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Implement a laboratory workshop in physics and electrotechnical disciplines in the face of COVID-19 pandemic

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ABSTRACT

Studying physics and many related disciplines at all education levels includes not only learning the theoretical material, but also the formation of skills and abilities to apply the knowledge gained in practice. This occurs mainly during laboratory work when students directly contact with specific laboratory equipment. With the forced transition to distance learning due to the development of the COVID-19 pandemic, the main difficulties in many universities arose precisely during the implementation of laboratory workshops. This study analyzed the possibilities of modern digital teaching aids for the effective remote implementation of a laboratory workshop in physics and related disciplines. The study was carried out on the basis of the Elabuga Institute of the Kazan Federal University. There were 79 students took part in the experiment (second and third-year students). The results showed that a well-arranged combination of various digital tools and technologies makes it possible to effectively implement laboratory works in physics and electrotechnical disciplines in a distance learning format. The research results are useful for university teachers using distance learning technologies in laboratory work in natural science disciplines.

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1. INTRODUCTION

The development of the COVID-19 pandemic temporarily overshadowed all the previous concerns of the world community, affected all areas of human activity [1]. These processes could not but affect the education system. The pandemic has affected educational processes in the vast majority of countries [2]–[7]. Some schools have closed and others, especially in higher education, have moved to online learning systems [5]–[8]. For example, in Russia in March 2020, all higher education institutions completely switched to distance learning. The forced transition to distance learning has put the entire education system in extreme conditions. This is noted by researchers from many countries [7]–[13]. Moreover, various aspects of this problem, both social and economic ones, are considered. For example, Yang *et al*. [14] examined issues related to the perception of self-isolation by younger schoolchildren. Noviani [15] examined the internal and external barriers to studying mathematics by distance learning during the Coronavirus disease-19 (COVID-19) pandemic. Moawad [5] examined the economic aspects of the problem associated with the transition of universities to distance learning. The fact is that full-time contract students, in the authors' opinion, fairly want to know about the possibility of changing the level of tuition fees [16]. However, the main problem for universities was the transition to a completely distance learning format without reducing the quality of educational services provided.

At the same time, such tools as Skype [17], Microsoft Teams [18], Zoom [19] are used for online communication between teachers and students. The learning management system (LMS) has been increasingly used recently for the organization of the entire process of distance and blended learning. The best-known LMS are Moodle, Blackboard, Canvas, eCollege, Cornerstone, SumTotal and WebCT (currently owned by Blackboard) [20]–[23].

The Russian higher education system coped with the set tasks primarily due to the experience gained in recent years in the introduction of distance learning technologies into the educational process [23]–[25]. At the Kazan Federal University of Russia, the main tools for the implementation of distance learning technologies in teaching various subjects are LMS Moodle, Google Classroom, Microsoft Teams. Over the past seven years, e-learning courses in all areas of physics and a number of related disciplines has been developed, tested and are successfully used at the university. The structure of these courses, the methodology and various models of their use for the implementation of blended learning in physics and mathematics have been studied in a number of works [26]–[31].

However, the forced complete transition to distance learning caused certain difficulties. The university course in physics, like a number of other natural science areas of human knowledge, is characterized by the fact that this science is experimental. Therefore, the educational process in physics at the university in all fields of study and levels of training involves both the study of theoretical material and practical workshops on solving tasks, as well as the implementation of a large amount of laboratory work. Thus, mastering a physics course is not only the acquisition of solid theoretical knowledge by students, but also the ability to apply this knowledge in practice. This aspect of the educational process organization caused certain difficulties.

Computer simulation of physical processes appears to be helpful in solving the problem of implementing laboratory practice in the absence of access to real experimental equipment. This approach is currently widely used in research experiments in various fields of physics and technology [32]–[39]. However, computer modeling in the field of educational experiment is used only sporadically [40]–[42]. Thus, the study explored possible ways of implementing a laboratory workshop in physics and electrical disciplines at the university in the remote mode. In particular, the study analyzed the experience of using three approaches, the main of which is based on the use of the Multisim 12.0 platform [43] designed for computer simulation of various electrical circuits and virtual study of their operating modes.

2. RESEARCH METHOD

The research analyzed the possibilities of modern digital teaching aids for the implementation of distance learning technologies during a laboratory workshop in physics and related disciplines, as well as to substantiate the choice of specific tools and to experimentally test their effectiveness. The paper examines the experience of the Department of Physics of the Elabuga Institute of the Kazan Federal University in the system of training bachelor-degree teachers and technologists in studying physics and related electrotechnical disciplines. The study involved 55 second-year students of the Department of Mathematics and Natural Sciences, as well as 24 third-year students of the Department of Engineering and Technology.

The research methods included theoretical methods, including the analysis of the research subject and its features based on the study of scientific, technical and pedagogical literature. It also employed empirical methods for the implementation of the developed distance learning technologies in the educational process, assessment of their effectiveness based on an interview and questionnaire survey of students.

As part of the study, we interviewed all the respondents available. Small as it might seem, their number was predetermined by a group of students of the same course. It allowed us not to exclude important observations and ensure the reliability of the results obtained.

3. RESULTS AND DISCUSSION

Since 2014, e-learning courses in all areas of physics and electrotechnical disciplines have been developed, introduced in the educational process and are successfully used at the university to implement blended learning [27]–[30]. The courses contain all the necessary teaching and control elements for effective remote support of various types of educational activities: studying the necessary theoretical materials, practicing skills and abilities to solve physical tasks, conducting educational and research experiments. That is why the forced complete transition to distance learning due to the COVID-19 pandemic went rather smoothly. The already available validated e-learning courses in LMS Moodle, supplemented by online classes on the Microsoft Teams platform, ensured a rather effective delivery of lectures on studying theoretical material and practical workshops on solving physical tasks. The main problems arose during the implementation of laboratory workshops due to the fact that students cannot use the laboratory equipment at a distance.

A laboratory workshop is one of the most important links for the successful mastering of physics and many other natural science disciplines. In this regard, the ongoing search for the most effective approaches to organizing students' in-class and independent work continues. These problems were identified in Russia a long time ago. As early as 15 years ago, Borodina and Shestakova [44] were engaged in the development of models for organizing and conducting a laboratory workshop by distance learning. With the emergence and improvement of modern information technologies, research has begun on attracting distance learning to certain laboratory classes. The rapid development of the COVID-19 pandemic all over the world has made this problem especially urgent, while the intensity of research on the possibilities of using distance learning technologies in the implementation of a laboratory workshop in natural science disciplines has significantly increased both in Russia and abroad [40]–[42]. One of the promising areas is the development of online training tools and simulators in a variety of disciplines [13].

In this work, the authors intend to use to the fullest extent the material that had been accumulated over the years. Therefore, the approach is based on e-learning courses in LMS Moodle. In addition, video conferences in Microsoft Teams were used. Such tandem turned out to be quite enough for the organization of learning the theoretical material online and training in solving tasks. It should be noted that the students already had sufficient experience of working in this format when blended learning was implemented; therefore, there were no particular difficulties.

The question arose about the online implementation of laboratory workshops. The following steps were taken to solve this problem. At the first stage, they were the same for all the disciplines and consisted of the following. Special blocks with additional materials, aimed at performing each of the laboratory works of the workshop, were added to the corresponding e-learning modules. A variant of such a module is shown in Figure 1.

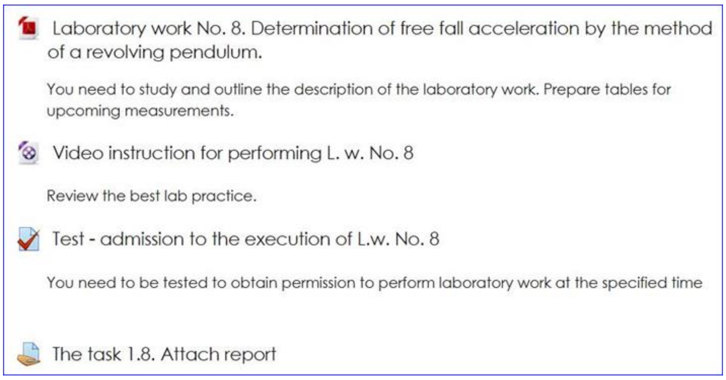

Figure 1. E-learning course materials on preparation for laboratory work

The algorithm for students' work with these e-learning course elements: At the preparatory stage, students study the description of the upcoming laboratory work, prepare tables for future measurements, discuss emerging issues at the forum with course mates and the teacher. Then, at a strictly defined time, they undergo computer testing and receive permission to conduct specific laboratory measurements. In addition, video instructions on the work performance were placed in a number of blocks.

To implement the next step, the authors used three different approaches for different disciplines and separate works. In the first (the simplest) case, students were given personal ready-made data of the "performed" measurements. Students were required to perform numerical processing of these results: to construct graphs and calculate measurement error. Then it was necessary to draw up a standard laboratory report and attach it as a file to the corresponding course assignment for a teacher to check. If necessary, a teacher could demand from a student to defend the work online on the Microsoft Teams platform.

In the second case, a video conference with a teacher making the necessary measurements on the Microsoft Teams platform was held. When conducting online laboratory workshops, ready-for-class students observed in a remote dialogue the performance of specific laboratory work by a teacher. Simultaneously with the teacher, the students "read out" and entered the results of the full-scale experiment into their tables. Then they also processed and calculated the results of the experiments performed. The completed report for each work was also attached as a file to the corresponding course assignment for the teacher to check and assess. It should be noted that this approach resembles a combination of full-scale and virtual laboratory workshops. This multifaceted type of students' distance work to observe the experiment and work with the e-learning course, after the teacher had given a preliminary assessment, was subjected to another type of experimental work (pedagogical research). It included a questionnaire survey and an interview, during which the experiment participants expressed their personal, independent opinion on the system of all forms, types and areas of the work done in a distance learning format. From among 79 participants in the pedagogical experiment, 69 students (87.36%) expressed their positive opinion on the implementation of this technology and 10 students (approximately 12.64% of all respondents) noted a number of shortcomings. The results of the primary pedagogical experiment, which was rather positive in general, nevertheless made it necessary to search for new technological solutions for organizing distance learning types of laboratory classes with students. This led to the development of one more technology.

This third option related to the conduct of laboratory work in electrotechnical disciplines, where the greatest efficiency was shown by another approach developed by the authors, based on the use of Multisim 12.0 software [39], intended for the interactive creation of various electrical circuits and the study of their operating modes. A feature of this platform is that it allows bringing the virtual experiment as close as possible to the real-life laboratory work of a stationary workshop [40]. The e-learning course for students is provided with a link to download and install the Multisim program. Experience has shown that to ensure reliability, the program should be installed step-by-step under the teacher's real-time supervision in a direct dialogue in Microsoft Teams. The first laboratory work is also best done together with the teacher as shown in Figure 2. The other works are performed by each student independently.

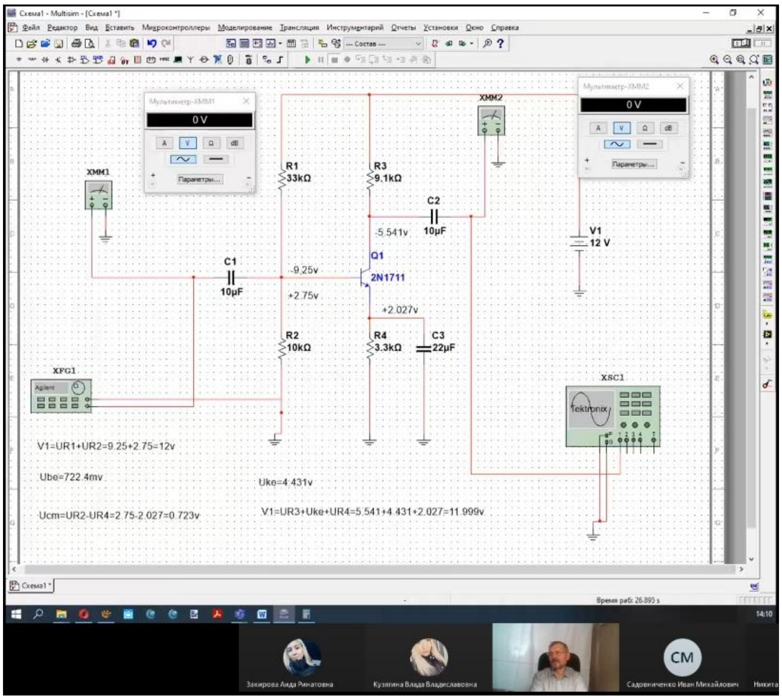

Figure 2. Simulation of the first laboratory work in Multisim

It should be noted that the measuring devices in this simulator have a layout and control that are completely similar to real devices, which brings the virtual work performance closer to a real experiment in the best way as shown in Figure 3. For example, the performance of the laboratory work "The Study of Common Emitter/Common Base/Common Collector Single-Stage Amplifying Cascades" is completely analogous to a full-scale experiment. The students enter the measurement results into Microsoft Excel tables, construct graphs and attach them as a file to the corresponding assignment in the e-learning course. After the teacher checks the results, the work is defended in Microsoft Teams (similar to what is done during in-class training). It should be noted separately that the effectiveness and ease of use of this simulator were noted by all participants (without exception) in an additional pedagogical experiment conducted by the authors.

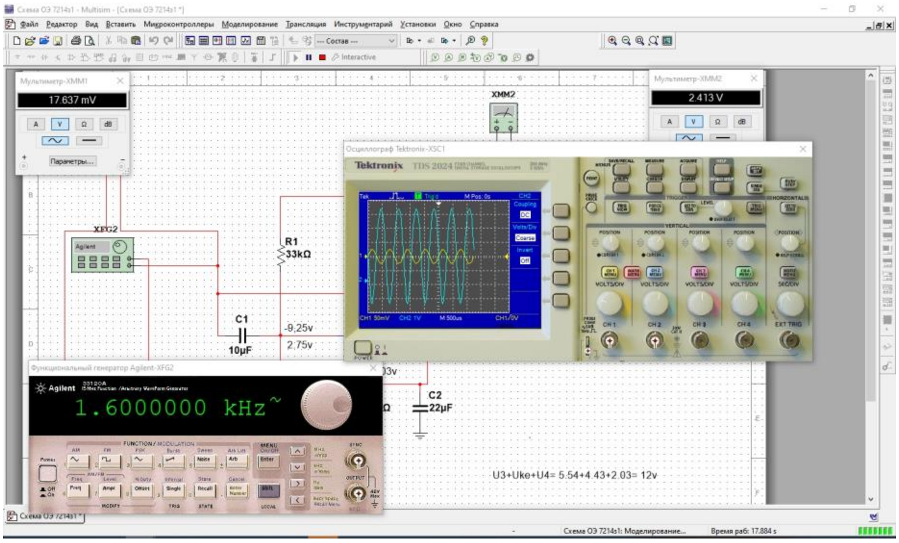

Figure 3. Layout of measuring devices in Multisim

4. CONCLUSION

The research revealed that modern digital tools and technologies, with carefully selection and well-considered use, are rather suitable for the effective preparation and implementation of laboratory workshops in physics and related disciplines in a distance learning format. Thus, the joint use of e-learning courses in LMS Moodle and online performance of laboratory work on the Microsoft Teams platform proved to be useful when holding laboratory classes in general physics. When implementing a laboratory workshop in electrotechnical disciplines, Multisim 12.0 software showed the greatest efficiency. Thus, with a competent, well-considered selection and use of digital tools and methods, distance learning can be as close as possible to the traditional mode of study, which contributes to the successful assimilation of educational material. We should note that the specificity of a particular discipline determines the choice of certain instruments as well as their combination. The research findings can be used in the educational process of a university in the preparation and conduct of laboratory works in a number of natural science disciplines.

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