating mode, etc.) is carried out by virtual controls, visually similar to real measuring instruments and equipment. A methodological guide has been developed for each experiment.

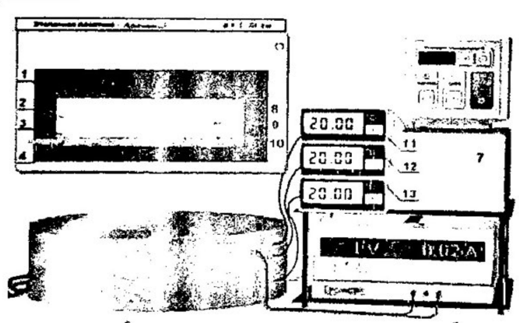


Fig. 2. "Determination of thermal conductivity of solids" virtual stand [16]: 1 - heater; 2, 3 - plates; 4 - refrigerator; 5 - heat-insulating casing; 6 - regulated power supply; 7 - thermostat; 8, 9, 10 - thermocouples; 11, 12, 13 - temperature indicators

The conclusions on the implementing virtual experiments are as stated below [16].

In the process of implementing virtual experiments it was found that they:

1) provide the possibility of repeated repetition of the experiment under different initial conditions;

2) expand the range of possibilities of virtual experiments in comparison with real ones;

3) help to see the physical patterns of ongoing processes;

4) reduce the risk associated with improper operation and violation of safety rules when working with real installations;

5) allow to investigate the dynamics of the process in real time and in slow motion;

6) allow to get more accurate results than in a real experiment;

7) increase the attractiveness of the disciplines;

8) give the teacher the opportunity to simultaneously work with students of the entire group;

9) require the development of special methodological manuals, including the necessary reference materials;

11) require the development of a pre-laboratory colloquium in the form of a programmed survey to check the student's readiness to conduct a virtual experiment.

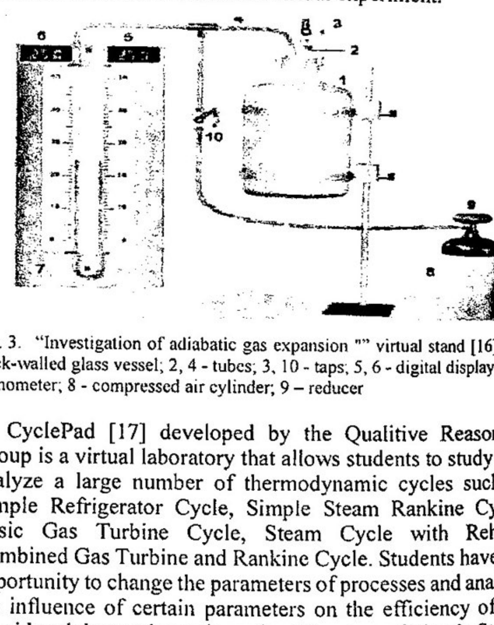


Fig. 3. "Investigation of adiabatic gas expansion "" virtual stand [16]: 1 - thick-walled glass vessel; 2, 4 - tubes; 3, 10 - taps; 5, 6 - digital displays; 7 - manometer; 8 - compressed air cylinder; 9 – reducer

CyclePad [17] developed by the Qualitive Reasoning Group is a virtual laboratory that allows students to study and analyze a large number of thermodynamic cycles such as Simple Refrigerator Cycle, Simple Steam Rankine Cycle, Basic Gas Turbine Cycle, Steam Cycle with Reheat, Combined Gas Turbine and Rankine Cycle. Students have the opportunity to change the parameters of processes and analyze the influence of certain parameters on the efficiency of the considered thermodynamic cycles. The view of Simple Steam Rankine Cycle is presented in Figure 4.

The free software Energy2D [18] can serve as a tool to deepen knowledge in Heat Transfer, gain practical experience and conduct research. An important advantage of this simulation tool and similar heat transfer simulation tools is the visualization of simulation results. For example, students can visualize and analyze the temperature fields, fluid flows and heat flows obtained as a result of modeling. In fig. 5a the process of infiltration in the building is visualized, and Fig. 5b shows the results of modeling the process of heating indoor air by means of solar radiation. However, it should be noted that Energy2D has some disadvantages. While the conduction part of Energy2D is quite accurate, the radiation and convection sections lack the 100% accuracy. In the case of convective and radiation heat transfer simulations should be considered as qualitative. Nevertheless, despite this, Energy2D can be effectively used for educational purposes.

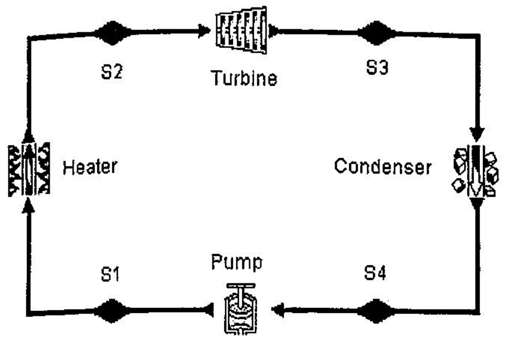
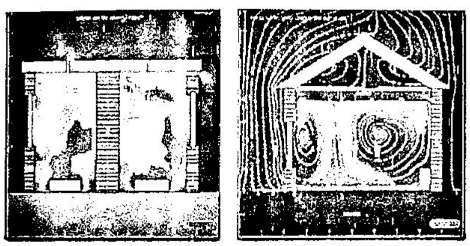


Fig. 4. Simple Rankine Cycle [17]



a b

Fig. 5. Results of simulations in Energy2D. (a) Infiltration of a house. (b) Solar heating through a window [19]

THERM is a heat transfer simulation tool developed by Lawrence Barkeley National Laboratory [20]. When using THERM, it is possible to simulate heat transfer processes in structural elements of buildings such as walls, roofs, windows, etc. The simulation results allow learners to assess the effect of thermal bridges on thermal resistance of building structural elements. The simulation results also make it possible to draw conclusions about the temperature distribution on the surface and in the thickness of the elements of building structures, assess the risk of condensation, and determine the energy efficiency of such structures. THERM can be used by students in writing their bachelor's or master's theses as well as in research. The simulation result of the temperature distribution in a steel framed wall [21] is shown in Fig. 6.

Fig. 6. Temperature distribution in a steel-framed wall [21]

V. Current Trends in Virtual Laboratories Development

As noted above, virtual laboratories have the inherent disadvantage that students, when conducting virtual experiments, do not feel like they are in a real laboratory. Therefore, one of the current trends in the development of e-learning is the development of laboratories with augmented reality. For greater involvement of students in the studied processes, such means as stereoscopic displays, haptic devices etc. can be used.

Another trend is the emergence of research activities aimed at creating virtual learning environments for special categories of students (for example, students with autism) [22].

Heraldo et al [23] highlights the main areas that merit attention for research: effective combination of virtual and remote access laboratories; development of systems for the shared use of virtual and remote laboratories by several universities; professional assessment of virtual laboratories.

Some researchers note the need to develop platforms that could take into account the educational level of users, the field of learning, as well as the role of the user of resources (learner, teacher) and offer appropriate experiments for the particular user [24, 25].

As mentioned above, one of the main components of engineering disciplines as is laboratory work. A convenient tool for the development of virtual laboratories is the LabVIEW programming environment (Laboratory Virtual Instrument Engineering Workbench) [26].

LabVIEW is a programming environment for creating applications using a graphical representation of all elements of the algorithm using the language "G" (Graphics), which is different from programming languages such as C, C ++ or Java, where text is used. Program development and execution environment is designed for researchers and engineers, for whom programming is only part of the job. LabVIEW runs on computers running all common operating systems: Windows, MacOS, Linux, and Solaris.

Benefits of the LabVIEW programming environment: intuitive graphical programming process; ample opportunities for collecting, processing and analyzing data, controlling instruments, generating reports and exchanging data via network interfaces; driver support for more than 2000 instruments; possibilities for interactive code generation; thousands of examples of application templates; high-speed execution of compiled programs; world-class training and technical support; compatible with many operating systems.

The simplicity of the created graphical structures, the ease of editing the program field, the clarity and readability of the applications - all this forces the LabVIEW programming environment to be preferred in many cases.

In addition, an urgent issue is to assess the effectiveness of existing virtual laboratories in order to determine their impact on the performance of students.

VI. Conclusions

The research is devoted to the review and analysis of existing virtual laboratories for engineering education. An analysis was made of various virtual laboratories that have free open access and which can be used for conducting virtual experiments by students in thermal, mechanical, electric, chemical as well as bioengineering. The advantages and disadvantages of such virtual laboratories were analyzed. It can be concluded that virtual laboratories are an effective tool for practical learning. Students have access to these laboratories anytime and anywhere. Such laboratories are a good alternative to real laboratories in terms of cost. Also in virtual laboratories it is possible to conduct experiments that are dangerous if they were carried out in real laboratories. Such laboratories can be tailored for users with special needs. However, it should be noted that conducting experiments in virtual laboratories does not give users the sensations they would experience if they were in a real laboratory. In addition, along with conducting experiments in a real laboratory, students learn how to work safely in the laboratory. Experiments in a virtual laboratory can create a false sense of security. In addition, students who are used to conduct virtual experiments may feel confused when they get into real conditions. Therefore, a blended form of education seems appropriate, in which, along with work in virtual laboratories, students also gain practical experience when conducting experiments in real ones.

The article also analyzes current trends in the development of virtual laboratories. It is noted that attention should be paid to an effective combination of virtual and remote access laboratories. It seems promising to develop platforms that would take into account the educational level of users, their role (teacher, student), as well as their field of study. Based on this data, such platforms could offer appropriate experiments to users. In addition, promising is the shared use of laboratories with remote access by several universities. This practice appears to be cost-effective and facilitates students' access to cutting-edge technologies.

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