

The Use of Virtual Physics Laboratories in Professional Training: the Analysis of the Academic Achievements Dynamics

Olena Semenikhina^{1[0000-0002-3896-8151]}, Marina Drushlyak^{1[000-0002-9648-2248]},
Artem Yurchenko^{1[0000-0002-6770-186X]}, Olga Udovychenko^{1[0000-0002-3401-3251]},
Dmytro Budyanskiy^{1[0000-0002-5699-6359]}

¹ Makarenko Sumy State Pedagogical University, Romenska St. 87, Sumy, Ukraine
e.semenikhina@fizmatsspu.sumy.ua, marydru@fizmatsspu.sumy.ua,
a.yurchenko@fizmatsspu.sumy.ua, udovich_olga@fizmatsspu.sumy.ua,
budianskiy1977@ukr.net

Abstract. The development of information technology cause the emergence of different classes of software such as virtual environment for various experiments. Among such a software, there are virtual physics laboratories that are means for educational, scientific and professional activities of physicists, physics teachers, computer science teachers and IT specialists. Numerous pedagogical findings confirm both positive dynamics and negative impact of such software on educational achievements. Given the ambiguity of the conclusions, we have formulated the problem: is it advisable to use virtual physics laboratories instead of relevant physics devices in the study of physics disciplines. The search for an answer to this question caused the organization and carrying out the pedagogical experiment, the results of which are presented in the article. Students of specialties “014 Secondary education (Physics)”, “014 Secondary education (Computer Science)”, “122 Computer science” were participants in the experiment. The purpose of the experiment was to study the dynamics of educational achievements of students whose training used virtual physics laboratories. Non-parametric sign test and Student’s test of comparison average values were used as methods of statistical analysis. Because of the experiment, the positive dynamics for all specialties were confirmed, but the largest dynamics were for the specialty 122 “Computer science”, and the smallest ones were for the specialty 014 “Secondary education (Physics)”. The best dynamics of results of IT students' achievements gives grounds to recommend to include more courses related to the study of information technologies in professional teachers’ training, because we consider this to be the cause of these results.

Keywords: Virtual Physical Laboratory, Professional Training, Educational Achievements, Physics Teachers’ Training, Computer Science Teachers’ Training, IT Specialists’ Training.

1 Introduction

Modern university training with necessity involves mastering information processes. The development of information technology (IT) in the field of physical education has led to the emergence of specialized software, the use of which involves operating computer means provided by developers. Such means can be divided into two types. The first allows you to model ideal processes. However, often in such situations, the actual implementation of research requires considerable costs of materials, electricity, time, availability of sophisticated equipment, significant monetary costs or reveals a factor of dangerous influence on the researcher. The second type involves the use of real data, which can then be used in the experiment with any model by a software. The first type is virtual physics laboratories, and the second is digital ones. Today, their use is possible at different levels of education from school to research institute, and therefore, their mastering is of interest to many educators, scholars and researchers in different fields of knowledge.

Virtual physics laboratories have been particularly developed, as often the study of natural processes requires either high computational costs or powerful visual support, or is life-threatening for the researcher. Therefore, the feasibility of using physics virtual physical laboratories today is beyond doubt. On the other hand, the qualitative training of IT specialists also requires the awareness of the physical processes that take place within the information system at the micro level, and therefore it is necessary for IT specialists to master the tools of such laboratories.

Let us mention one more group of specialists who also need to master the tools of virtual physics laboratories during their professional training. It is worth noting that the facilities of educational institutions do not have modern quality physical equipment because of its high cost. At the same time, the outdated equipment is not used or even written off. Instead, educational institutions are trying to replace the lack of physical equipment with information equipment – they buy specialized software. We should add that the introduction of modern equipment in the educational process provides solutions to the problems of modernization of the educational base and informatization of education, which are formulated in the National Strategy for the Development of Education in Ukraine for 2012-2021 [1] and in the Concept of the state target social program for improving the quality of school science [2], which stated the need for natural and mathematical subjects teachers' training and the introduction of modern information technologies in the educational process, equipping chemistry, biology, physics, geography, mathematics laboratories with modern equipment. Compliance with the legislative requirements for improving the quality of school natural and mathematical education results in the advanced future physics teachers' training who are able, among other things, to work and organize research in laboratories of this type.

Therefore, virtual physical laboratories are means of both educational and professional activities of physicists, physics teachers, computer science teachers and IT specialist. Therefore, research of the effect of their use in professional training is a relevant pedagogical problem.

Professional training in the field of use of information technologies is the subject of many scientific and pedagogical findings:

- theoretical principles of the informatization of the education, including professional (M. I. Zhaldak, L. P. Martirosjan, I. V. Robert);
- the involvement of the specialized software in the training of IT specialists (V. S. Kruhlyk, T. V. Voloshyna, A. M. Striuk);
- the introduction of ICT in the professional computer science teachers' training (T. V. Pidhorna, H. V. Tkachuk, V. V. Chernykh);
- the use of IT in the physicists' and physics teachers' training (A. M. Andrieiev, A. Yu. Yurchenko).

The review [3] presents the attempt to synthesize recent (up to 2005) empirical studies that focus on comparing learning outcome achievement using traditional lab (hands-on) and non-traditional lab (virtual and remote). It is found out that student learning outcome achievement is equal or higher in non-traditional lab versus traditional lab across all learning outcome categories (knowledge and understanding, inquiry skills, practical skills, perception, analytical skills, and social and scientific communication).

The features of organizing and conducting a physical experiment based on virtual laboratories are studied in the foreign researchers' findings. The problem of choosing a virtual laboratory and mastering it in the process of physics teachers' training is solved in [4]. The finding [5] deals with the use of virtual physical laboratories for educational experiments in physics in the future engineers' training. The use of an innovative 3D virtual reality learning environment, which aims to help students in learning and teachers in explaining the various processes of the physics course is described in [6]. The results of the impact of the use of virtual laboratories on the improvement of creative abilities of future physics teachers is highlighted in [7]. The finding [8] reports of a novel approach of computer science students' teaching using virtual laboratory.

The analysis of the mentioned and other findings confirmed the effectiveness of involvement of IT in the professional specialists' training. At the same time, we recorded the findings about the negative impact on the educational achievements [9, 10].

Given the ambiguity of the findings and the constant development of specialized software, in particular the development of virtual physical laboratories, the problem arose: is it advisable to use the virtual physics laboratories instead of ordinary physical devices in the study of physical disciplines. Finding the solution of this problem led to the organization and conducting of a pedagogical experiment, the results of which are presented in this article.

2 Dynamics of students' academic achievement in the process of virtual physics laboratories use

The pedagogical experiment lasted for 2015-2019. Students of Makarenko Sumy State Pedagogical University, future physics teachers (27 people), computer science

teachers (44 people) and IT specialists (specialty “Computer Science”, 18 people) were participants of the experiment. The purpose of the experiment was to clarify the nature of the impact (positive or negative) of the use of virtual laboratories on the level of educational achievement of students – future physics teachers, computer science teachers, IT specialists.

The use of virtual physical laboratories in the future specialists’ training is summarized in Table 1. The disciplines that required the mandatory use of virtual physics laboratories are mentioned in the Table.

Table 1. General information about the period of the virtual physics laboratories use

Specialty	Discipline	Semester of study	The volume	Note
014 Secondary education. Physics	The fundamentals of microelectronics	5	5	Maple, Electronics Workbench (EWB), Multisim
014 Secondary education. Computer Science	The fundamentals of microelectronics	5	5	Maple, Proteus, Multisim
122 Computer science	The fundamentals of microelectronics	5	5	Maple, Proteus, Multisim

The special course on which the experiment was conducted involved the study of the following topics.

1. The calculation of the differential resistance of the diode.
2. Non-equilibrium and equilibrium bridges.
3. Measuring the parameters of the bipolar transistor.
4. Amplifiers.
5. TTL and CMOS basic elements.
6. Decoder modeling.
7. Relaxation generators.
8. Triggers.
9. Modeling of arithmetic and logic devices.

Each topic was mastered at a laboratory session (4-6 hours each). Comments and instructions for getting started with the mandatory use of a virtual physical lab were offered to get the job done.

In order to confirm the assumption that “the use of virtual physical laboratories to demonstrate physical phenomena and processes is positively impact on the level of educational achievement”, we applied the sign test as a non-parametric method of statistical evaluation of educational achievements. This method is intended to compare the status of some properties of members of a sample based on measurements made on an ordinal scale.

At the beginning and at the end of the pedagogical experiment, respondents were asked two modeling tasks in any virtual physics laboratory of physical (for example, simulation of the operation of a resistance transistor, a majority amplifier, etc.). Such

tasks could be solved by students, because the general physics course was provided for each specialty at the first year, and the study of physical and mathematical laboratories was foreseen at the second year. Let us note that unlike future computer science teachers and IT specialists, future physics teachers have studied different physics branches for 4 semesters. This gave reason to talk about the possible highest level of educational achievements in physics before conducting the experiment. But we studied the dynamics of educational achievement, and therefore this fact was neglected.

The results of solving physical problems were recorded on a 5-point scale for each respondent. Since a different number of students of these specialties were involved in the experiment, it was decided to take 15 paired results randomly (Table 2-4).

Table 2. The results for the specialty 014 “Secondary education (Physics)”

Students (№)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
The first control	3	2	3	3	3	4	3	3	4	4	4	4	2	2	3	3,13
The second control	3	3	4	3	4	5	4	5	3	4	4	3	3	3	4	3,67
Sign of difference	0	+	+	0	+	+	+	+	-	0	0	-	+	+	+	

Hypothesis H_0 : "The use of virtual laboratories does not impact on the level of academic achievement". The alternative hypothesis H_a is "The use of virtual labs has a positive effect on the level of students' academic achievement".

Table 3. The results for the specialty 014 “Secondary education (Computer Science)”

Students (№)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
The first control	3	3	3	4	4	3	3	3	3	2	4	2	3	4	3	3,13
The second control	4	2	4	5	4	4	4	4	3	4	4	3	3	5	5	3,87
Sign of difference	+	-	+	+	0	+	+	+	0	+	0	+	0	+	+	

Table 4. The results for the specialty 122 "Computer science”

Students (№)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
The first control	3	3	3	3	3	3	2	3	4	3	4	3	3	4	3	3,13

The second control	5	4	4	3	4	4	4	3	5	4	4	3	3	5	4	3,93
Sign of difference	+	+	+	0	+	+	+	0	+	+	0	0	0	+	+	

We apply the one-sided sing test [11]. We need to calculate the value of the statistics T of the test, which is equal to the number of positive differences (last row of tables). The value of n is calculated as the number of non-zero results. To determine the critical values of statistics at the significance level of 0.05, we use the appropriate table [11] for $n < 100$ (Table 5).

Table 5. The Grounds for hypothesis

Specialty	T	n	T_{crit}	Conclusion on the acceptance of the hypothesis	Dynamics of educational achievements
014 “Secondary education (Physics)”	9	15-4=11	8	$H_a (9>8)$	+0,54
014 “Secondary education (Computer Science)”	10	15-4=11	8	$H_a (10>8)$	+0,74
122 “Computer science”	10	15-5=10	8	$H_a (10>8)$	+0,80

Therefore, according to the decision rule for all specialties the null hypothesis is rejected at the significance level $\alpha=0.05$ and the alternative hypothesis is accepted. This allows concluding that statistical improvement of educational achievement in physics is due to the use of digital laboratories.

Analysis of the dynamics of academic achievement on the basis of comparison of averages suggests that at the beginning of the experiment the initial level of educational achievement for all three samples was the same on average (average score 3.13), but at the end of the second control it differs. The largest dynamics were recorded for specialty 122 “Computer science”, and the smallest dynamics were recorded for specialty 014 “Secondary education (Physics)”. In the sense of our experiment, this means that the level of educational achievement in physics is more influenced by information technology training, not physics training: modeling. Therefore future IT specialists than by future physics perceive awareness of physical processes better teachers.

3 Conclusion

Thus, the study allows us to state the following.

1. The use of virtual physical laboratories in the teaching of courses in physics, in particular, the basics of microelectronics, has a positive effect on the level of academic achievement of students of specialties 014 “Secondary education (Physics)”, 014 “Secondary education (Computer Science)” and 122 “Computer Science”. According

to the results of the pedagogical experiment on the statistical sign test at the significance level of 0.05, a positive shift in the levels of students' academic achievement was confirmed.

2. The dynamics of the averages for each of the samples is set at: +0.54 for the specialty 014 "Secondary education (Physics)"; +0.74 for specialty 014 "Secondary education (Computer Science)"; +0.80 for specialty 122 "Computer Science". The better dynamics of the results of students' academic achievement for the IT specialties gives reason to recommend the inclusion in the professional training of physics teachers more courses related to the study of information technology, because we consider it the reason for these results.

3. According to the results of the pedagogical experiment, the following questions are open. How the use of digital physical laboratories influences the level of educational achievements in physics? Do either digital laboratories or virtual ones have a greater impact on the level of academic achievement in physics? Is it important to use two types of physical laboratories in the professional training of specialists?

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