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MODEL OF PROFESSIONALLY DIRECTED TRAINING OF FUTURE ENGINEER-TEACHERS

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Abstract. The article provides scientific substantiation and development of a professionally oriented physics training model for future engineering teachers using professionally oriented training. The relevance of the problem, its insufficient theoretical and practical development, as well as the need to resolve the identified contradictions determined the purpose of this article: to substantiate and develop a model of professionally oriented physics training for future engineering teachers. It was determined that physics training should be considered as a process reflecting the interaction of a teacher and applicants for higher education with the involvement of the latter in physics activities that are close to professional ones. It is aimed at developing a professional orientation of an individual, a harmonious combination of theoretical and practical training using the method of interdisciplinary relationships between physics and professionally oriented disciplines by the types and functions of an engineer teacher's activity. Based on the model of professionally oriented training, a methodology for teaching physics to future engineer teachers was theoretically substantiated and developed, contributing to the formation of knowledge and skills in physics and the ability to apply them in the professional activities of an engineer teacher. The results of the experiment showed that teaching students using the developed methodology helps to increase the level of fundamental and professionally oriented knowledge in physics by 10– 15%; the use of fundamental knowledge in physics to solve problems related to future professional activity when studying disciplines of professional and practical training increased by 25%.

Keywords: professional orientation; competence; physics; teaching methods

Problem statement

At the present stage of the development of physical education, which is marked by active, innovative processes, it is important to differentiate the physics course and its teaching methods in accordance with the profile of specialists' training. Fundamental training in physics is of great importance in the system of training future engineer teachers. This academic discipline significantly contributes to students' practical and polytechnical training since it introduces them to the scientific foundations of engineering and production.

A feature of engineering and pedagogical education is its goal – training and education of a specialist with a system of engineering knowledge, skills and abilities in a certain area of production and capable of professionally performing educational functions in the field of vocational and higher education in educational institutions of I – II levels of accreditation. Analysis of standards, qualification characteristics, curricula and programs for engineering and pedagogical specialties showed that the physics program for these specialties does not reflect the professional orientation of training; the content of the physics course does not differ from the content of the physics course for other specialties and specialized literature, other than individual manuals developed by educational institutions, is almost absent.

However, the issues of improving the methodology of teaching physics in higher educational institutions in engineering and pedagogical specialties at the present stage remain insufficiently studied. The analysis of the sources used in the study revealed contradictions between:

– modern criteria set forth in Ukraine's state regulatory documents regarding the quality of engineer-teacher education, along with an evaluation of its current state;

– the significant scientific and methodological capabilities of physical science are not being fully exploited in the training of engineer teachers;

– there is an absence of clear methodological guidelines on how to implement professionally oriented physics instruction for students with the corresponding profile.

In this context, the problem of improving the training of future engineers-teachers becomes relevant, requiring clarification of the content and improvement of the quality of teaching physics, ensuring its professional and practical focus. It is also necessary to introduce such teaching methods and tools that would contribute to the deep acquisition of knowledge, the formation of skills and abilities, as well as the intellectual development of the individual.

Analysis of recent research and publications

Some problems of theoretical and methodological foundations of professional training of future engineer-teachers are reflected in the studies of M. Pechko, A. Pekhota, I. Bendera, V. Duganets, N. Nichkalo, G. Zhukovsky, L. Tarkhan, etc. Scientific works on the specifics of introducing professional training into the educational process were used by such foreign researchers as David Perkins, John Briancon, Carlos Cardoso, Maria de Miguel, Ronald Miller and others.

Research goal

The relevance of the problem, its insufficient theoretical and practical development, and the need to resolve the identified contradictions determined the purpose of this article—to substantiate and develop a model of professionally oriented physics training for future engineering teachers.

Research methods

To achieve the set goal, the following research methods were used: theoretical methods (analysis of psychological, pedagogical and scientific and methodological literature, which helped to determine the directions of the study and the conceptual and categorical apparatus; analysis of educational and qualification characteristics, current programs in physics, as well as general technical and professionally oriented academic disciplines to identify interdisciplinary connections related to the functions and types of activities of an engineer-teacher); empirical methods: pedagogical observation of students' educational activities, as well as a survey and questionnaire, which were used to determine the results of students' academic work, assess the level of their professional training and professional focus; statistical methods: application of mathematical statistics methods to assess the reliability of the results of the study and quantitative analysis of the pedagogical experiment data.

Presentation of the primary material of the research

Engineering and pedagogical education in Ukraine aim to form harmoniously developed specialists who combine engineering and pedagogical skills related to the ability to solve technical problems, think systematically, design and construct technical devices, and orientate issues of economics and labour protection.

Recently, fundamental natural science training of specialists in the agrarian and technical sectors has become increasingly important. The content of all professionally oriented and specialized disciplines is based on general natural science subjects (physics, mathematics, chemistry, biology, ecology). In such conditions, it is important to change the content of fundamental disciplines, adding sections and topics to the curricula that contribute to the formation of professional knowledge, skills, as well as personal traits and qualities that reflect the success and professional competence of an engineer-teacher. (Nikolaenko et al. 2022, pp. 638 – 644).

In the course of the analysis of educational, professional and training programs for training applicants for higher education in engineering and pedagogical specialties, we identified a list of academic disciplines in the cycle of professional and practical training based on the concepts and laws of physics: machine parts and equipment; technical mechanics; electrical engineering; agricultural machinery; materials science and TCM; mechanics of materials and structures; theory of mechanisms and machines; development of production and processing of agricultural products; mechanical and technological properties of agricultural materials; fuels and lubricants, etc. The relationship of the educational material of physics sections with the educational material of professionally oriented disciplines by types and functions of the activities of an engineer-teacher is presented in Fig. 1.

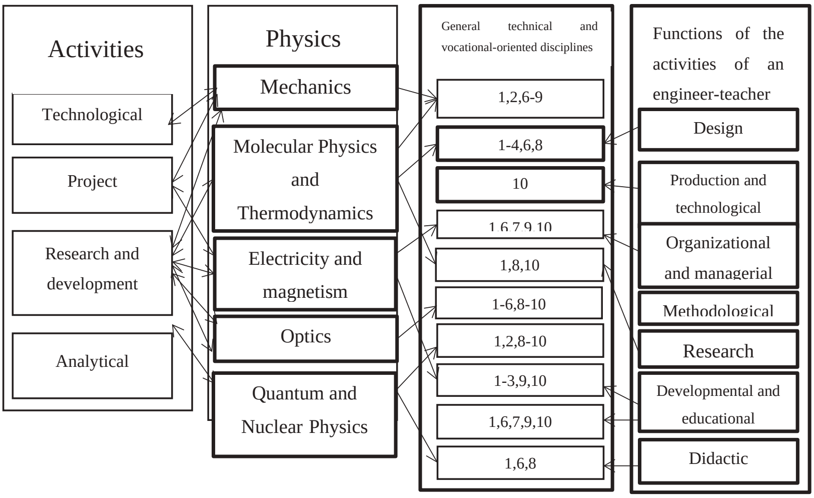

Figure 1. Interdisciplinary connections between physics and general technical and professionally oriented academic disciplines according to the functions and types of activities of an engineer-teacher:

1 – Machine and equipment parts;
2 – Technical mechanics;
3 – Electrical engineering;
4 – Agricultural machinery;
5 – Materials science and construction materials technology;
6 – Mechanics of materials and structures;
7 – Theory of mechanisms and machines;
8 – Technology of production and processing of agricultural products;
9 – Mechanical and technological properties of agricultural materials;
10 – Fuels and lubricants.

We integrated the content of physics and professionally oriented academic disciplines through interdisciplinary connections by types and functions of the activities of an engineer-teacher. When studying physics and professionally oriented academic disciplines, it is possible to identify knowledge and skills necessary for performing technological, design, research, and analytical physics activities that correspond to an engineer-teacher's professional activities.

We designed an algorithm that selects teaching aids and methods by analyzing the interdisciplinary connections between physics and specialized fields, considering an engineer-teacher's various roles and functions. The algorithm's essence is to identify teaching aids and methods for developing skills to perform professional activities to implement a particular function of an engineer-teacher in special disciplines and to use them in organizing the educational process in physics (Fig. 2).

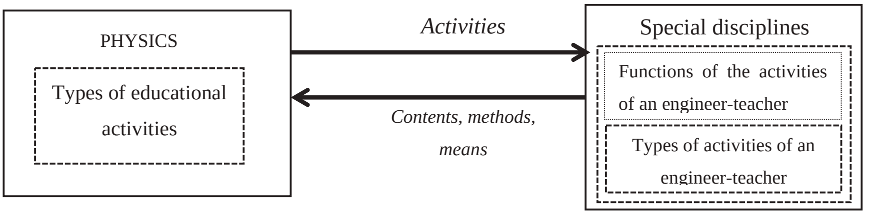

Figure 2. Scheme of the algorithm for selecting teaching aids and methods based on interdisciplinary relationships between physics and special disciplines according to the types and functions of the activities of an engineer-teacher

Considering the interdisciplinary connections of physics and professionally oriented academic disciplines plays an important role in the formation of motivation and interest in studying physics (Bulgakova et al. 2023. pp. 661 – 666).

We also support the statements of David Perkins that learning with a certain motivation is a more natural and, therefore, effective process. In particular, in order to make learning more meaningful and effective, it is consistent with our main educational method of teaching in the use of interdisciplinary connections. In fact, interdisciplinary connections are the element that contributes to improving the quality of learning (Perkins 2009).

The content of the physics course for applicants for higher education in engineering and pedagogical specialties is determined by the learning objectives, bachelor's degree programs in this profile. The purpose and objective of the academic discipline "Physics" is to form an understanding and provide knowledge about physical phenomena and their patterns, methods of physical research, physical quantities and their dimensions, the role of physics in the development of agricultural machinery and its influence on the development of physics.

The set of final goals – a list of tasks that a specialist should be able to solve upon completion of training – is a model (profile) of a specialist based on educational and qualification characteristics. Following the educational and qualification characteristics of bachelor in specialty 015 "Professional Education", the professionally oriented content of the course "Physics" should contain fundamental concepts and laws necessary for solving typical problems of activity, namely:

1. To study the mechanical motion of bodies when using machines and equipment in agriculture, applicants must be able to use a physical model of a material point and be able to measure and theoretically find kinematic and dynamic quantities experimentally. Based on knowledge of the dynamics of rotational motion of a solid body and continuum mechanics, graduates can calculate the moment of inertia, moment of force and impulse, deformation and stress in a solid body, use the laws of conservation of angular momentum and energy, the basic equation of the dynamics of rotational motion, etc.

2. To study macroscopic processes in bodies, upon completion of the physics course, a bachelor must, based on knowledge of the laws of molecular-kinetic theory, be able to determine the thermodynamic parameters of gases, the speed of gas molecules, the type and concentration of molecules at different heights, analyze the processes of diffusion of viscosity and thermal conductivity. Knowledge of the laws of thermodynamics allows you to determine the heat capacity of gases, work, change in internal energy, amount of heat, efficiency of thermal processes and entropy. Applicants must also learn to determine the thermodynamic parameters of real gases and classify and determine the various phases of matter and its transformations.

3. To study electrical and electromagnetic processes in agricultural machinery and equipment, applicants must, based on knowledge of the laws of electrostatics, be able to calculate the force of interaction of electric charges, the strength of the electrostatic field, its potential for point charges and charged bodies in various environments, the capacity of one or more capacitors. It is also necessary to be able to calculate the energy of a system of charges, a conductor, a charged capacitor and an electric field; be able to measure the characteristics of an electric current, power, and the work of current in branched and unbranched electrical circuits. Based on knowledge of the laws of electromagnetism, a bachelor must calculate the strength and induction of a magnetic field, the force of interaction of parallel currents, the force of action of a magnetic field on an electric current and a moving charge, the work of moving a conductor and a circuit with current in a magnetic field; be able to apply the law of total current, determine the electromotive force of induction and self-induction, the inductance of conductors, currents during closing and opening of electrical circuits, voltage and current in transformer windings, magnetic field energy; classify magnetics and know their properties.

4. To study wave oscillations and optical phenomena in mechanical and electromagnetic devices, applicants must be able to analyze harmonic oscillation equations, formulate unidirectional and mutually perpendicular harmonic oscillations,

and analyze free, damped, and forced oscillation equations based on knowledge of the laws of oscillatory motion. We agree with V. Sergienko that professional material should be selected in such a way that it clearly illustrates the laws of physics, that is, gives the most vivid picture of the application of a particular law or phenomenon, its manifestation in agriculture. In addition, the example should not replicate the main content of the physics course; instead, it should serve as an auxiliary tool for explaining a particular phenomenon or law of physics while ensuring that the applied material is closely connected to physical theories (Sergienko 2005).

An experiment was conducted to identify the effectiveness of the provision and level of training of applicants for higher education in engineering and pedagogical specialties in physics. The following tasks were accomplished during the experiment:

1. To identify the level of training of applicants for higher education in physics.
2. To check, based on the existing provision of the physics course, the level of training of applicants for higher education for studying general technical and professional disciplines.
3. It will determine the weaknesses of the current method of training applicants for engineering and pedagogical specialties in physics.

The experiment involved first- and second-year applicants of the higher education institution "Podolsk State University". To determine the content of professionally oriented material and its place in the physics course, an analysis of the content of general technical disciplines and disciplines of professional and practical training was conducted, and a survey of applicants for higher education was conducted. Almost 95% of applicants for higher education believed that the physics course in an agrarian and technical educational institution is primarily of a general educational nature and does not play a significant role in studying professional disciplines. At exams in general technical disciplines, more than 60% of applicants for higher education associate courses in general technical disciplines ("Electrical Engineering", "Theoretical Mechanics", "Machine Parts") with questions on physics and for such disciplines as "Theory of Mechanisms and Machines", "Mechanics of Materials and Structures" the connection with the physics course, according to applicants for higher education, is not traced at all. (Nikolaenko et al. 2021, pp. 212 – 219).

Examinations in professional disciplines showed that, when studying the disciplines of professional and practical training, applicants rarely address the issues and laws of physics; that is, more than 87% of applicants for higher education do not connect physics and the disciplines of professional and practical training. The reasons for this state of affairs are the insufficiently formed professional focus of the physics program. The traditional system of teaching physics in higher education did not sufficiently contribute to the implementation of the professional focus of training and did not allow a significant impact on the professional development of applicants for higher education. (Savytska et al. 2024, pp. 55 – 62).

One of the objectives of the pedagogical experiment was to collect the results and perform statistical processing of the results of the success of applicants for higher education before introducing a new method of teaching a physics course and to identify the shortcomings of the traditional one. The success of the training of applicants for higher education was analyzed based on the results of semester assessments in physics and disciplines from the cycle of professional and practical training for the introduction of a new model of professionally oriented training (Table 1).

Table 1. Analysis of the success of students studying at higher education level

Groups	Number of students	Disciplines											
		Physics				Agricultural machinery				Hydraulics and water supply			
		Excellent	Fine	Satisfactorily	Unsatisfactory	**Excellent**	Fine	Satisfactorily	Unsatisfactory	**Excellent**	Fine	Satisfactorily	Unsatisfactory
1	222	11	33	112	66	22	22	110	88	00	88	111	33
2	112	33	55	33	11	33	44	33	22	11	22	44	55
3	221	44	44	88	55	33	33	88	77	22	33	77	99
4	116	55	11	110	00	11	88	55	22	00	44	77	55
5	224	22	112	88	22	00	59	110	55	44	112	44	44
6	226	11	66	111	88	11	16	112	77	22	77	110	77
Total	1121	116	331	552	222	110	332	448	331	99	936	443	333
Share (of total)		113,2	225,62	442,97	118,2	88,26	226,4	339,7	225,6	77,4	229,7	335,5	227,3
Average value		3,34				3,17				3,17			

We determined the level of theoretical knowledge in physics and the possibilities of its application, taking into account future professional activity in the traditional teaching of the physics course material, using tests, which included 12 versions of problems and questions. The tests were offered to applicants of the first and second years of the specialty.

The problems and questions offered to applicants of the first year concerned the material of the section "Physical foundations of mechanics." Applicants of the second year were offered the material of the section "Electricity and magnetism." The first six versions of the work had three tasks to identify knowledge at the level of simple reproduction.

1. Formulation of the laws of the physics course.

For example, formulate: conservation laws (momentum, energy, angular momentum); basic laws of dynamics; Ohm's laws for direct and alternating currents; the Ostrogradsky-Gauss theorem, etc.

2. Definition of professional objects in which physical laws are applied.

3. A physics problem involving abstract objects or objects unrelated to future professional activity (the problem sets proposed in the physics course program are used).

The following six versions of tests had three problems in order to identify the level of knowledge, taking into account the explanations of phenomena, laws and regularities of the physics course and the possibility of applying this knowledge in solving physics problems with professional content.

1. What is the logical connection between Newton's three laws?

2. What is the weight of a freely falling body?

3. Derive the expression for the potential energy of a material point in a field of central forces.

4. What is the qualitative disparity between work and heat exchange as forms of energy transfer made up of?

5. Why is the potential of an electrostatic field always a continuous function of coordinates?

The second question of the problem assumed the implementation of a connection between fundamental knowledge in physics and the objects of professional activity of applicants for higher education in agricultural and technical educational institutions.

For example:

1. What physical laws and phenomena are observed as a result of the action of tillage mechanisms?

2. How will the thermal conductivity of the soil change if the amount of humus in it increases?

The third question is solving a physical problem at professional sites (movement of grain along a conveyor, movement of a body along a helical line of a vibratory hopper; determination of the forces acting on grains when moving in a sorting machine).

The results of the test assignments are presented in Table 2, the average values of the percentage of correct answers to all questions included in the assignment are given.

Table 2. The results of the control tasks (proportion of correct answers)

Work	Task number	Correct answers of students, %	
		First year	Second year
First	1	21%	22%
	2	17%	18%
	3	9%	10%
Second	1	14%	15%
	2	7%	9%
	3	5%	6%

As can be seen from Table 2, the level of knowledge of applicants for higher education is higher than the performance of tasks related to the simple reproduction of the material of the physics course and significantly lower - the performance of tasks on the application of knowledge, especially with the solution of problems in which not abstract, but specific objects related to professional activity appear. Thus, the obtained results allow us to conclude that the content and structure of the traditional physics course do not fully allow for mastering the techniques and methods for performing specific tasks related to the future professional activity of engineering teachers.

To identify the effectiveness of the proposed model of a professionally oriented physics course for applicants for higher education in engineering and pedagogical specialties, we used sections of the physics course in an experimental study, as well as professional disciplines: “Agricultural Machinery,” “Hydraulics and Water Supply,” and “Machines and Equipment of the Agro-Industrial Complex.” Professionally oriented material was used for all types of physics classes.

The experiment involved 417 applicants from the Faculty of Engineering and Technology. These students were divided into two groups. The first group consisted of 208 people and was the control group (CG). The second group consisted of 209 students and was the experimental group (EG). The groups were determined based on the results of the first-semester examination session in natural science disciplines (information technology, higher mathematics, chemistry). The success of applicants for higher education in these disciplines was, on average, the same in the control and experimental groups. In the experimental groups, training was conducted according to the developed methodology for teaching physics, and in the control groups, it was conducted according to the traditional one. The tests’ tasks to identify the level of assimilation of knowledge elements contained questions on physics of both theoretical and professionally oriented content. The number of applicants for higher education who completed the tests at a high and sufficient level in the experimental groups is 26% more than in the control groups (Table 3).

Table 3. Results of completion of tests by applicants in experimental and control groups

Groups	Number of students	Level			
		High	*Sufficient*	*Average*	*Low*
Experimental	209	43	94	49	23
Control	208	37	45	94	32

The ability to apply knowledge of physical phenomena, concepts, and laws to the analysis of agricultural facilities and some agricultural operations (conscious acquisition of knowledge) was tested using a professionally oriented test offered to applicants after studying the Mechanics section:

Option 1

1. What kinematic quantities must be considered for adjusting the reel of a combine harvester?
2. What is the effect of the speed of a soil-cultivating cutter on the height of unevenness at the bottom of a furrow?
3. What movement does the blade of the cutting unit make during the operation of a combine harvester?
4. How is a tractor's mass considered to determine its nominal traction force?

Option 2

1. What types of movement does the header of a harvesting machine make?
2. How is the speed of movement and the width of the capture taken into account for spraying crops?
3. What types of movements are performed during the operation of a soil cutter?
4. What types of forces act on the grain mixture in the indented drum?

Option 3

1. What kinematic quantities characterize the movement of the disc-cutting unit of the mower?
2. What types of energy do the soil and cutter knives acquire during processing?
3. What forces act on the grain material in the sieve state of the grain cleaning machine?
4. What forces act on the grain in the vertical airflow?

Option 4

1. What movement does the reel bar of the harvesting machine make?
2. What kinematic quantities characterize the rotational movement of the rotor of the rotary dams?
3. What movement does the grain make when thrown out of the grain pulverized conveyor?

4. What trajectory relative to a stationary observer do the disk points of the transplanter have during its movement?

The test's performance was assessed on a five-point scale (correct and complete answers): four questions – 5 points; three questions – 4 points; two questions – 3 points; one question – 2 points.

Table 4 presents the results of the professionally oriented test for the control and experimental groups, respectively.

Table 4. Results of professionally oriented test work (control groups)

Academic year	Groups	Quantity	Level				*No-shows*
			High	*Sufficient*	*Average*	*Low*	
2023–2024	**Control groups**	31	4	8	15	3	1
		23	2	3	9	9	0
		24	0	4	9	10	1
		29	4	5	10	7	3
		28	4	7	7	8	2
		27	2	5	12	6	2
		24	1	6	16	0	1
		22	1	4	12	4	1
Total		208	18	42	90	47	11
Share (of total quantity), %			9	20	43	23	5

To check theoretical knowledge and practical skills, they compared the exam scores obtained by the applicants of the control and experimental groups (table 5).

Table 5. Comparison of exam grades in physics

Groups	Number of students	Level			
		High	Sufficient	*Average*	*Low*
Control	208	17	51	106	34
Experimental	209	30	65	90	24

From the table, it is clear that implementing the principle of professional orientation in training corresponds to a higher level of theoretical knowledge. By connecting tasks with professional content, students more deeply understand the laws of physics and can give concrete examples related to professional activity.

To determine the strength of knowledge, an observation was made of the work of higher education applicants in the further study of professional disciplines, whose teachers asserted that the applicants' knowledge of higher education in physics was used sufficiently freely in the performance of professional tasks.

The decisive criterion for the effectiveness of the proposed methodological support should be the results of the training, which show the influence of the knowledge obtained during the study of physics at the level of the study of the professional disciplines “Mechanical-technological properties of agricultural materials”, “Agricultural machines”, “Hydraulics and water supply” and other disciplines. With this goal, the success of the applicants of the higher education control and experimental groups in the specified disciplines was compared according to the results of the exams. These data are shown in Tables 6 and 7.

Table 6. Examination grades in professional disciplines

Number of grups	Total number of applicants for higher education	Number of higher education applicants who passed exams											
		Agricultural machines				*Mechanical-technological properties agricultural materials*				*Hydraulics and water supply*			
		5	4	3	2	5	4	3	2	5	4	3	2
	208	18	62	94	34	9	52	112	35	10	60	101	37
Average score		3,3				3,17				3,21			

Table 7. Examination grades in professional disciplines

Experimental groups	Total number of applicants for higher education	Number of higher education applicants who passed exams											
		Agricultural ma-chines				*Mechanical-technological properties agricu;tural materials*				*Hydraulics and water supply*			
		5	4	3	2	5	4	3	2	5	4	3	2
	209	29	68	88	24	22	67	92	28	18	74	91	25
Average score		3,5				3,3				3,4			

A comparison of success rates in the disciplines “Agricultural machines,” “Mechanical-technological properties of agricultural materials,” and “Hydraulics and water supply” allows us to state that they are higher in experimental groups than in control groups. Reviews of teachers who conducted classes in professional disciplines testify that applicants of experimental groups, to a greater extent, use physics connections with professionally oriented disciplines.

Analyzing the experiment’s results, it can be concluded that applicants to higher education institutions who studied according to the proposed model of professionally oriented training formed deep fundamental knowledge and skills;

that is, they are able to project their knowledge of physics into the disciplines of the professional-practical cycle.

The experiment's results showed that training students according to the developed methodology contributes to increasing the level of fundamental and professionally oriented knowledge in physics by 10–15%; the application of fundamental physics knowledge for solving tasks related to future professional activity in the study of disciplines of professional and practical training increased by 25%.

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