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THE IMPACT OF THE VIRTUAL LABORATORY ON THE PHYSICS LEARNING PROCESS

Loreta Juškaite
Riga Technical University, Latvia

Abstract. *ICT has invaded the educational process and is providing us with many opportunities to exploit. An additional challenge faced by Physic educators has been the integration of Virtual laboratories in the teaching process. In recent years, Inquiry-Based Science Education has proved its efficacy in education by expanding on "traditional" lessons and motivating students to actively participate in science. Digital technologies support necessary educational innovations and can be the catalyst for change in educational patterns (in regard to its form, space, functions, services, tools, roles, procedures). Virtual laboratories are an essential digital tool. In fact, many Latvian schools are equipped with computer classes, tablets and high-speed internet connection while using a huge variety of web-based learning applications, simulations and visualizations. The paper evaluates necessary skills and abilities which can be developed at the secondary level, analysing and planning the interaction between the physics education process and technological development. The article also highlights the direction of future research. The paper evaluates necessary skills and abilities which can be developed at the secondary level, analysing and planning the interaction between the physics education process and technological development. The article also highlights the direction of future research.*
Keywords: *abilities, interactions, physics education, skills, strategic decisions, sustainable competitive advantage, virtual laboratory.*

Introduction

Globalization, technological change, intense competition, changing labour market demand, economic and political change encourage young people to take higher risks when choosing future study pathways and career as well as appropriate strategies. What skills and abilities should be acquired in order to be flexible and adapt to technological change? What are the skills and abilities that allow you to develop dynamic capabilities and what are the benefits of physics education? This leads to the question of how some young people are able to successfully adapt to the changing labour market and the dynamics of change in general, also being able to develop their careers

The experimental activity is an indispensable practice in the process of knowledge development in Physics and the lack of modern and equipped laboratories is one of the main reasons of the separation between theoretical approach and the practical one. This problem is experienced by most of the

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secondary schools in Latvia. The virtual lab can be defined as virtual studying and learning environment that stimulates the real laboratory. It provides the students with tools, materials and lab sets on computer in order to perform experiments subjectively or within a group at anywhere and anytime. These experiments are saved on localized data storage sites, recorded on different types of data carriers or on web site. The diverse and wide range of modern virtual labs often put physics teachers in a serious dilemma of when and how to choose... terms of selection of such programs and their adaptation to the subject matter in the pre-service and in-service teacher training processes (Bybee, 2014).

Regarding the enhancement of learning, the use of the computational resources contributed significantly to the understanding of the content by the students, allowing the better relationship between theory and practice. Empowering young individuals to construct their own learning by being autonomous, taking initiatives, analysing, synthesizing and evaluating their knowledge and understanding is the basis of constructivist pedagogy (Brooks & Brooks, 1999). The virtual laboratories are delivered with computer technology and offer investigations, which involve simulated material and equipment and are performed by the students. A physical process can be described using some different representations: text, diagrams, formulae, and applets. Showing animations of a dynamical system and tying it to a coordinated graph, diagram or plot can help the students develop skills in using different representations.

Materials and methods

Research methods:

1) analysis of scientific literature;
2) descriptive statistics and dependency analysis were used to process the data. The analysis of the research data was carried out using Classical Test Theory (CTT) (Ballantyne, 2000) and Test Analysis Program ITEMAN™ for Windows (Kehoe, 2005). The charts and tables were created using MS Excel and Tableau Public (Perez, 2010).

The aim of this study is to inform physics educators, teachers, and pre-service teachers of the virtual labs used in teaching physics nowadays, to demonstrate which skills and abilities can be improved and developed, as well as to present a comparison of the results of students (who worked in different types of laboratories). This research is intended to contribute to utilization of virtual physics labs by users with expected efficiency.

A virtual laboratory is an essential component of the Physics study

Over the last 10 years, virtual laboratories are constantly evolving and improving, a repository for online experiments has been developed which includes online labs, learning applications, and virtual inquiry learning spaces making them accessible to teachers all over the world (Pellegrino & Hilton, 2012). Laboratory course is an essential component of the physics study. To which extent can technology be used when organising laboratory exercises, investigation and experiments? Laboratory work is a typical form of experiential learning (Potkonjak et al., 2016). The role of experience in learning is well known. It is especially important in learning of the sciences. Learning models based on experience date back to the ideas of British empiricism and John Locke; John Dewey's philosophy of pragmatism; Jean Piaget's theory of cognitive development; David Kolb's experiential learning, etc. (Pellegrino & Hilton, 2012). These models imply a concrete experience, active laboratory experimentation, in which the earner 'touches all the bases' (Kolb, Boyatzis, & Mainemelis, 2001) and has a tactile contact with the object of study. Effective learning is seen when the learner progresses through a cycle of four stages: of (1) having a concrete experience followed by (2) observation of and reflection on that experience which leads to (3) the formation of abstract concepts (analysis) and generalisations (conclusions) which are then (4) used to test hypothesis in future situations, resulting in new experiences (Kolb, Boyatzis, & Mainemelis, 2001).

In classes, where the study was conducted, it was mainly used for virtual simulations of well-known experiments in Physics, which offered the opportunity to compare them directly with hands-on laboratories and were user-friendly, easily accessible online for all students, and provided a wealth of experimental skills to students of all learning levels (Kolb, Boyatzis, & Mainemelis, 2001).

Table 1 ***The main components of the virtual labs***

No	Tools	Notes
1.	The lab sets & equipments	The virtual lab is considered integral to the traditional lab but not an alternative to it. The existence of the traditional lab is very necessary, but in lower numbers and requirements, which help in the possibility of using it by several users outside the lab (Kolb, Boyatzis, & Mainemelis, 2001)
2.	ICT or/and mobiles devices	They are represented in personal laptops, Smartphone's, data loggers, which are linked to the local net or to the international net so that the student can work directly in the lab, or distantly at anywhere and anytime.
3.	Communication network & the related hardware	In case of performing experiments electronically, all the sets should be linked to the necessary device, because the link between the users with a lab will be through digital communication.

No	Tools	Notes
4.	The Software of the Virtual Lab	This software is represented in the simulation programs, which are designed by professionals. It is necessary to design this program in an interesting and attractive form; as these programs were designed to attract students' attention and urge them to complete the experiment. This is maintained by the animation and simulation techniques, video, and the three dimensions pictures (Potkonjak et al., 2016).
5.	Co-operation software/ Programs & Management.	These programs are concerned with the method of managing the lab and the ones who perform the experiment, including students and researchers. These special programs register students in the lab program and determine the kinds of access that should be provided to each user in the different experiments.
6.	Technical support	It is important that the educational organization has a technical team to support the training of teachers.
7.	Methodical support	According to the author and after discussions with Latvian physics teachers, the most essential part of the learning process is methodological support. Only by applying methodically multi-functional virtual laboratories it is possible to get the desired results. In Latvian schools, it is the most common problem.

An alternative learning environment, a virtual laboratory, seems to contribute to the occurrence of meaningful learning. It is gaining popularity in many ways: there are numerous educational applications, computer-assisted simulations, copying natural phenomena and conditions of an experiment (Basher & Isa, 2006). The main tangible and intangible benefits of a virtual lab in addition to a physical one are the following.

The benefits of a virtual laboratory:

- The general view is that simulations and virtual labs are learner-centred and inquiry-based, which promotes higher levels of thinking and retention. It also allows students to receive immediate feedback and correct their faulty understanding of a concept (González-Gómez et al., 2013). The physical labs reflect traditional learning (Basher & Isa, 2008).
- Virtual laboratories are seen as a low-cost solution for laboratory experiments. Experiments that would be too expensive (either cost of instrumentation/equipment or supplies), complicated or even dangerous to work with can be recreated safely in the virtual environment, thus bridging the gaps found in traditional laboratories (Tatli & Ayas, 2013), (Basher & Isa, 2006). In addition, experimentation time significantly reduces and routine procedures of processing experimental results become less complex.

- Remote labs are used as supplementary tools for complementing in-person laboratory education (Tatli & Ayas, 2013) including virtual elements which interact with real ones, thus exposing students to blended learning (González-Gómez et al., 2013). Another benefit offers more possibilities to simulate and visualise quite a number of complex scientific concepts. Students increase their knowledge regarding unobservable molecular and atomic level phenomena and acquire a better conceptual understanding (González-Gómez et al., 2013).
- Students become more positive toward using computers for learning. They find the simulation of laboratory assignments motivating and creating a lot of experience (González-Gómez et al., 2013). Simulation supports students in the accomplishment of cognitive tasks and enhances their learning processes (Tatli & Ayas, 2013).

Research analyses and findings

In order to emphasize the importance of experimental and research skills in the acquisition of subjects and to involve as many students as possible in the development of laboratory work, in 2016/2017 and 2017/2018 VISC (National Centre for Education) offered schools diagnostic laboratory works in grade 11 physics and chemistry. Physics and chemistry diagnostic laboratory works is organized at the same time. Educational institutions will be able to allow pupils to choose in which diagnostic job they will participate in (Cābelis, 2018).

In total, 243 students participated in this study. Participants were randomly assigned to 3 groups: 2 experimental groups (n1 = 109, n2= 109) and control (tests) group (n = 25). The first experimental group n1 was provided with a virtual lab-based inquiry learning environment, the second experimental group n2 was provided with a blended (virtual and traditional laboratory works). The control (test) group n was taught in a traditional format (teacher's instructions in book or worksheet). All students volunteered to participate in the experiment and the assessment process. They were curious to monitor their progress and receive feedback on their achievements. Students were provided with 3 learning environments: traditional in-class learning;

- blended learning – virtual laboratory combined traditional in-class learning;
- virtual laboratory combined with IT tools and mobile technologies (sensors, data loggers).

Laboratory sessions also include calculations, writing a lab report and a final assessment. In classes, where the study was conducted, it was mainly used for virtual simulations of well-known experiments in Physics, which offered the opportunity to compare them directly with hands-on laboratories and were user-friendly, easily accessible online for all students, and provided a wealth of experimental skills to students of all learning levels. The effectiveness and results of laboratory work were evaluated by comparing these factors: the lab reports of the experimental group students with the lab reports of the control group students and test results which aimed to assess student achievement of learning objectives (development of such skills as analysis of results quality, data interpretation and analysis, research skills).

1. Is there a difference between the resulting applied knowledge and skills in the experimental groups and in the control group?
2. Are there any differences in the content of students' laboratory reports in the experimental groups and the control group?
3. Are there different results for pupils working in groups, which require collaboration, communication and information search skills?

The experiment has three stages: ascertaining, formative and summative. At the ascertaining stage, all groups were put to a pre-lab test to compare students in terms of their relevant prior knowledge of physic phenomena and experimental (laboratory) experience. Then, all students performed traditional laboratory work and wrote lab reports. These results were important for comparing all groups. Before each practical laboratory class, all students were given equal time-on-task to get prepared for a traditional lab.

First, they were tested about the knowledge of physics content and the understanding of physical processes. The test consisted of 25 tasks (20 multiple choice questions (Ballantyne, 2000) and 5 solving tasks). The time allowed for this test was 80 minutes. The tests included also the following tasks such as:

1. Describe the specifications of an instrument, the procedure and the use of instruments. (Given names and purpose of the instruments, you need to select and write a specification. It is possible to work with catalogues, device descriptions, search for information on the Internet).
2. Choose and describe the relevant method for determining the surface tension coefficient of a liquid, using available devices. The best-suited method should be chosen for research).
3. Determine key figures using the graph and summarise conclusion and give a recommendation. (Different graphs and images are provided (results of statistical data, changes of physical parameters).

The results of the physics content knowledge and physical process test are shown in Figure 1.

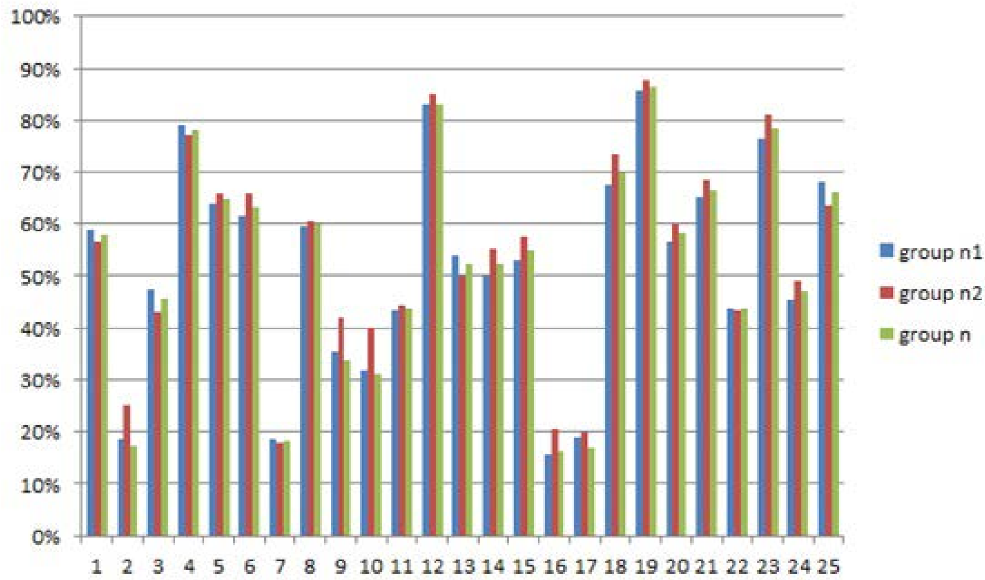

Figure1 ***The results of the physics knowledge and physical process***

As shown in Figure 1, students from the n2 group showed better results in solving tasks with graphical and visual information.

Lab reports they were instructed what requirements their reports should meet. The requirements for report writing in fact repeated 8 criteria (Physics diagnostic laboratory works criteria VISC, 2015) to evaluate the quality of student reports. They are as follows:

1. scientific validity and clearly formulated objectives;
2. relevant description of methods and instruments;
3. critical approach, depth and logic of theoretical background;
4. ability to make measurements;
5. ability to process obtained results (including graphics);
6. ability to critically analyse obtained results, to describe abnormal or unexpected results;
7. validity and clarity of conclusions;
8. practicality and clarity of recommendations.

The results of comparing student laboratory reports from the all groups based on 8 criteria at the summative stage are presented in Figure 2.

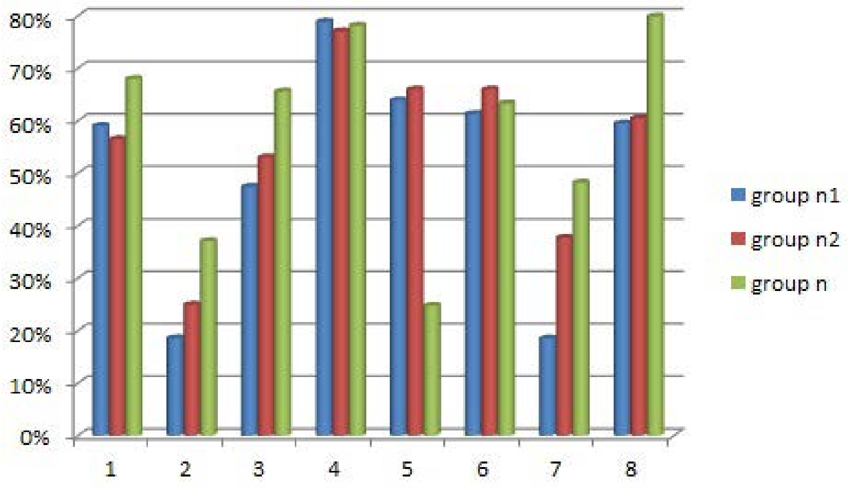

Figure 2 ***The results of comparing student's laboratory reports***

As evident from Figure 2, it is apparent from data that the groups show statistically significant differences in some parameters. Students in the control (test) group n have outperformed students in another group in terms of research skills and practices. Statistically significant differences (Attali & Tamar, 2000) were observed for criteria 1, 2, 3, 5, 7 and 8. Thus, the null hypothesis that there is no difference in laboratory report writing skills in the experimental and control groups was rejected and the alternative hypothesis that the experimental and control students are different in terms of report writing skills was proposed. These differences are statistically significant with regard to the following specific abilities: clearly formulate research goals and objectives; describe methods and instruments; critically analyse obtained results; make valid conclusions, and offer practical recommendations. Can be seen despite some differences in some tasks that overall there are no statistically significant differences between the results (Attali & Tamar, 2000). Students who studied with virtual laboratory (Fig. 1) had better success with graphics and visual tasks, but for them, problems were caused by textual tasks and the tasks that included the elements of the research activity. At the summative stage, context-based testing was used as an assessment tool of context-based learning and cooperation skills. The latter aims are to help students gain a better knowledge of how to learn to find and use information according to context and to collaborate and communicate. Pupils were offered tasks that require productive collaboration between pupils throughout the group because the results depend on the performance of each member of the group. The members of the group have different skills and abilities; learn from each other, exchange ideas and relevant information, looking for information according to the context and providing unified answers.

Conclusions

The general studies and the research of the pedagogical experiment confirm that the best results in learning content can be achieved by using a mixed teaching method, i.e. virtual lab physics should only be used together with the traditional method, choosing methodically which of the laboratory works will be done virtually in the traditional way.

As the results show with the help of the virtual laboratory it is possible to strengthen students' ability to read and interpret graphic information, but to learn to work with text and understand the context, traditional methods are better. Cooperation and communication skills are strengthened by traditional works when pupils are forced to cooperate and help each other, which is necessary during traditional laboratory work.

It is better to teach the reports of laboratory work in the traditional environment. Students get used to a particular scheme, structure.

It might also provide hands-on experience with the physical phenomenon and build a fundamental understanding of physical concepts. Combinations of virtual and traditional laboratories offer advantages of attaining learning objectives.

A virtual laboratory might contribute to developing student scientific literacy and an appreciation for physics' place in society.

The author admits that there are limitations in the study, as the pedagogical experiment has been carried out in city schools (small regional schools were not included) and the total number of participants is not so big to make a comprehensive conclusion. This allowed to test existing knowledge and set up new research tasks that would make it possible to find out what specific elements of physics are best learned through virtual laboratories, as well as

To overcome these limitations, future work is planned aiming to enlist more participants, to collect more evidence and to make findings more representative.

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