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RESEARCH OF USING THE SYSTEM APPROACH TO INCREASE PROFESSIONAL COMPETENCE OF STUDENTS IN THE PROCESS OF STUDYING NATURAL SCIENCES

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Abstract. The study deals with the formation of professional competence of future agricultural engineers in higher education institutions. Based on the analysis of modern concepts, we rethink the essence, purpose, and content of the training of future mechanical engineers from the perspective of the implementation of the competency approach. The purpose of the article is to study the formation of sustainable professional competence of future agricultural engineers in the process of studying natural sciences. We use theoretical research methods: study and analysis of psychological-pedagogical, normative and special literature on the research problem; analysis of state educational standards, programs, books and methodical materials. We have developed a structural-functional model of formation of professional competence of mechanical engineers, which will allow to ensure effective formation of professional competence of future specialists in the agricultural and technical field. The study emphasizes the importance of implementing the principle of professionally oriented training of future engineers in the process of forming their professional competence. It also proves the effectiveness of the formation of professional competences of future engineers with the aim of training highly qualified specialists in the agrarian and technical field.

Keywords: professionally oriented training; competence; interdisciplinary connections; natural sciences

Problem statement

In the conditions of globalization and integration processes, the problem of improving the quality of training of specialists for professional activities, in particular in the agrarian and technical sphere, becomes particularly significant. These fields require qualified specialists who are able to apply knowledge and skills in modern market conditions of business, which are rapidly changing. It becomes necessary to significantly modernize and improve the educational process, to implement a competency-based approach and a person-oriented educational paradigm, what is reflected in such basic educational normative documents as the “National Doctrine of the Education Development of Ukraine in the 21st Century”, the laws of Ukraine “On Education”, “On Higher Education”, “Strategy for the Development of Higher Education in Ukraine for 2022 – 2032”, “Concept of Implementation of State Policy in the Field of Professional (Professional and Technical) Education “Modern Professional (Professional and Technical) Education” for the period until 2027”.

Progressive changes in the functioning of higher education institutions lead to further scientific research that will contribute to the training of a competent, competitive specialist on the labor market, who is fluent in the profession and oriented in related fields of activity, capable of effective work in a specialty at the level of world standards, ready for constant self-improvement, social and professional mobility.

Reforming the system of higher education involves strengthening the fundamental component of the training of future specialists in the agrarian and technical field. This makes it necessary to review the theoretical and methodological foundations of the educational system of the higher education institution, especially at the stage of selection and differentiation of the content of natural sciences, the professional direction of which contributes to the formation of professional mobility and competence of future specialists.

Analysis of basic research and publications

Problems of modernization of higher education and improving the quality of professional training became the subject of research of such scientists as: V.A. Adolf, O.E. Antonova, V.I. Baidenko, I.D. Boichuk, R.S. Hurevych, E.F. Zeier, S.O. Klymenko, Z.N. Kurliand, V.I. Luhovyi, O.P. Mitriasova, V.A. Petruk, S.O. Sysoieva, S.E. Shyshov, L.V. Stefan et al.

In the process of analyzing scientific publications, studies related to the formation of professional competence were of particular interest. Among them there are dissertations and scientific articles by T.A. Lazarieva, M.S. Lobur, N.S. Sychevska, L.M. Krainiuk, V.O. Potapov, L.M. Yancheva, who emphasized the role of professional disciplines in the process of forming the professional competence of future specialists.

Specifics of introducing professional training into the educational process became the focus of research by such foreign researchers, as X. Cheng, L.-Y. Wu, H. Mizell, M. Mulder, D. Nurhayati, A. Jumadi, J. Wilujeng, S. Sandhu, T. Afifi, F. Amara, et al.

Despite the rather broad representation of the studied phenomenon in scientific research, there is still no ambiguity both in its operationalization and in the definition of its composition, and therefore, the selection of ways of its development. Thus, the topicality of the topic is due to the insufficient justification of the methods of development of professional competence and the increasing demands of social practice in competent specialists.

Research aim

The relevance of the issue, its insufficient theoretical and practical development, the need to overcome the outlined contradictions determined the aim of this article: to form sustainable professional competence of future agricultural engineers in the process of studying natural sciences.

Research methods

To achieve the set aim and implement the tasks, we used a complex of research methods: theoretical analysis of philosophical, psychological and pedagogical literature on the topic of the study with the aim of selecting and understanding the actual material; analysis of concepts, theories and methods aimed at identifying ways to solve the researched problem as close as possible to the future professional activity of students.

Research material and its discussion

Modern agriculture is characterized by significant modernization, changes in the nature and content of the specialists' work, which provide for the improvement of existing and introduction of new competitive technologies, modern requirements for the creation of energy-saving technologies, new requirements for the quality of agricultural products according to European standards.

Recently, the importance of fundamental natural and scientific training of specialists in the agrarian and technical field is growing. The content of all professionally oriented and special disciplines is based on general natural and scientific disciplines (physics, mathematics, chemistry, biology, ecology). Under such conditions, it is important to transform the content of fundamental disciplines, to include in syllabus sections and topics that would contribute to the formation of professional knowledge and skills, personal traits and qualities that are an indicator of success, professional competence of a mechanical engineer (Nikolaenko et al. 2022, pp. 638 – 644).

Broadly speaking, the general education and fundamental components of training should be oriented towards the specific professional education of young people, only then it will have a real meaning. At the university, teaching natural sciences should not be for the sake of actual physics, chemistry, mathematics, etc., but primarily for the sake of a professional specialty, that is, natural sciences should have a clear professional orientation. In turn, professional training becomes more qualitative if it provides breadth of knowledge, its polytechnicity, mastery of generalized skills and abilities (Kurliand et al. 2012, pp. 46 – 47).

The model we developed is aimed at the formation of the professional competence of specialists during studying natural sciences and makes it possible to understand that the study of only one of the above training cycles is not able to solve this task. Only complex system knowledge acquired in the process of studying all cycles of educational disciplines will ensure the effective formation of professional competence of future specialists in the agricultural and technical field (Fig. 1).

The competency-based approach that we used when building the model is a method of modeling and designing educational outcomes (Bulgakova et al. 2023, pp. 661–666). The application of this approach to the training of specialists in specialty 208 Agricultural engineering involves:

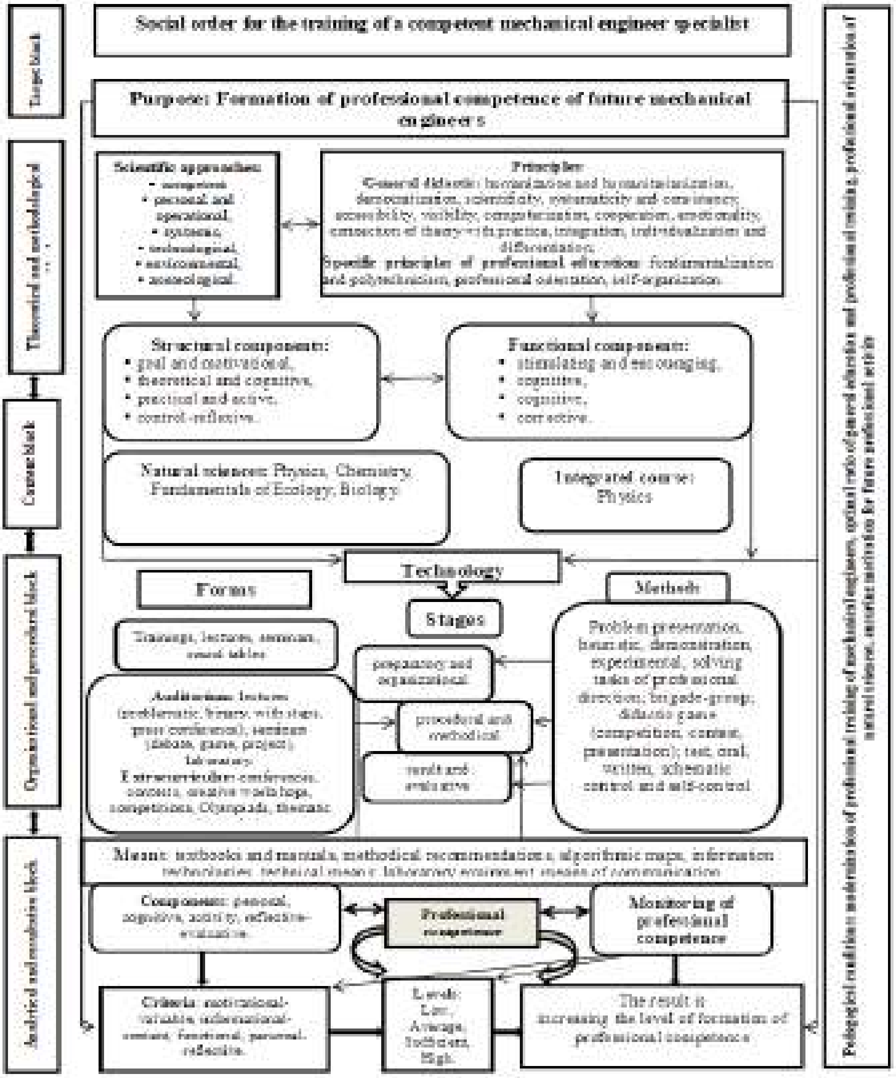

Figure 1. Model of formation of professional competence of future mechanical engineers in the process of studying natural sciences

1. Determination of the list of competencies (key and professional) from all educational disciplines (general education, fundamental, professionally oriented and professional), which ensure the formation of professional competence of a specialist.

2. Determination of the structure of professional competence of future mechanical engineers.

3. Development of a structural and functional model of formation of professional competence of mechanical engineers.

4. Formation of subject competencies according to the discipline syllabi based on the application of modern technologies, methods, and teaching tools, which provide for the modernization of the content of education, the organization of the educational process, and views on the structure, form, and content of the evaluation of graduates, which must meet the conditions of the modern labor market and requirements of employers.

5. Creating conditions for the development of educational, cognitive and practical knowledge, abilities and skills of students.

6. Formation of students' motivation for continuous learning, continuous work and self-improvement throughout life.

The professional orientation of natural sciences is reflected in the system of interdisciplinary connections (Turytsia 2013, pp. 40 – 60). The implementation of the principle of interdisciplinary connections ensures overcoming the disparity of knowledge, abilities and skills of students in the conditions of multidisciplinary education, contributes to increasing the level of mobility of knowledge and skills of students. At the same time, the professional orientation of education is significantly strengthened, which optimizes the improvement of practical training, encourages students to solve scientific, industrial, social, economic, and environmental problems in order to successfully master the chosen profession. Interdisciplinary connections of disciplines should be reflected in curricula, syllabi, content of disciplines and textbooks.

In order to establish them, we analyzed the curriculum of specialty 208 Agricultural engineering, syllabi in the disciplines Physics, Materials Science, Theoretical Mechanics, Agricultural machines, Mechanical and Technological Properties of Agricultural Materials, etc. The analysis testified to the insufficient full implementation of interdisciplinary integration in educational and methodological documents, which prompted the justification of a complex of interdisciplinary connections between natural sciences and professional disciplines. To create a solid theoretical base, we analyzed the connections of physics with the main general technical, practical and professional training disciplines. For example, the study of the discipline Theoretical Mechanics is based mostly on the kinematics and dynamics of a material point, which are studied in the course of physics. The study of the cycle of professional and practical training disciplines is also interconnected with the study of sections and specific topics of the physics course. Thus, the study of the professional disciplines Mechanical and Technological Properties of Agricultural Materials, Agricultural Machines is impossible without knowledge of such sections and topics of the physics course as Kinematics, Dynamics, Elastic Forces, Conservation Laws. Studying the disciplines Energy Resources in the Agro-Industrial Complex, Hydraulics and Water Supply, Soil Science and others requires knowledge of the material of various sections of the physics course, such as Physical Foundations of Mechanics, Fundamentals of Molecular Physics and Thermodynamics, Electricity and Magnetism.

The content of the physics course is a fundamental basis without which the successful professional activity of an agricultural engineer of any profile is impossible. In order to successfully solve the problem of teaching the physics course, we performed a thorough analysis of the relationship between the physics course and the main general technical and professional and practical training disciplines. This made it possible to determine what physical knowledge, skills and abilities will be used in the further professional training of students (Zbaravska et al. 2010).

We determined the content of the course issues on the basis of the analysis of intersubject relations of physics and professional disciplines (table 1).

Table 1. Interdisciplinary connections of the disciplines of the professional cycle of training of mechanical engineers

Professional disciplines	**Interdisciplinary connections**	
	General scientific, natural and mathematical disciplines	**Professional and general professional disciplines**
Tractors and cars	Physics (physical phenomena); Chemistry (combustion reaction); Drawing (folding drawings, reading); Engineering graphics; Technical mechanics; Electrical engineering; Materials science	Basics of agronomy; Agricultural machinery; Hydraulic drive of agricultural machinery; Fuel and lubricants and other operating materials
Agricultural machines	Physics (kinematics, dynamics, statics); Chemistry (fertilizers); Drawing (reading drawings); Engineering graphics; Technical mechanics; Materials science	Basics of agronomy; Tractors and cars; Mechanization of animal husbandry; Hydraulic drive of agricultural machinery
Repair of agricultural machinery	Physics; Chemistry; Drawings (working, assembly drawings, reading and execution); Machine parts; Engineering graphics; Technical mechanics; Materials science; Electrical engineering	Tractors and cars; agricultural machinery; Mechanization of animal husbandry; Operation of machines and equipment; Electrical equipment and means of automation of agricultural machinery; Hydraulic drive of agricultural machinery; Fuel and lubricants

Operation of machines and equipment	Physics (kinematics, dynamics, statics); Technical drawing; Biology (plant protection); Horticulture (plant processing); Chemistry (fertilizers, chemical treatment of plants); Machine parts; Technical mechanics; Materials science; Electrical engineering	Basics of agronomy; Basics of animal husbandry; Tractors and cars; Agricultural machinery; Mechanization of animal husbandry; Electrical equipment and means of automation of agricultural machinery; Fuel and lubricants and other operating materials
Mechanization of processing and storage of agricultural products	Physics (physical phenomena); Chemistry; Drawings (folding drawings, reading drawings)	Basics of agronomy; Basics of animal husbandry; Tractors and cars; Agricultural machinery; Mechanization of animal husbandry; Operation of machines and equipment; Electrical equipment and means of automation of agricultural machinery; Fuel and lubricants and other operating materials
Electrical equipment and means of automation of agricultural machinery	Electrical engineering; Physics (section Electricity and magnetism); Machine parts; Engineering graphics; Technical mechanics; Materials science	Tractors and cars; Agricultural machinery; Mechanization of animal husbandry; Mechanization of processing and storage of agricultural products; Fuel and lubricants and other operating materials

Comparing the content of sections and topics proves that professional disciplines are „carriers of fundamental knowledge" (Zbaravska et al. 2019, pp. 327 – 330). Certain sections and topics of natural sciences have a clear professional direction, which significantly increases the motivation to study natural disciplines, without the ability to operate with the knowledge and skills of which during technological processes and production situations, it is impossible to become a competent specialist. The process of studying natural sciences (especially physics) not only provides the formation of knowledge that serves as a basis for the development of professional thinking in future specialists, the ability to model real situations that are related to the performance of professional tasks, but also contributes to the formation of intellectual abilities of students, activation of cognitive activity and independence, development of creative abilities, communication skills, i.e. creation of a foundation for acquiring professional competences, ability for further productive professional activity. Knowledge of physics is based not only on the study of theoretical issues of general technical and professional disciplines, but also on the performance of professional tasks (Table 2).

Table 2. The use of industrial experience and professional knowledge during the study of the physics course

Topics of the physics course	Use of industrial experience and professional knowledge
1	2
Curvilinear uniform movement. Relativity of motion	Movement of a car, tractor, combine harvester. The movement of plow bodies, disc knives in multi-body plows relative to the ground and relative to each other, the tractor. Speed of movement of agricultural machines and mechanisms, animals. Determining the speed of cars and animals
Adding motions	Movement of knives in combines, hay mowers, harvesters, movement of plants on a conveyor, combine harvesters
Superposition and decomposition of forces	Superposition of forces of two tractors that harvest straw with a windrow. Decomposition of the force on the component in the ploughshare, the conditions for its stability and uniform deepening; decomposition of forces on harrow teeth, cultivator paws, coulters of planters. Decomposition of the traction force of the tractor on the component when the straw is skimmed with a drag. The use of a wedge in the working parts of agricultural machines (knives, ploughshares, disk knives, cultivator teeth). Inclined plane in loading and unloading operations (straw cutting, beet hill, inclined conveyors). Decomposition of the forces acting on the connecting rod of the crank mechanism.
Uniformly variable motion	Acceleration of various vehicles when starting from a standstill. Effect of accelerations on living organisms
Adding parallel forces. Center of gravity. Stability	Adding parallel forces in tractor units (sowing, for plowing with multi-hull plows). Machine operating conditions on slopes. Changes in the stability of the machine during the transportation of straw and hay
Friction	The role of friction in agricultural machines, in living organisms. Friction of parts of machines, working bodies of processing machines, plowshares, teeth, shelves, friction discs. Friction and resistance of the environment - soil resistance. The force of friction and resistance in living organisms. Bearings sliding, rolling in tractors, cars. Anti-friction pairs of materials. Principles of operation of the clutch mechanism.
Inertia. Newton's First Law of Motion	Grain cleaning and sorting using sieves. Grain cleaning using a grain control. Scheme of grain cleaning in the winnowing machine. Inertial grain movement of some self-pollinating plants. Flywheels of internal combustion engines (tractor, car), locomotives. Analysis of the forces acting on a car, a tractor during their uniform movement. Hydraulic ram installation

Newton's Second and Third Laws of Motion	Traction force of tractors of different brands, in different gears. Traction force of cars. Measurement of forces with a dynamometer
Work and energy. Law of equality of work	Examples for calculating the work of a tractor, a stacker, and a forklift. Examples of performance of work and power in living nature. Dependence of the traction force of the tractor engine, car on the speed of movement. Hammer crusher. The lever in the automatic pump. Levers for driving a tractor, a car. Hydraulic jack. Hydraulic device for lifting attachments on a tractor. The length of the car's braking distance
Curvilinear motion	The movement of water droplets in a sprinkler system when the water jet is directed at an angle to the horizon. The movement of the thrown grain by inertia from the belt of the grain controller. Rotational movement of wheels, drums, pulleys. Centrifugal regulator of revolutions of the crankshaft of the internal combustion engine. Centrifugal pumps (motor and stationary). Jet centrifuge for fine cleaning of oil in the DT-175 tractor. Centrifugal fertilizer spreaders. Separator. Honey race. The role of the counterweight on the engine crankshaft.
Oscillations and waves	Periodic oscillating movement of the cutting knives of the harvester; fluctuations of the grate conditions of fans, harvesters. Oscillations of sound signal membranes, diaphragm fuel pump in a car. Centering of rotating drums. "Anti-resonance" springs in the intake and exhaust valves of internal combustion engines. Prospects for the use of vibrating tillage machines.

Dealing with the industry standard of specialty 208 Agricultural engineering, we analyzed the connection of production functions and typical activities of future specialists with the cycle of professional and practical disciplines and physics. The content of these connections one can see in table 3.

Table 3. Connection of production functions and typical activities

Content of production function	Name of typical activity	Cycle of professional and practical disciplines	Physics
1. Design	Design of non-standard equipment	Machines and equipment of the agricultural industry, operation of machinery in the agricultural industry, automation of production, technical service in the agricultural industry, reliability and repair of machines and equipment	Physical foundations of mechanics, solid state physics, elements of physical electronics, molecular physics, waves, electricity

2. Organization	Organization of compliance with occupational safety and hygiene	Basics of labor protection, electric drive and electrical equipment	Electricity, optics, nuclear physics
3. Management	Analysis and evaluation of the use of technical equipment, systems and their management	Technical service in the agricultural industry, reliability and repair of machines and equipment, automation of production, control and measuring devices, electric drive and electrical equipment, hydraulics and water supply	Physical foundations of mechanics, electricity and magnetism (electrical oscillations), solid state physics, molecular physics (contact thermoelectric phenomena)
4. Performance	Analysis of loads on working bodies and parts of machines, indicators of their strength	Reliability and repair of machines and equipment, control and measuring devices, mechanical and technological properties of agricultural materials	Physical foundations of mechanics, solid state physics, molecular physics (oscillations of the atomic crystal lattice, crystal structure), electricity (electric field, electromagnetic induction)

For instance, when studying the topic "Strength of elasticity", the material is divided into two parts: basic and professionally oriented (Table 4).

Table 4. Consideration of the topic "Strength of elasticity"

Main part	Professionally oriented part
A general idea of elastic force. Concept of elastic deformation	Elastic deformations in agricultural machines and units. The influence of elastic deformations on the quality of mechanical processes
The concept of stiffness. Stiffness coefficient	The stiffness of materials on the examples of parts and devices of agricultural machines
Hooke's law. Proportionality between elastic force and deformation	Correlation between elastic force and deformation on the examples of agricultural machines
Elastic modulus of (Young's modulus). Mechanical stress	Mechanical stress that occurs during the operation of devices and units

The concept of shear. Relative shear. Shear modulus	Shear deformation. Calculation of the strength, reliability and durability of agricultural parts

To determine the expediency of implementing the proposed model of formation and development of professional competence of future specialists, we conducted a pedagogical experiment. We highlight the following sequence of formation and development of students' professional competence:

1. Assessment of the level of formation of professional competence components at the initial stage.
2. Development of professional competence components in the process of performing laboratory and practical work within the framework of the proposed didactic system.
3. Assessment of the level of formation of the students' professional competence components (after performing laboratory and practical work).
4. Verification of the effectiveness of the acquired methodical knowledge and skills of students in practice in the formation and development of a professional personality.

To test the effectiveness of the model, we conducted an educational experiment at the higher education institution Podillia State University. 60 students of the Faculty of Engineering and Technology took part in the experiment. These students were divided into two groups. The first group consisted of 29 people and was the control group (CG). Classes in these groups were held according to traditional teaching methods. The second group consisted of 31 students and was experimental (EG). For students of the second group, lectures, laboratory and practical work were conducted according to the methodology described in this article.

At the initial stage, before laboratory and practical work, we asked all students to answer questions that were case proposals. Each of the proposed cases was aimed at determining the level of formation of four components of professional competence: outlook, communication, organization and information.

The analysis of the educational experiment results showed that at the initial stage (before the experiment) both the control and experimental groups had an almost equal percentage of students with the same level of professional competence (Fig. 2). Thus, 28% of students of the control group and 26% of students of the experimental group had an average level of professional competence, in both groups the percentage of students with low and sufficient levels of professional competence was 18% and 41%, respectively. Before the start of the experiment, 8% of students in the control group and 12% of students in the experimental group demonstrated a high level of professional competence.

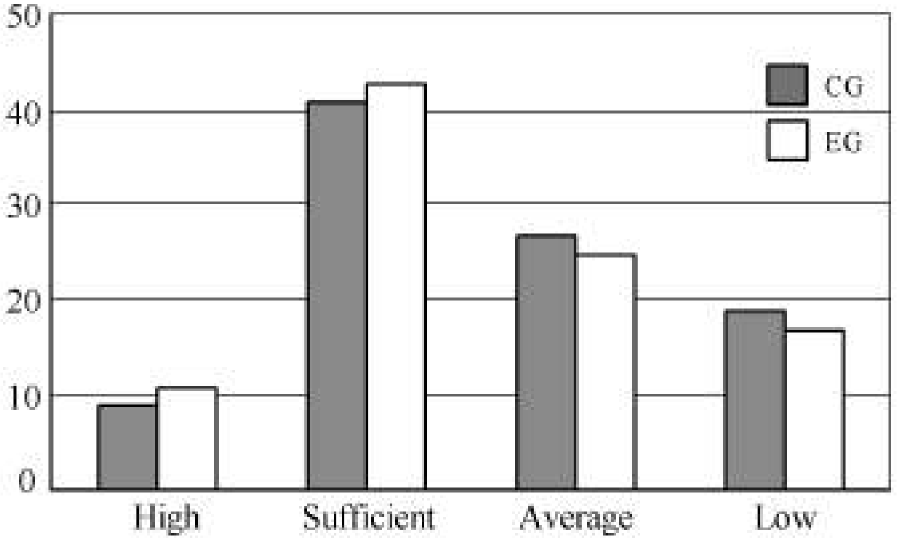

Figure 2. Comparison of the level of professional competence formation of students of the control and experimental groups before the start of the experiment, %

At the end of the course of laboratory works, we compared the number of students of the control group who had low, average, sufficient and high levels of professional competence. The results of the comparison are shown in fig. 3. One can see that performing laboratory work in the "classical" way leads to a decrease in the number of students with a low level of professional competence formation.

Before laboratory work in the control group, 27% of students had a low level of professional competence. After performing laboratory work, this number decreased to 17%, but the students did not increase the existing average level of professional competence formation to a high level. This indicates that the traditional way of conducting laboratory work in physics affects the formation of professional competence.

A comparison of the number of students in the control and experimental groups after performing laboratory work according to the developed scheme (Fig. 3) showed that in the control group the number of students with a low level of professional competence was 17%, and in the experimental group this level was 12%; the number of students with an average level of professional competence in the control group was 31%, and in the experimental group 23%.

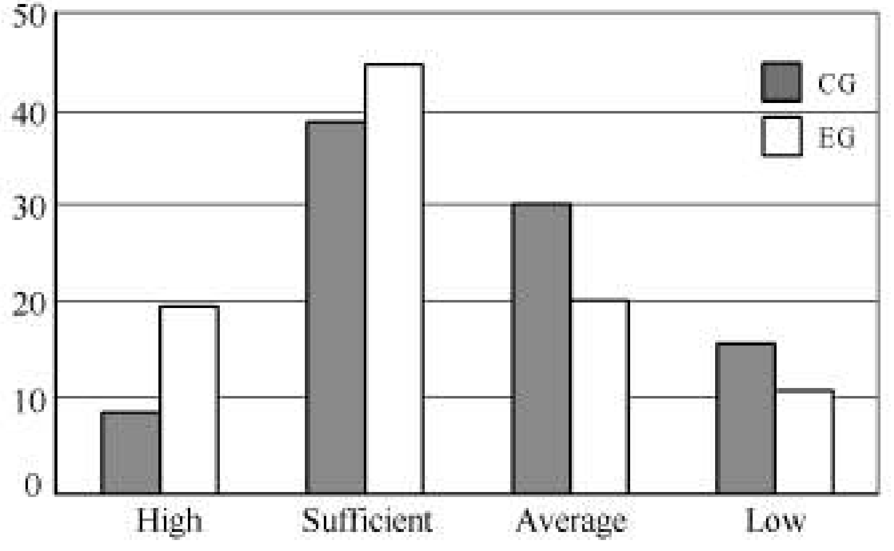

Figure 3. Comparison of the level of professional competence formation of students of the control and experimental groups after the experiment, %

As we can see, after the experiment, the number of students with average and high levels of professional competence formation in the experimental group is greater compared to the number of students with this level in the control group. Thus, 46% of students in the experimental group had a sufficient level of professional competence formation, while in the control group – 38% of students. In the experimental group, 19% of students had a high level of professional competence formation, and only 8% of students from the control group had such a level. These results indicate that the developed system increases the level of professional competence, which indicates the correctness of this system.

Thus, the use of the developed model of formation of professional readiness of future mechanical engineers in lecture and laboratory classes in physics makes it possible to increase the number of students who have an average and high level of formation of professional competence compared to the number of students who studied according to the traditional system.

Conclusions

The developed model is aimed at forming the professional competence of specialists during the study of natural sciences. But it is obvious that the study of only one of the above training cycles is not able to solve this task. Only comprehensive systematic knowledge acquired in the process of studying all cycles of educational disciplines will ensure the effective formation of a specialist's professional competence. In the study, the principle of professional orientation, which is carried out thanks to the integration of natural and professional disciplines, is particularly important for the modeling process and its practical implementation. We consider the process of integration as an objectively determined process of interaction and interpenetration of scientific knowledge, aimed at their systematization into a coherent system. In the context of the research, the integration of natural-scientific and professional knowledge forms a comprehensive view of technological processes, ways of managing them during use in the agrarian-technical field, which is an important component of the professional competence of the future specialist.

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