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DETAILED ANALYSIS OF THE ADVANTAGES OF VIRTUAL LABORATORY WORKS IN PHYSICS

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Due to the fact, that there is a significant modernization of university laboratory equipment, the widespread transition to computer measurement systems, the widespread introduction of Internet technologies for conducting theoretical and laboratory studies, a number of virtual laboratory works (VLW) have been developed using software resources, such as MATLAB, LabVIEW, LabVIEW Web services, VIPM Browser National Instruments, Wolfram Mathematica, Flash Adobe. The purpose of creating the lab works under consideration was to instill the skills of working with measuring instruments, independent measurements and calculations by each student, the ability to do research on the topic of lab by changing the initial conditions of the system and analyzing their influence on the behaviour of the system.

It was studied, what in common and what differences have VLW and real laboratory work (RLW) in terms of didactic goals, their content, role in obtaining practical skills, acquiring research competencies. The definition of VLW and RLW, as well as the corresponding remote work, is given. The advantages, possibilities, expediency of the development and application of VLW, created on software products and simulating real physical processes, phenomena and patterns, are discussed.

Prospects for further research of VLW with the involvement of actual material of real laboratory work, methods of their software implementation and modelling packages are outlined

Keywords: *Information and communication technologies, virtual laboratory, virtual laboratory work, real laboratory work, advantages of virtual laboratory work*

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1. Introduction

The information and technological breakthrough of the 21st century, the transition to distance learning during the pandemic, the prospects for the introduction of artificial intelligence in everyday life and in education, in particular, lead to a violation of the patriarchal structure of the systemic pedagogical process, which is based on the unity of content, forms, methods and means. Higher education makes the transition from traditional teaching, education to self-education using information and communication technologies. Digital pedagogy appears – this is the study and use of modern digital technologies in teaching and learning [1].

The sequestration of classroom hours for laboratory work almost 3 times (from 60 hours in the 2013–2014 academic year to 24 hours in 2015, and then until 16 hours from 2016) is compensated by the use of a remote virtual laboratory work (DVLW). A number of virtual labs have been developed using modern software resources. The purpose of creating the works under consideration was to instill the skills of working with measuring instruments, self-dependent measurements and calculations by each student, the ability to do research on the topic of work by changing the initial conditions of the system and analyzing their influence on the behavior of the system.

Deep computerization of the laboratory practice, rejection of the traditional system of preparation, conduct and control of knowledge during laboratory work, which has been established over the past hundred years, requires a detailed analysis of the advantages of VLW in comparison with classical LW.

2. Literary review

Since the subject of this work is VLW, as a part of ICT, initially we will define the concept of VLW and RLW. By real, sometimes called bench, we mean work that is performed, as a rule, manually using accessories, instruments, measuring instruments directly on laboratory equipment, stand, and facility. Computer LW, when a computer is used as a means of measurement, registration, we also refer to RLW. The main feature of VLW is the presence of a model of a phenomenon or process. Remote LWs using Internet technologies can also be divided into DVLW and DRLW. The criterion for such a division is the object of research - a real process, phenomenon, patterns, or their model.

In [2] a virtual laboratory is defined as an online laboratory that provides remote software simulation. Remote laboratory is an online laboratory that allows you to control real equipment and implement real measurements over the network. Hybrid Lab is a combination of remote and virtual labs.

P. Hazerli [3] defines a virtual laboratory as one where a student interacts with experimental equipment, which is essentially remote from the student or has no immediate physical reality. That is, P. Hazerli attributes work to VLW on two grounds: remoteness and model. Remoteness, as we believe and in accordance with [2], is not a sign of virtuality: the radiologist, making a fluorography or X-ray picture, is at a distance from the X-ray apparatus. Physicists study objects that are located in a complex measuring facility, often in neighboring rooms, and sometimes in distant countries - the LHC is located on the border of France and Switzerland, the analysis of the data, obtained on it, is performed by computing centers around the world, including Kharkov. An interactive experiment on the screen is distinguished into a separate category in [3], dividing it with software simulation. Again, we see that the object of observation is not a real stand, but its visualization and reaction to a mouse click, i.e. for the object of observation, an interactive experiment also refers to VLW.

Mususami [4] defines VLW as one of the types of interactive multimedia objects, which consists of different formats, including text, hypertext, sound, images, animation, video and graphics. VLW are available in three formats: 2 – d, 3 – d simulation with sensors, control systems and remotely controlled VLW. And here we see the absence of distinction, differentiation between VLW and RLW.

A.V. Trukhnin [5] defines VLW as: 1) a software and hardware complex that allows experiments to be carried out without direct contact with a real stand, or 2) in the complete absence of such. The first case is called a laboratory setup with remote access, which includes a real laboratory, computer control, analog-to-digital converters (ADC) and computer networks. Moreover, the author [5] emphasizes that in practice both types of laboratories are often called VL, but this concept is definitely suitable only for the second type.

The advantages and disadvantages of using VLW in the educational process of a university were previously considered in a number of works: the authors [6–8] limit themselves to a simple listing of the advantages and disadvantages of VLW, without analyzing and specifying. In similar works of other authors, which we do not cite, they simply repeat the same advantages and disadvantages in a larger or smaller volume (about 7–10).

3. The aim and objectives of research

The purpose of this work is to analyze the advantages of VLW, the transition to which began in many universities in the world and in Ukraine, in comparison with traditional bench laboratory work, morally and physically obsolete.

To achieve the goal, it is necessary to solve the following tasks:

1. Give a clear definition of the virtual LW, its difference from the real one. Without such a definition, it is impossible to talk about advantages, since the objects of comparison are not differentiated.

2. Consider the didactic goals of RLW and VLW. Show that virtualization of the laboratory practice contributes to the filling of the virtual educational environment.

3. Conduct a detailed analysis of the advantages of VLW relative to RLW.

4. Materials and methods

In the process of scientific research, the following methods were used: analysis and systematization – during the review of scientific articles, reports of scientific conferences, teaching aids, in which certain developments, reviews, descriptions of issues, related to VLW, are presented. Comparative analysis method with real LW; synthesis, comparison, systematization, generalization – while obtaining and discussing the results and formulating the conclusions of the work.

5. Research and discussion results

It is known, that laboratory work is one of the types of unaided practical work of students and is carried out in order to consolidate theoretical material. According to the methods of execution and processing of the results, LW can be divided into those, in which:

a) observations,

b) quality experiences,

c) measuring work,

d) quantitative studies of functional dependences of quantities, etc.

When considering the methods of performing and processing the results of LW, one can distinguish classical or manual, when a student at the stand or at the facility conducts an experiment, makes measurements, as a rule, with a dial gauge or scaler, made at best before perestroika, and some especially high-quality exhibits were made before the thaw. On the other hand, many works can be performed on a modern base using a computer, laptop, tablet, smartphone.

Information and communication technologies significantly change the system of teaching fundamental disciplines and physics, in particular, developed in the pre-computer era. In this system, theoretical material is presented in lectures, and its consolidation occurs in practical lessons. An integral part of the physics curriculum is a laboratory workshop, the conduct of which is aimed at:

a) experimental confirmation of theoretical lecture material, in-depth study and understanding of physical phenomena,

b) instilling skills, habits and abilities of unaided work with measuring instruments, laboratory equipment,

c) teaching elementary research competencies – carrying out measurements with an understanding of the physical principles of the operation of the stand, processing the measurement results according to certain methods with an assessment of the obtained results and measurement errors, registration of the results.

However, an epoch-making change in the basis and superstructure of modern society led to a shift in the emphasis of education on self-education and a corresponding decrease in the hours of classroom studies of the three components of the physics course, with the course program, remaining practically unchanged. The requirements of the law of conservation of energy (load) act like a hydraulic press in communicating vessels of different cross-sections: a small section of classroom hours requires a large amount (height of movement) of teaching materials for self-preparation, in order to raise the sometimes infinite section of the student's knowledge to a certain height. In practice, such communicating vessels are ICTs.

ICT as applied to a laboratory practice today means a remote laboratory practice, network laboratories, an automated laboratory model, a remote access stand, a virtual training laboratory. ICT in this case acts as a system of e-science, e-tools, e-learning and allows to remotely carry out measurements, scientific and technical research, computerize engineering training, partially compensate for the severity of the existing problems of material and technical support of educational laboratories with modern expensive equipment. In this case, ICT acts as an element of today's popular cloud technologies (CT) in the Software as a Service – SaaS segment, as cloud-based simulators – CT programs, designed to form and consolidate abilities and practical skills, mastering methods, procedures for performing certain types of educational or professional activity, as well as for self-training. In addition, the considered DVLW can be attributed to such CT segments as: didactic demonstration materials; modeling environment; workshops – programs, designed to consolidate practical skills; subject environments – to automate actions; computer mathematics systems – for all of the above plus automation of calculations, etc. This can be justified by the fact that today DVLW means not only virtual devices and stands, but also virtual classrooms, systems of mathematical, physical, simulation, information, structural – functional and other types of modeling.

The task of implementing the DVLW today is being solved with the help of mathematical, physical, technical modeling packages. There are hundreds of computer simulation programs [9]. Among the most widely used are LabVIEW National Instruments + Multisim, Wolfram Mathematica + SystemModeler, MATLAB + Simulink, Maple + MapleSim, Modelica, COMSOL Multiphysics, Flash Adobe, Interactive Physics.

So, on the basis of MATLAB and LabVIEW, we have developed fifteen VLWs, which make it possible to "perform" experiments in 3 sections of physics on a computer screen [10]. Then, in [11], we examined the use of a smartphone when performing real LWs and, finally, in [12], we described the VLW based on LabVIEW Web services.

Let's conduct a detailed analysis of the advantages of VLW.

1. *Introduction of ICT in the educational process*. Because we live during the fourth industrial revolution, in which there is a massive introduction of cyber-physical systems into production (industry 4.0), there is a transition from an analog noosphere to a digital (discrete) one, when babies play on smartphones and fall asleep to audio stories, read by tablets, and suddenly at a university students of generation Z (digital people) are faced with the need to work on devices, released in 1948, 1956 or in some economic council, because only they can supposedly test and understand the meaning of electromagnetic induction (ballistic galvanometer); the Komovsky G. F., patented in 1927, serving to conduct demonstration experiments with the Magdeburg hemispheres (von Guericke's experiment in 1654); the PP-100 scaler – a kind of discotheque of the 70s, the B-2 radiometric apparatus (1960), the scaler PP-16 (1972). Not a laboratory, but some kind of quest room. “In general, perhaps, as an exhibit for collectors, someone may be interested in …” [13].

For almost three decades, the departments of physics of universities have become more and more like the M.V. Lomonosov museum in the Kunstkamera: ancient rarity devices, exhibited in rooms with European-quality repair.

We can formulate a disadvantage, corresponding to the first advantage: No experiment is carried out on real experimental equipment, no research experiments, no tactile perception of the cognitive component of training.

Denial of this disadvantage: RLW in physics set as their goal: a), b), c) (see above). It is now possible to conduct research (experiment) on real laboratory equipment in remote access mode. Many students already use the “smart home” system in everyday life, when, for example, the temperature in the house is set via the Internet using underfloor heating, a heat pump or an air conditioner. It is also possible to remotely set not only the temperature of the experimental setup, but also other physical parameters: voltage, current, circuit resistance, pressure, etc. The entire experimental part can be carried out on-line. Yes, in this case, switching the toggle switches, turning on the pump or moving the rheostat slider is done with the mouse or by moving your finger across the screen, but the result is the same as when acting on a real setup. It is quite understandable why we are now seeing a sharp surge in on-line laboratories and stand around the world.

Naturally, the advantages, inherent in e-learning, will also be inherent in VLW, as one of the elements of this training system.

2. *Freedom of access*, when a student can conduct an "experiment" from anywhere in the world, connected to the Internet. It is possible either to work remotely, or to download VLW to the gadget and perform it off-line.

3. *Flexibility of training* – the study of the material occurs when there is an opportunity and need, there is free time for study. This also includes the regulation of the duration of the VLW "experiment", the repetition, if necessary, of the experiments as many times as it takes to achieve the desired result.

4. *Development of skills in working with modern computer technologies*, electronic resources, the formation of research competencies, the formation of skills and abilities of independent acquisition of knowledge, scientific research on the questions, posed in the work or by the performer him/herself.

5. *Equal Learning Opportunity* – access to open on-line courses, which today can be classified by volume – MOOC and STOC and by time – SMOC and SSOC. These are courses, such as MIT, Coursera Udacity, Khan Academy, FutureLearn, edX, Canvas, Network, MyEducationKey. A Ukrainian project EdEra, which is a site with online courses in the MOOC format. The project includes interactive lectures, notes with illustrations and explanations, exams and homework, communication with other students and teachers. Another project that has Ukrainian roots, and declares itself as a MOOC project, is the Knowledge Hypermarket.

6. *Work of trainees in a digital (computer) environment familiar to them*, and therefore easier assimilation of the studied material, increased interest in work,

increased motivation in obtaining knowledge in a specific section of the discipline and corresponding experimental methods.

7. *Conducting VLW frees the student from the need to perform routine work* of mathematical, and often arithmetic, calculations when building graphs, finding measurement errors. For example, in the work "Investigation of magnetic induction and magnetic permeability in iron", up to 60 preliminary calculations are required, and then the plot of two graphs on them. Most of the students do not have time to complete these calculations in a class, do them at home, make mistakes, recounts again, and there have been cases when the calculations took 1.5–2 months. The appropriate VLW does all the calculations and plotting graphics at the same time as the work is done.

8. A common advantage for all types of e-learning is the possibility of remote learning, and for VLW – implementation, both on-line and off-line, *365/24/7*.

9. Simulation modeling, visualization have reached such a level that they allow you to create realistic laboratory benches. Astronaut, pilot, steelmaker, machinist, driver, NPP operator, doctor, etc., today they interact with actuators through a touch-sensitive liquid crystal screen, acting on which they achieve real movement of mechanisms, devices, machines, apparatus. Working in the VLW environment, a student develops understanding, skills, reflexes that actions with the screen of a computer, laptop, smartphone, having a real physical result. The student is in a computer environment that is familiar to him/her and this, in general, has a beneficial effect on the quality of education. In addition, 3d modeling of processes, occurring in setups and devices, allows you to achieve clarity and, accordingly, a better understanding of the processes. For example, in the work on determining the specific charge of an electron by the magnetron method, when the solenoid current (magnetic field strength) increases, the electron does not reach the anode and begins to rotate between the anode and the cathode. Not a single student in 30 years has correctly shown the trajectory of an electron during rotation. VLW builds the trajectories of an electron when the current (intensity, Lorentz force) changes.

A lot of RLWs are built in such a way that the study of a simple physical phenomenon or low occurs with such indirect methods that the essence of the work, its purpose, is lost. For example, the work on electricity "Determination of the capacitance of a capacitor using a PP-100 scaler". The description says: "The conversion of current into pulses is carried out by a blocking generator, assembled on half of a 6N2P double triode, in the anode-grid circuit of which a small-sized pulse transformer MIT-8 is connected." How many teachers, associate professors, professors of physics will be able to draw and explain this diagram, which, moreover, does not in any way explain the concepts of capacity in parallel and serial connection. VLW, on the contrary, allows you to "use" the RLC meter, with an accuracy of $C \sim 10^{-15}$–10^{-17} F and "carry out" direct measurements of the capacitance.

10. *There is no need for maintenance of rarities* of the Soviet industry, search for consumables. The memorable PP-100 in the unit section has neon bulbs that were clearly not designed for 50 years of operation, there is simply nothing to replace them with, out of 10 there are only 1–2. Therefore, when measuring on it in the category of ones, we write zero. High-order decatrons are still working.

11. *You can "use" the most modern laboratory instruments and equipment*, both domestic, if they are still being developed and produced, and foreign, which, as a rule, cannot really be purchased.

12. It is possible *to carry out "modernization" of measuring devices almost every year*. From 12) it follows

13. *The cost of "modernization" of VLW is insignificant*, does not go beyond the remuneration fund for teachers, does not affect such budget items as operating costs, modernization, depreciation, auxiliary educational staff.

14. *Individuality of training*. In many universities, including national universities, at specialized physics departments and chairs, RLW is performed by a group of 2–3 or 5 people. The group members are heterogeneous. A successful, understanding student often performs work and calculations on his/her own, and the rest of the group hangs out in social networks, games, or in any other way are absent from the class mentally, being physically present. VLW for such students will be a kind of game and can arouse interest in the topic under study.

15. *Varying the stand parameters*.

As a rule, the available LWs allow measurements to be made for one specific case, without allowing changing the system parameters. The virtual LW is just able to get rid of the limitations of real stands and conduct research, varying the parameters of the system within reasonable limits, to exert “external” influences on the system, which in a real setup would require significant modernization.

16. *Experiments that cannot be performed in a training laboratory* due to complex expensive equipment, factors, affecting the body: ionizing, microwave, laser radiation, etc., long-term processes are implemented using VLW.

17. *Unlimited set of LW*. Virtual works provide versatility and multifunctionality, as well as flexibility and ease of adaptation to various objects. Hundreds of newly developed VLWs in a wide variety of technical specialties are reported at annually held LabVIEW technology conferences. Reducing the cost of creating LWs allows in a short time to significantly expand their base and thereby provide greater flexibility in training.

18. *Prevention of accidents*. Real devices have a very high voltage, for example, in a B-2 setup, up to 700 V. Glass bulbs, used in thermodynamic and molecular physics work, can break with corresponding consequences. In the work on determining the moment of inertia, the flywheel – axle – shaft, sometimes the system is twisted so that the weight breaks off the thread and flies into the student. The most beautiful section of the laboratory in physics – wave and quantum optics, turns out to be the most harmful in terms of the effect on the eyes of students. Constant complaints of eye pain take place after performing work on a spectrometer with mercury and hydrogen lamps, when determining the Stefan-Boltzmann constant using an optical pyrometer with a disappearing filament, determining the radius of curvature of a lens using Newton's rings – radiation from a mercury lamp, determining the wavelength of light using

a diffraction gratings – it is necessary to look through the grating at a powerful incandescent lamp, determining the laser wavelength using a diffraction grating – in the manuals it is written in bold text that it is strictly forbidden to look at direct laser radiation. Electrical devices, used on very many laboratory stands, are included in the 220 V network and carry significant danger.

19. *They allow you to devote more time to the theoretical part of the work*, the assimilation of the phenomenon, studied in the work, not to be distracted by the routine of registration and calculations. Preparation of a report, including tables of measurements, calculations, graphing, occurs simultaneously with the execution of the work. The student either prints out the report and the results of the work, or saves them on the computer. If there is a desire for the calculations to be carried out on a calculator, then you can programmatically add a calculator to the VLW, moreover, it may not be a standard one, but a calculator, containing additional buttons for constants and quantities, used in the work.

20. The use of VLW *simplifies control* not only over the implementation, but also over the preparation of a student for a specific LW.

It is known, that the description of the RLW contains such sections as:

1) the number and title of the work;

2) Aim of achieving;

3) Theoretical part;

4) Description of the stand, devices and accessories;

5) The order of work. Before performing the work, the student must make a synopsis – a blank, including sections 1–3, calculation formulas and tables.

When performing the work, tables are filled in, measurement results are recorded, calculations using these results, errors, measurement accuracy, and graphing are found. Both the template and the report often represent a rewritten unsubscribe. The teacher is forced to check the prepared blanks, control the execution of calculations and the completion of the report, wasting precious time of a few LWs.

However, it is often possible to see that the created computer LWs use a computer as a measuring instrument, that is, an analog-to-digital converter or sensor is placed at the input of the computer, in which an ADC is already built-in, and the signal from the sensor is displayed in digital form on the monitor, and the students record it in the report. Then calculations are made on a calculator, graphs are built on graph paper.

21. VLW "saved" the educational process in the context of the coronavirus pandemic.

The study does not describe the shortcomings and weaknesses of VLW, psychological and pedagogical aspects, physiological impact on students, since this is not the subject of our research.

In further work, it is planned to consider in detail, using real examples, the methods of software implementation and mathematical, physical, technical modeling packages.

6. Conclusions

1. VLW is a laboratory work that has the same goals and objectives as RLW, but the object, phenomenon or process of research is the corresponding program model. VLW is performed using computer technology or a smartphone when working with a specific program. There are no material objects, such as stands, plant, laboratory equipment, instruments, accessories, measuring instruments, etc. RLW, sometimes called bench system, is performed manually or using a computer as a means of measurement and registration on the material objects listed above. The criterion of division into remote RLW and VLW is considered.

2. The leading didactic goals of RLW and VLW are the same. Both types of LW provide skills in working with laboratory equipment and instruments; contribute to the acquisition of research competencies.

3. The process of virtualization of the subject area of physics is carried out, including through the introduction of VLW into everyday life. Having a large number of advantages over RLW, VLW is firmly included in the educational process. Probably, by 2030, a complete computerization of the laboratory workshop in physics will take place, and the share of VLW will reach 80–90 %. Awareness of the advantages of VLW will allow to overcome the psychological barrier of mistrust on the part of teachers and students who prefer traditional teaching methods, but at the same time actively use computers, laptops and smartphones.

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COMPARATIVE CHARACTERISTICS OF FUTURE THEATER ART SPECIALISTS' PROFESSIONAL TRAINING IN UKRAINE AND THE USA

Sergei Nabatov

The article provides a comparative analysis of the training of future theater professionals at universities in Ukraine and the United States. The author reviews modern scientific works on the problem of professional training in general and optimal approaches to the selection of criteria for comparative research. On the basis of a comparative comparison, common and different aspects of professional training of future theater professionals at universities in Ukraine and the United States were clarified.
The author determined that the peculiarities of the methodological principles are that in the United States they are presented more widely and more thoroughly in legislative documents; the concept of professional training of future specialists in theater art, approaches and principles in general determine the vector of further development of the system of professional training in the research area; standards in the United States are also comprehensive and specific, which provides better control over the quality of higher education in the theater; qualification requirements in the United States and Ukraine largely coincide (qualifications, features of vocational education – terms and institutions where it is possible to get a profession); content structure and list of disciplines is characterized by flexibility, diversity and differentiation in the US, which provides a wider range of individual trajectory of vocational education, while in Ukraine the list of disciplines and their content is much narrower); forms, methods and tools that are also component components of organizational and methodological principles in the system of university education in the United States and Ukraine are characterized by variability and generally provide quality training for future theater professionals in both countries
Keywords: *specialists in theater art, professional training systems in the USA and Ukraine, methodological foundations, organizational and methodological foundations, university education*

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1. Introduction

The development of society in the context of global social challenges and transformations forms more and more requirements for the professional development of specialists in all industries, consisting in the approval of a personality-oriented paradigm of coexistence and interaction between representatives of various social groups. Consequently, one of the priority areas of higher education in Ukraine and the world is the formation of an open to interaction, competent in its profession, personality, able to flexibly respond to new challenges and to act promptly in the given circumstances. The semantic component in this context is a cycle of professional training, in which the humanitarian component is highlighted, which ensures the development of communication skills, skills of group and team interaction, skills of the 21st century, which were