PROFESSIONALLY ORIENTED LABORATORY PRACTICUM IN PHYSICS FOR ENGINEERING STUDENTS

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Abstract. The subject of studying physics at higher school, in addition to the system of ideas about the physical picture of the world, is the methods of scientific knowledge, its general structure and components. This study is devoted to the problem of organizing and conducting professionally oriented laboratory work in physics for training the future agricultural engineers. One of the ways how to implement the requirements of modern society for the quality of fundamental education is the professional orientation of the physics teaching. Physics is the basic foundation for the study of professional training disciplines at higher education institutions. In the system of physics education, a teaching experiment plays an important role for the development of skills of applying theoretical knowledge to practical activities. Therefore, it is necessary to pay special attention to the educational experiment in physics in the system of the students' professional training. This is what determined the main goal of our research: to theoretically substantiate and develop a methodology for the formation of professionally oriented experimental skills of the future agricultural engineers in the process of performing laboratory work in physics under the conditions of integration of fundamental and professional training. A methodology has been developed for teaching physics to the students of educational institutions that would correspond to the professional direction of the laboratory work of the discipline and would be based on the unity of the fundamental and applied components of the discipline "Physics" at higher education institutions. There was experimentally studied the efficiency of the developed methodology for studying physics in terms of organizing the laboratory work with a professional direction. It has been proved that the professional orientation of physics training changes the student's attitude towards theoretical training, helps him to identify the dependence of the theoretical issues of the course upon his future professional activity, his formation as a specialist.

Key words: physics, laboratory work, professional training, agricultural engineer.

Introduction

Formulation of the problem. The educational goal of the laboratory workshop is to develop among the higher education applicants ideas about the structure of scientific knowledge, basic physical models and skills in processing and interpretation of the research results. In the course of the laboratory work, the applicants better assimilate the program material since many calculations and formulas that seemed abstract to them become quite concrete, and there are many details about which the applicants previously had no idea, although they help clarify complex scientific issues. None of the forms of the educational work requires from the applicants for higher education such manifestation of initiative, observation and independence in decisions made as work in the laboratory. Laboratory work, adapted to the educational and professional training program for the future agricultural engineers, allows the applicants to understand many complex technologies and processes of the agricultural technology industry, and become familiar with the physical principles of functioning of the elements and components of the agricultural machinery.

Analysis of topical investigations. Research in the problem of formation of professional orientation of training among the specialists of various profiles was revealed in the scientific works by: I. Zvereva, A. Kaspersky, I. Kozlovsky, V. Maksimova, S. Pastushenko, V. Sergienko, A. Sergeeva and others**.** Of greatest interest are the works that investigated the problems of interdisciplinary connections in the system of training specialists at higher educational institutions, where the main attention was paid to interdisciplinary connections between physics and technical disciplines: I. Beloev [1], O. Bulgakova [2], O. Chaliy [3], S. Nikolaenko [4; 5], L. Zbaravskaya [6], N. Sosnitskaya [7], E. Timoshenko [8], G. Shishkin [9], and this problem is reflected also in scientific publications of V. Bulgakov [10-12].

A laboratory workshop is the main structural element in the organization of the educational process. The laboratory work can help increase understanding of the physics concepts. R. Kustijono focused on the positive impact of the laboratory practice, which serves as a means of learning, feedback and improving the students' motivation [13]. The famous methodologist D. Kolb developed a theory of knowledge, acquired through experience. He emphasizes that experience plays a crucial role in the learning process: "Learning is a process in which knowledge is created through the transformation of

experience" [14]. In his works J. Juhji emphasizes the need for teachers to be creative in their teaching approaches to encourage their students to take an active role and explore their own potential. So, it is expected that the students will be able to develop skills of experimental work and implement them in the future [15]. The applicants for higher education need to be guided and trained in the experimental work skills as this will be very useful not only for the accumulation of knowledge but also in professional activities. Thus, the students learn to think logically when solving every problem [16]. In the light of the inevitable need for a competency-based approach to higher professional education, Cao Cu Giac points to an even deeper integration of theoretical training and practice, considering the latter in the context of not just laboratory experience, but professionally oriented: "The organization of experimental activities is the implementation of the principle of training in combination with practice, education combined with labour production, theory connected with practice." By encouraging the students to participate in a real experiment, they will have the opportunity to consider the subject from different perspectives and approaches, avoiding imposition; and be able to offer innovative solutions that have an individual format" [17].

During training, especially in the laboratory, not all indicators of general scientific abilities can develop well [18]. Therefore, it is necessary to conduct research to be able to develop all the general scientific abilities to support the laboratory skills, identical to the professional activities [19]. The use of such innovative approaches can also be applied when conducting modern scientific research [20].

Although the scientific and methodological works analyse this issue, they do not indicate solutions, that is, if it is advisable to develop such teaching materials that would specify the system of methods and means of teaching physics in order to form and develop the professional qualities of the applicants and help eliminate the problem. Since the educational materials do not focus attention of the higher education applicants on the problems, related to their future profession, the issues of developing professional activities at the beginning of their studies require special investigation. This is what determined the main goal of our research: to theoretically substantiate and develop a methodology for the formation of professionally oriented experimental skills of the future agricultural engineers in the process of laboratory work in physics under the conditions of integration of fundamental and professional training.

In order to evaluate the developed methodology, the following research methods were applied: a comparative analysis of scientific, methodological and pedagogical literature; questionnaires, testing (introductory and initial), conversations (with applicants for higher education, teachers of the fundamental and professional disciplines), scientific observation.

Materials and methods

The main task of a laboratory workshop in physics in the system of training the future agricultural engineers is the formation of generalized experimental skills among applicants for higher education. When performing the laboratory work in a physics course in the process of training specialists, in our opinion, it is desirable to make maximum use of the physical phenomena and processes that form the basis for the operation of agricultural machinery. Such an approach significantly increases the interest of the higher education applicants in studying physics and promotes a deeper understanding of the physical processes occurring in the devices and units of agricultural machinery. Understanding the physical principles of operation of individual components of the agricultural machinery, based on fundamental science, increases the level of professional training of the higher education applicants.

We have determined a list of laboratory works, given in Table 1, the content of which is traditional, that is, it corresponds to the current curriculum in physics for the applicants for higher education in agricultural engineering specialties.

We have made an increase in professional orientation of the laboratory practical work in physics for the applicants of higher education in engineering specialties through the following complementary methods:

1. By developing a system of professional questions for the traditional laboratory work of general educational significance (Table 2);

2. By setting up laboratory work on the traditional equipment, implementation of which contributes to a better understanding of the fundamental concepts and laws of physics that are necessary for mastering general technical disciplines (Fig. 1);
3. By setting the laboratory work on the equipment, which includes the units and blocks of agricultural machinery (Fig. 2).

Table 1

List of traditional laboratory work in physics for the applicants of higher education in the agricultural engineering specialties for the Section 1: Mechanics

Topic No.	Laboratory work topic
1	Study of the laws of uniformly accelerated motion and Newton's second law on Atwood's machine.
2	Determination of Young's modulus of a rod by the deflection method.
3	Determination of the coefficient of internal friction by Stokes' method.
4	Checking the basic law of rotational motion of a rigid body using Oberbeck's pendulum.
5	Determination of the inertia moment using the trifilar suspension method.

For all the laboratory work, given in Table 1, we have developed a system of professional control questions. The applicants receive these control questions with assignments for laboratory work, and, when presenting their work results, they are interviewed. For example, the questions of a professional nature for the laboratory work from Section 1 Mechanics may be:

Table 2

Professional questions for laboratory work in Section 1. Mechanics

Topic No.	Questions
1	1. In which agricultural machines and mechanisms falling of the load from different heights is observed? 2. Give examples of mechanisms that perform uniformly accelerated motion? 3. What aspects of the motion of Atwood's machine might be similar to the motion of technical objects in agriculture?
2	1. How is the modulus of elasticity of a rod taken into account in various agricultural parts? 2. What types of a body deformations are used in agricultural processes? 3. Explain the principle of operation (action) of a spring in the vehicle?
3	1. How to explain the phenomenon of viscosity, based on the concept of "internal friction"? 2. Is there a relationship between the viscosity of a lubricant used and the pressure in the engine? 3. How does the viscosity of a liquid depend on the changes in the ambient temperature?
4	1. How to determine the speed of rotation of a pulley and the speed of movement of a belt in flat and V-belt drives? 2. How to determine the angular speed of rotation of the cutting drum? 3. How does the magnitude of the moment of inertia affect the behaviour of agricultural machines during rotational motion, and what factors can change it?
5	1. How are the moments of inertia of rotating parts of machines and mechanisms (box of the shaft, crankshaft, etc.) taken into account? 2. Why is the crankshaft balanced when it made? 3. How can changes in the mass or geometry of the farm equipment affect the moment of inertia and, therefore, the performance on the field?

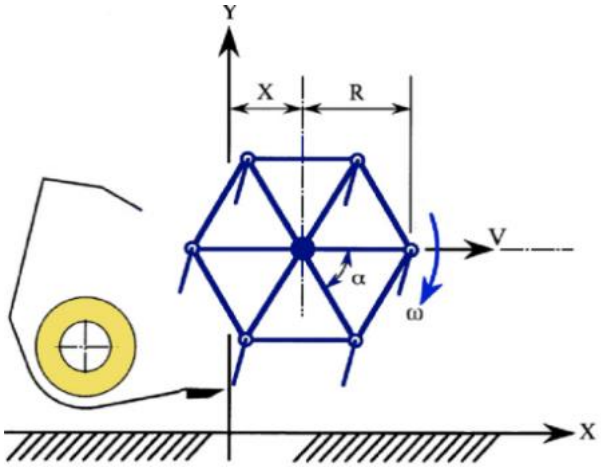

Fig. 1. **Simulation of a professionally oriented situation, using the example of laboratory work "Testing the basic law of rotational motion of a rigid body using Oberbeck's pendulum"**

Fig. 2. **Setting up laboratory works on equipment including assemblies and units of agricultural machinery**

As the investigations have shown [1; 20], such an approach to organizing a laboratory workshop, significantly increases the interest of the higher education applicants in studying physics. The applicants see practical use of knowledge in physics in their future professional activities.

Results and discussion

In order to determine the priority of the focus of the educational process on the development of professional skills of applicants in the process of performing laboratory work in a physics course, a pedagogical experiment was conducted. Applicants from the higher education institution "Podolsk State University" in specialties 208 "Agroengineering", 274 "Automobile Transport" took part in the experiment. At different stages of the experiment the knowledge and skills, acquired by the applicants, were monitored by testing and writing test papers. Questionnaires and conversations were held in order to identify the level of awareness of the importance of fundamental knowledge for further training and practical activities in the specialty, the formed interest in learning, in general, and identifying interest in the discipline "Physics", the acquired knowledge, the level of developed intellectual skills, the changes in the level of the existing professional competence at the beginning and the end of the experiment. In the experimental (n = 120) and the control (reference) groups (n = 119), professional knowledge samples were taken and the level of motivation to study the discipline "Physics" was identified.

Thanks to the introductory testing, the initial stage of the experiment made it possible to establish that the applicants in the experimental and control groups had an insufficient level of the developed professional knowledge, skills and abilities, acquired while studying the discipline of the fundamental cycle "Physics".

The performance of the laboratory works by the applicants for higher education in the physics course according to the traditional organizational scheme forms a fairly limited number of both general physical and professionally oriented research skills and laboratory work skills. Therefore, the developed methodology of teaching physics oriented the applicants to understand the importance to acquire knowledge and skills of a professional nature, necessary not only for further education, but also in further practical activities in their specialty. Classes in the control group were conducted according to traditional methods according to the discipline program. The applicants from the experimental group worked according to the developed teaching methodology in the physics laboratory. It is advisable to note that the higher education applicants in the control (reference) and the experimental groups reveal a high level of importance of fundamental knowledge for the full mastery of the disciplines of the professional training cycle. The results of the experiment are presented in Table 3.

Table 3

Summary results of the cross-section of formation of the professional knowledge

No.	Knowledge	C(R)G		EG	
		Level of importance	Level of formation	Level of importance	Level of formation
1.	208 “Agroengineering”	0.72	0.57	0.79	0.69
2.	274 “Automobile Transport”	0.68	0.49	0.77	0.57
Final indicator		0.7	0.53	0.78	0.63

In a similar way there was investigated the level of professionally oriented skills, acquired by the first-year applicants during the laboratory work in physics, presented in Table 4. The results of the research, presented in the table, showed a higher level of development of professional skills in the experimental group: the experimental group – 63%, the control (reference) group – 53%. This component of our study confirmed the expected results of the experiment.

Table 4

Summary results of formation of professional skills

No.	Skills	C(R)G (control group)		EG (experimental group)	
		Level of importance	Level of formation	Level of importance	Level of formation
1.	208 “Agroengineering”	0.61	0.54	0.76	0.62
2.	274 “Automobile Transport”	0.79	0.58	0.84	0.76
Final indicator		0.7	0.56	0.8	0.69

Performance of laboratory work of professional content, constant emphasis on the use of the acquired knowledge and skills in the further training and practical activities in the specialty indicated an increase in the level of knowledge and skills of the applicants for higher education in the discipline “Physics”, an increase in their interest and motivation for learning. The applicants for agricultural engineering specialties directly in the physics laboratory were convinced of the practical significance of the discipline for their further education. So, the analysis of the results of the conducted research made it possible to identify a higher level of development of professional knowledge and skills of the higher education applicants in the experimental groups and an increase in motivation to study the disciplines of the fundamental cycle, using the example of the discipline “Physics”. The obtained data indicate the efficiency and expediency of the work done: the general level of knowledge, skills and abilities in the discipline of the fundamental cycle “Physics” and the level of awareness of the need to study it for further training and study of disciplines of special training courses have increased. The results of the level of professional competence of higher education applicants are presented in Table 5.

Table 5

Level of professional competence of the higher education applicants

No.	Levels	C(R)G (control group)		EG (experimental group)	
		Number of students	%	Number of students	%
1	Low	30	25.5	10	8.5
2	Medium	47	39	30	25
3	Sufficient	33	28	57	47.5
4	High	9	7.5	23	19
Total		119	100	120	100

The results obtained indicate that the level of professional competence of the higher education applicants in the control (reference) group is lower, compared to the level of professional competence in the experimental group.

To evaluate practical knowledge and professional skills of students, the characteristics of the levels of mastery of these skills were described:

I. Low. The student demonstrates the ability to use individual devices, can draw up an experiment scheme only with the help of a teacher, performs a part of the work during which significant errors are assumed, observes safety rules, does not know the rules for calculating experimental errors, has difficulty formulating conclusions according to terminology, has difficulty giving answers to control questions; cannot indicate the limits of the application of skills and abilities acquired in the physics laboratory in further education and life.

II. Medium. The student performs the work according to the model (instructions) or with the help of the teacher, the result of the student's work makes it possible to obtain the correct conclusions or part of them, mistakes are made during the execution of the work, he cannot identify all the errors of the tasks, formulates the conclusions of the work with the help of the teacher, uses terminology; gives clear answers to the majority of control questions, partially indicates the limits of the application of skills and abilities acquired in the physics laboratory in further education and work in the field.

III. Sufficient. The student independently mounts the necessary equipment, performs the work in full, observing the necessary sequence of conducting experiments and measurements; correctly and accurately makes entries, tables, diagrams, graphs, calculations in the report, independently draws a conclusion; shows all errors in calculations; can indicate the limits of the application of skills and abilities acquired in the physics laboratory in further study and work in the field.

IV. High. The student fulfils all the requirements provided for a sufficient level, performs the work according to the self-made plan, analyses the results, calculates all the errors required by the laboratory work task; can improve and modernize the installation of laboratory work; indicates the clear limits of the use of acquired skills and abilities, their role in studying professionally oriented disciplines and in further work in the profession; capable of predicting the situation when changing parameters and devices.

The obtained work results make it possible to assert: the level of professional competence of the students of the control group is lower in comparison with the level of professional competence of the experimental group. High indicators of professional competence of the students of the experimental group were determined by the high level of interest and constant growth of motivation to study the discipline "Physics", which was repeatedly noted by the teachers of professional disciplines of the higher education institution "Podilskyi State University"; the covered volume of educational material, as evidenced by the answers to control questions for laboratory work, a high level of responsibility in the work in the physics laboratory and independence in acquiring new knowledge; the level of preparation of forms for reports on the work performed; the ability to be critical of the work and the obtained measurement results; the ability to predict future results; development of thinking in the process of integration of fundamental and professional components; the ability to replace devices with similar ones and to modernize laboratory facilities in accordance with the set goals.

Figure 3 presents a histogram of the experimental data regarding the levels of the applicants' formed professional competence, based on a combination of fundamental and professional components when performing laboratory work in the process of studying the discipline "Physics".

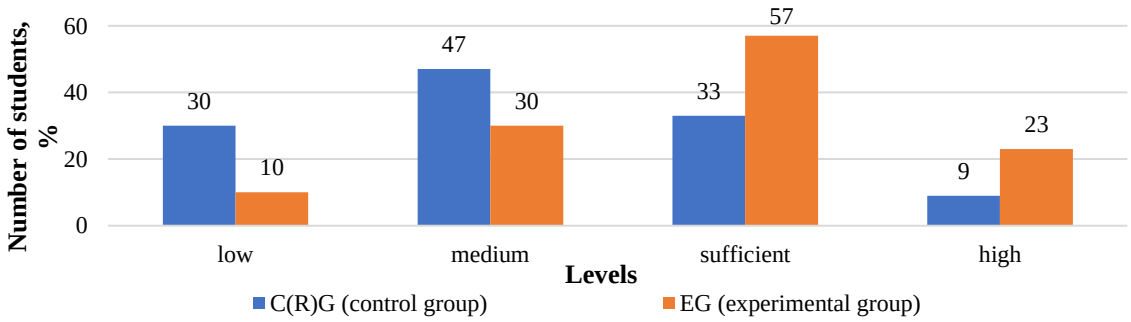

Fig. 3. **Comparison of the student distribution by levels of professional competence**

Thus, the results of the pedagogical experiment confirmed that the formation of professional competence of the higher education applicants, based on integration of fundamental and special training, requires modernization of the methodological system of teaching physics to the future specialists in the agricultural and technical industry, in particular, in the process of performing laboratory work in a

professional direction. Introduction of professionally oriented laboratory work in physics into the practice of training the future agricultural engineers can be considered an efficient way how to reveal the applied nature of physical knowledge and improve the quality of the specialists' professional training in the agricultural and technical industry.

Conclusions

1. The present investigation of the introduction of professionally oriented laboratory work differs from the existing ones in the following aspects:
   - a new approach to the development and conducting of fundamental and professionally oriented laboratory work has been proposed, taking into account the current trends in education and labour market requirements for training specialists in the agricultural and technical industry;
   - the developed new methodology for conducting the laboratory work is aimed at solving specific problems or needs in the agricultural-technical field that are urgent at the moment, corresponding to the characteristics of professional training and contributing to better acquisition of the material of the physics course.
2. Analysis of the results of the conducted pedagogical experiment confirms the efficiency of the developed methodology for the introduction of the laboratory work in physics of a professional content into the educational process of training the future agricultural engineers.
3. Based on the experiment, it was established that the laboratory work of a professional content in physics under the conditions of integration of student fundamental and professional training is productive; it increases the quality of knowledge by 11.5% and efficiently contributes to the formation and development of professionally significant competencies.

Author contributions

Conceptualization, O.B.; methodology, I.S. and O.B.; software, I.S.; validation, A.R. and O.B; formal analysis, O.B and L.Z.; data curation, I.S., O.B. and L.Z.; writing – original draft preparation, A.R.; writing – review and editing, O.B. and L.Z. All authors have read and agreed to the published version of the manuscript.

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