European Proceedings of
Social and Behavioural Sciences
EpSBS

www.europeanproceedings.com
e-ISSN: 2357-1330

DOI: 10.15405/epsbs.2021.06.03.105

AMURCON 2020
International Scientific Conference

THE EXPERIENCE IN ORGANIZING A HANDS-ON COURSE IN PHYSICS IN E-LEARNING ENVIRONMENT

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Abstract

The paper considers the issues of organizing Laboratory Practicum when changing to online training in March-April 2020. The authors analyze the possible usage of virtual laboratory works in Physics available on the Internet for distance learning in higher education. It is shown that many hands-on and lab sessions respectively do not allow using virtual labs available on the Internet, at the Physics Department at Pacific National University. There are three main options for doing laboratory works in a remote learning at the department. The authors use electronic courses developed at the department and based on the virtual learning environment Moodle. The researchers do a comparative analysis of the first-year students' performance in Physics in the summer exams of 2019 and 2020. They also analyze the academic performance of 110 students. Remote learning did not affect students' academic performance greatly. They did a survey to compare the degree of students' satisfaction with learning in laboratory classes offline and online. It was done in October 2020 among 66 second-year Engineering students in two majors. It evaluated the training outcomes for the preceding year. The students' answers to the questionnaire are shown in the table as credits. Students highly appreciate the laboratory classes online. At the same time, the marks differ a little from those of the lab works in the classroom. The transition to online training discovered several problems in organizing distance learning. These problems are most referred to the subjects in the syllabus of which laboratory classes are included.

Keywords: E-course, Physics, virtual course, distance learning, laboratory works

https://doi.org/10.15405/epsbs.2021.06.03.105
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eISSN: 2357-1330

1. Introduction

The main task of e-learning is to organize distance independent learning activities for students. It is necessary to study e-learning contents of the subject, a lecturer's tuition, engaging in the syllabus of the subject, knowledge control and self-control, interaction with other participants in the virtual study group, etc. The condition of distance e-learning is an opportunity for students to work with various multimedia applications through electronic gadgets that have access to the Internet (personal computer, tablet, mobile phone, smart TV). Such arrangement of students' activities allows one to build an individual learning trajectory, access to educational resources, interaction with an educator, both online and offline, that is, synchronously and asynchronously, and there are no time and space restrictions. Students have available access to educational services, equal learning opportunities, reduced training costs, the opportunity to study constantly at a convenient time on-the-job (Sjasina, 2020).

The emergency that took place in many Russian universities in the spring of 2020 because of the transition to distance education is connected to several factors. First, the technological unavailability of previously designed platforms for their massive usage for e-learning of the entire university at the same time. Secondly, the lack of methodological readiness of a larger part of e-learning courses for practical application in the conditions of a quick (three to seven days) transition to online learning. Third, the lack of experience in conducting this type of training for most of the academic staff, and psychological unpreparedness of many lecturers for intensive work online. It also included many problems, both technical and organizational, on the part of students. The analysis of all these factors about the universities of the Russian Federation is quite a complex and compound task, and cannot be completed in one article.

2. Problem Statement

The Department of Physics at the Pacific National University (PNU) is a graduate chair in two areas. They are Physics is a Bachelor's degree, major Information systems in Physics and MA course in Condensed Matter Physics. The second area is a Bachelor's degree in Teacher education with two majors-Physics and Computer Science (5-year course of study). The Department also provides training in Physics and several other subjects for students in various majors at the university, the curriculum of which provides laboratory works. When shifting to e-learning in March 2020, it was necessary to organize laboratory works (LWs) for a large number of laboratory practicums fast. In the main building of PNU there were three workshops on General Physics for Engineering and IT students of PNU (20 LWs for 71 groups of students); three workshops on Physics for Physics students (30 LWs for 3 groups of students); workshop on Physical fundamentals of Electronics (9 LWs, 4 groups of IT students). In the building of the Teacher Training Institute of PNU, there were nine different workshops for Teacher education students (59 LW in total, 4 groups of students).

Before the transition to online training, the students completed from one third to a half of LWs, the rest of LWs had to be performed remotely. Taking into account the changes made to LW schedule, students had to perform 40-50% of LWs, in total, and this amounted to 60 different laboratory works in 82 groups of students.

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The only laboratory works related to direct measurements with the instruments on systems (facilities) and stands in the laboratories of the department are mentioned above. Also, the department has several workshops performed on computers, for example, Special Practice: Mathematical Modeling of physical processes. This article does not observe the problems of their preparation online.

3. Research Questions

The use of laboratory works in education is undoubtedly crucial for vocational training. Studies by Russian and foreign scientists show that the correct organization of laboratory works from the point of view of methodology generates the most important professional competencies and skills of students (Anoshina, 2019; Artun et al., 2020; Hernández-de-Menéndez et al., 2019; Rannih, 2015; Senthamarai, 2018). Virtual and remote laboratories used as a research and educational sites, which have grown in number in recent years, reduce the cost of practical laboratories (reducing the cost of equipment, space, maintenance, upgrades, training, etc.).

3.1. The possibility of using virtual laboratory works in the context of the transition to distance learning in the spring of 2020

Virtual science labs are improving year by year as more and more students seek to improve their education and careers through online learning. At the same time, professional laboratories are increasingly using robotics, remote sensors, and related technologies to make laboratories more versatile, efficient, accurate, and remotely controlled. There are quite a lot of web portals that offer virtual laboratory works on a variety of topics, and one can perform them both online and off-line. One of the most developed portals dedicated to virtual laboratories is the online resources of Virtulab.Net and PhET Interactive Simulations. They allow students to carry out virtual experiments in Physics, Chemistry, Biology, Ecology and other subjects.

The PhET Interactive Simulations portal is a powerful non-profit Open Educational Resource (OER), the project of the University of Colorado, founded in 2002 by Nobel Prize winner Carl Wieman. Most of the virtual experiments have been translated into 65 languages, including Russian. You can also use the PhET app, which is available for both iOS and Android devices.

Similar domestic resource Virtulab.Net is the largest collection of virtual experiments in various academic subjects in Russia, but its disadvantages include the use of outdated Adobe Flash technology, as well as the lack of openness of the content posted. At the same time, the PhET portal allows one to run experiments online, download them to a user's local computer, and embed them on other web pages.

Another source of online laboratories is the multi-industry resource Wolfram Demonstrations Project, which is supposed to be a single platform with a unified catalogue of interactive laboratories. According to its developers, this will avoid problems related to the use of various training resources and development platforms. Currently, the portal contains more than 12 thousand interactive demonstrations. However, to use them, a user needs to install special software. Also, the disadvantages include the use of only English in the portal interface. The advantages include open source code in Wolfram Language.

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In addition to multi-industry projects in the modern Internet, there are many specialized online laboratories specialized in Physics. For example, the Russian project Virtual Laboratory (Bessonov & Dergobuzov, 2018), specializing in physical phenomena. The design of laboratories is schematic and pure. The main focus of the experiments is placed on performing specific tasks and testing the user's skills. Devices are shown as diagrams, it is proposed to build graphs and choose answers from the available options. Experiments in Virtual Laboratory are more difficult than in the online resource VirtuLab.

The common disadvantages of these resources include the inability to adapt the practicum within the course being taught (depending on the major of students). Also, most laboratory works have either a simplified interface that does not allow one to work with it at the university or the emphasis is not on the physical core of the phenomenon explored (a large number of settings that are not related to the physics of the phenomenon). This leads to the need to design and develop a virtual laboratory workshop adapted for students of a particular university. Virtual work in its functions should be as close as possible to its interface to a real stationary laboratory facility, as well as correspond to the syllabus of the subject being mastered. The last requirement is that the Internet resources discussed above cannot provide due to their universality. The intuitive interface of the virtual laboratory work (close to a stationary facility) allows students to master the management of this work faster and carry out all the necessary measurements quickly. This is especially important when working in a distance learning format.

Many native and foreign authors note that any type of laboratory (virtual or real) is not a sufficient condition for ensuring success in education (Hernández-de-Menéndez et al., 2019; Sorokova, 2020). Any type of laboratory offered as a separate tool, with no connection to the learning contents, usually leads students to use a cut and try a strategy, which does not contribute much to the successful training. Blended learning (i.e. a combination of hands-on activities, virtual and/or remote labs) may be the best suggestion for Engineering education instead of using just one type of lab. In the paper (Hernandez-de-Mendez et al., 2019), it is noted that practical laboratories could be used in the first stage to draw confidence policing in the virtual experiment that will be used in the second stage.

4. Purpose of the Study

The analysis of the resources available on the Internet revealed a number of organizational factors that prevent the use of virtual laboratory works in the transition to online training in the present conditions at the Department of Physics of PNU. The main ones are a large number of laboratory workshops with a different set of LWs; the impossibility or high cost of simultaneous use of one or several LWs by a large group of students; technological difficulties in using a number of resources connected to the adaptation of the resource software; the need to prepare methodological support for each new LW and a number of others.

- The objectives of this research are:
- Consider the problems that appear during the transition to distance e-learning in the spring semester of the 2019-2020 academic year at the Department of Physics of PNU in organizing laboratory workshops.
- Evaluate the impact of performing laboratory works online on students' academic performance.
- Determine students' satisfaction level with laboratory classes with learning in the classroom and remotely.

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5. Research Methods

5.1. Organization of laboratory works at the Department of Physics at PNU

Technologically, the University was prepared to conduct classes online since the University has been operating an electronic educational environment (EEE) for several years (Maslennikova & Nadezhdina, 2014; Smoljaninova & Ivanov, 2019) based on the virtual learning environment Moodle and the electronic library of the University. All educators took various advanced training courses on the use of IT in the learning process. Students are also introduced to EEE during the first weeks of their studies. In the first semester of the 2019-2020 academic year, fully-featured e-learning courses for correspondence and a number of full-time courses were designed at the Department of Physics of PNU in EEE.

However, despite the work done, a number of difficulties arose during the transition of the full-time department of the university to distance learning in March 2020. Most of them were overcome within one or two weeks. The main difficulty at the Department of Physics was the process of organizing laboratory works.

According to the above arguments, it was decided to organize the LWs online by the lecturers of the department based on their self-design projects. At the same time, it was taken into account that the department already had experience in conducting laboratory works online for extramural students. In February-March of the spring semester, students performed part of the LWs in the laboratories of the department and got acquainted with the devices and stands. Different approaches were used for different workshops. At the same time, all standard types of control were provided in the electronic course: preparation of a report for laboratory work, delivery and control of results, answers to test questions on the theory of this LW. In accordance with the curriculum and schedule of the LW, a colloquium was held on the topics of the lecture content. According to the lecturer's decision, the colloquium was held either as an electronic testing online (10-15 versions) or in a virtual classroom, on distributed questions and panel discussion of answers.

The students performed laboratory works remotely according to three scenarios:

A small video file was shot: the lecturer introduces the students to the laboratory facility and takes measurements. The measurement results are displayed on the device screen. The video file was placed in the EEE electronic course with the instructor's comments. The student calculated the required values based on the given measurement data.

In the electronic course, pictures of the laboratory facility and scales of measuring devices were given to a certain LW. At the same time, the experiment was carried out 3-5 times, respectively, and the instrument readings were given the same number of times.

In the electronic course, tables of measured values were provided for each laboratory work, for example, the current-voltage characteristics of the diode at different temperatures. The task of the students was to build graphs and calculate the required values. At the same time, in this version, the ratios of the values in the tables changed when the next team of students (usually 2 people) performed the work.

The first option was used in most of the laboratory workshops of the Teacher Training Institute of PNU, the second one was used in electronic courses on General Physics, and the third one was used in

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Physical Foundations of Electronics course. In all three cases, the students sent a handwritten report on the laboratory work as PDF or JPEG files to the EEE.

6. Findings

6.1. Impact of online laboratory work on students ' academic performance

The authors made a comparative analysis of the performance in Physics of first-year students in the summer sessions of 2019 (students worked in a regular mode) and 2020 (from the end of March to June distance learning mode). They analyzed the academic performance of three groups of Construction students and three groups of IT students, 110 people in total. The differentiation of the results of the end-of-semester exams showed no significant deviations in terms of the number of credits (in groups of IT major) and the number of positive marks during exams (groups of Construction students). At the same time, the scatter of readings between individual groups in one exam period was more than the differences between end-of-semester exams. Similar results were obtained for exam or credit eligibility criteria for performing laboratory works. Thus, the transition to distance learning did not significantly affect the students' academic performance. This conclusion is the same as the previously obtained results of several authors. In particular, the conclusion that online learning is as effective as conventional learning is made in the review of Nguyen (2015).

Possible significant impact on the results of academic performance in the 2020 exams was influenced by the possibility of applying for the Internet assistance, as well as plagiarism (cheating) when performing LWs online. This, for example, is indicated by the results of intermediate testing of students of three groups on Physical Foundations of Electronics. 95% of students answered correctly to 11 or more questions (75%) on the first attempt in 40 minutes when doing the test consisting of 15 questions. During classroom sessions, the result was always less than 70 %, provided that it was impossible to access the Internet. This problem is discussed in sufficient detail in various works, for example, in (Gorbov & Chigrin, 2013).

6.2. The level of students' satisfaction with conducting laboratory classes in distance mode

In addition, a survey of students was conducted to compare the level of their satisfaction with learning in laboratory classes, offline and online. A questionnaire includes nine questions (Table 1). 66 second-year students in two Engineering majors participated in the survey in October 2020. It evaluated the training results for the previous year (1st year). The students were required to give a mark from 1 to 5 points for each question. Table 1 shows the number of ratings depending on the scores for each question.

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Table 1. The number of students' grades depending on the scores when answering the questionnaire

Questions	Points				
	1	2	3	4	5
Evaluate how satisfied you are with the quality of training manuals for laboratory works posted on the website of the Department of Physics.	0	0	4	14	48
Evaluate how satisfied you are with the equipment for performing laboratory works in the classrooms of the Department of Physics.	0	12	4	24	36
Evaluate how satisfied you are with the lecturer's communication in the classroom during laboratory classes in September-March 2020.	0	0	10	20	36
Evaluate how satisfied you are with communicating with the lecturer during laboratory classes in distance learning in April-June 2020.	2	4	6	8	46
Evaluate how satisfied you were with the methodological support of the distance laboratory works in April-June 2020.	0	4	4	22	36
Evaluate how much you are satisfied in April-June 2020.	2	2	6	22	34
Evaluate how much, in your opinion, laboratory works contribute to the study of the subject.	0	8	16	24	18
Evaluate how satisfied you are with the quality of teaching in the subject as a whole.	0	0	8	30	28

As can be seen from the table, students quite highly appreciate both the methodological support and the process of conducting laboratory classes in distance mode. At the same time, these estimates actually differ little from the estimates of the work on LW performance in the classroom. This can largely be explained by the fact that students worked in the laboratories of the department in the first semester and almost half of the second one and could manage the equipment. Also, it is confirmed by the fact that performing LWs online according to the *scenarios* described above was much easier for them than performing *real* LWs.

The highest ratings were awarded to the methodological support of the LWs (point 1 of the questionnaire) and communication with an educator during laboratory classes in distance learning (point 4 of the questionnaire). The latter, apparently, suggests that most students had an opportunity to communicate with the instructor online and received advice on issues on time. On the other hand, this can also be interpreted as a more liberal attitude of lecturers to the evaluation of the results of LWs and answers to theoretical questions, compared to the offline format.

7. Conclusion

In conclusion, the review shows that the transition to online learning has revealed a number of problems in organizing distance learning. These problems are most relevant to the subjects in the syllabus in which laboratory classes are required. The transition to distance learning did not lead to a decrease in academic performance in Physics at the end of the exam period. Students are generally satisfied with the quality of LWs in distance learning. The negative aspects of the transition to online training include the inability to simulate interaction with real measuring devices while performing LWs: assembling the facility, configuring the devices, taking readings, evaluating the results of measurements and calculations, and several others. On the one hand, distance learning showed the rapid adaptation of educators to practical work in the Moodle environment and organization of virtual classes. Most of them note a lack of

competence in the technological and pedagogical skills required for online teaching. This problem is common to most universities in Russia and abroad (Downing & Dyment, 2013).

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