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Educational Conditions For Formation Of Special Competence Of The Future Specialists In Agricultural Engineering

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Abstract **— The article deals with the educational conditions for the formation of special competence of the future agricultural engineering specialists in the process of professionally oriented training in physics. The authors analyse approaches to integrating physical knowledge with professional tasks, relevant to the branch of agricultural engineering, emphasizing the importance to develop in the students a comprehensive understanding of the relationship between the theoretical foundations and the solutions of practical engineering. There is revealed the importance of an interdisciplinary approach in creating educational programs, aimed at the development of the students' ability to apply physical laws and principles in order to solve real problems of production. There are identified the key educational conditions that contribute to the formation of special competence, including: application of problem-oriented learning, aimed at the development of the students' skills in independent analysis of engineering problems and finding solutions; the use of modern technologies for modelling physical processes, allowing for the visualization of complex phenomena and the reproduction of working scenarios of the agricultural engineering activities; the development of critical thinking, ensuring the ability to evaluate and interpret scientific data in a professional context; the formation of teamwork skills, which is important for efficient interaction in production conditions and solution of complex problems. Particular attention is paid to the digital educational technologies, such as virtual laboratories, digital simulators and software packages that simulate technological processes in the agricultural sector. These tools allow the students to practice engineering skills, to test various models, and analyse their efficiency without the risk of real losses. An impact is assessed in the study of these educational conditions upon the level of training the students in the field of agricultural engineering. The results showed that the use of an integrative approach and digital technologies helps to raise the level of mastery of the educational material by 30–35%, to increase the degree of the students' involvement in the educational process, and develop practical engineering skills. Analysis of academic performance has shown that the students studying in a digital and practice-oriented educational environment are by 40% better at the tasks that require an analytical approach and by 25% faster at adaptation to professional conditions. A conclusion is made that the creation of favourable educational conditions, based on a combination of traditional and innovative teaching methods, can improve the efficiency of professional training of agricultural engineers, ensuring their readiness to solve complex engineering problems, develop innovative thinking and successfully adapt to digital transformations in the agro-industrial complex.**

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I. INTRODUCTION

Training qualified specialists with developed special competence is one of the priority areas in the field of professional education. Specialists who are ready to efficiently solve professional problems are in demand in the conditions of the modern agro-industrial sector. This requires the introduction of new approaches to teaching that ensure a harmonious combination of theoretical knowledge with practical skills and an emphasis on professionally oriented tasks.

Physics, being the foundation of the engineering education, occupies a special place in the training of the future specialists in agricultural engineering: it provides an understanding of the basic laws of nature, underlying agricultural technologies, and forms scientific and technical thinking.

The accelerated development of the agro-industrial complex necessitates improved training of the personnel for this area, which underlines the relevance of the research topic. Application of innovative educational technologies and the integration of academic disciplines, such as physics, with professional activities make it possible to create conditions for the development of the students' competencies that are necessary for the solution of complex engineering problems. In this context professionally oriented training in physics plays the key role, as it promotes not only an in-depth study of theory but also the development of skills for its application to solve the current problems in the agricultural engineering industry.

Research of the problem of forming professional orientation of training specialists of various profiles is widely presented in the works of the domestic and foreign scientists, involved in pedagogy, psychology, and also in methods of professional education. As a rule, there are considered as the basis the issues of the motives for professional activity, interests and value orientations, pedagogical conditions for training specialists, etc.

Investigations into the problem of development professional orientation for training specialists in various fields have been revealed in the scientific works of Beloev, I. et al. [1], Johnson, D. et al. [2], L. Miller, A., Green, T. [3], Smith, J., Brown, K. [4].

The experience of transforming professional education in the field of agricultural engineering is presented in cases from various countries (Germany, Kenya, India, Canada). Particular attention is paid to the implementation of dual learning, digital technologies and a STEM-oriented approach. The authors [2; 5; 6] analyse the use of digital tools and modelling in teaching engineering disciplines.

Comparison of the traditional and the digital teaching methods, as well as an analysis of the students' academic achievements after the implementation of digital solutions were made by Taylor, P., Wang, H. [7]. The authors conclude that there is a need for further development of digital tools in the education of agricultural engineering to adapt to the requirements of modern industry. There are considered the key aspects of digitalization of education and its impact upon the learning process, proposing strategies for the integration of online resources, virtual laboratories and interactive platforms into the learning process [8; 9]. Lin et al. consider the importance of professional support and exchange of experience among the teachers for successful implementation of digital technologies into modern education [10].

In their works [11; 12] the authors examine modern teaching methods, aimed at integration of fundamental physical knowledge with the professional training of the future engineers. The authors note the importance of further development of innovative educational methods in the training of the future specialists.

Although the scientific and methodological publications often examine this topic in depth, they often lack a clear plan of action. Therefore, there is a need to develop detailed methodological materials that would regulate the set of methods and teaching tools within a specific discipline. Such materials should not only contribute to the formation and development of professional qualities of the students but also contribute to the solution of current problems. An example of such an approach and its scientific interpretation can be considered in the form of solving specific scientific and production problems [13; 14]. This approach - when the analysis is accompanied by specific recommendations and practical ways of implementation - is the key factor for the improvement of the quality of education.

Within the framework of modern pedagogical discourse, the educational results are most often viewed through the prism of a competency-based approach. From his point of view, the result of training is expressed in the formation of a set of competencies – a kind of "arsenal" of knowledge, skills, abilities and personal qualities – that allows one to act efficiently in various professional contexts. If talking about a future specialist in agricultural engineering, then his special competence means the ability to use academic disciplines (in particular physics), taking into account the current challenges and realities of the sphere of agricultural engineering, as well as the ability to successfully solve a set of technical problems in the process of training and in the future professional activity.

Practice and the research show that the efficiency of professionally oriented teaching of natural science disciplines in universities is directly related to how the main educational blocks are distributed in time: natural science, general professional and specialized disciplines. The linear structure, adopted in the traditional curricula, often makes the students lose interest in their chosen profession. In the early years of study, when the interest is focussed on theoretical courses, many students experience

the lack of a link between the subjects they study and their future professional activities, which leads to a decrease in their motivation and disappointment in the specialty [11].

Bringing the study of natural science disciplines closer to specialized courses allows one to enhance their professional significance, strengthen the students' confidence in the correctness of their choice of profession, and increase their academic motivation. With such an approach natural science and he general professional subjects are perceived not as abstract theoretical courses but as important tools for understanding the key aspects of the specialty. This eliminates an accumulation of the "reserve" knowledge, accelerates its use in professional training and helps the students develop the necessary competencies. In addition, this approach creates conditions for consistent and systematic implementation of the research work which can begin at the early stages of training and be completed within the framework of the diploma project, ensuring the integrity of the educational process and the development of the applied skills. Therefore, the purpose of the conducted study is to identify and substantiate a set of educational conditions that ensure the formation of special competence of the future teachers of the agricultural engineering profile when studying physics in a professionally oriented format.

The research of the efficiency of the new methodology applied the following modern tools: a digital pedagogical experiment with online platforms and educational analytics to assess the quality of the classes, electronic surveys through specialized mobile applications to receive the feedback, analysis of academic performance by using the big data methods and machine learning algorithms to compare the results, remote expert assessment using the video conferencing and online collaboration tools, as well as automated monitoring of the educational process through the tracking systems of the students' involvement.

II. Materials and methods

For efficient formation of special competence, certain educational conditions are necessary which in total will stimulate the students' cognitive interest, ensure a high practice-oriented focus of training and develop the personal qualities of the future agricultural engineers. Let us consider the main conditions in more detail.

A. An interdisciplinary approach

The connection of physics with other disciplines, such as technical mechanics, hydraulics and heat engineering, engineering graphics and computer modelling, agricultural machinery, etc., allows the students to see the practical significance of the phenomena being studied. A link between physics and these disciplines plays the key role in the formation of the students' professional thinking [12].

For example, the study of the law of energy conservation in physics may be associated with the calculation of the efficiency of the internal combustion engines, used in agricultural machinery. The laws of hydraulics find practical application in the design of the irrigation systems, where exact calculation of the water pressure and flow is required. The knowledge of mechanics is important for the analysis of the load on the components and assemblies of the agricultural equipment, allowing to design more reliable machines. In thermodynamics the students study the heat transfer processes, which finds application in the development of the heat pumps and heating systems for agriculture. Electrodynamics, in turn, helps to understand the operation principles of electric generators and motors that are used in the production of modern agricultural.

Practical classes may include modelling of the irrigation systems, calculation of the parameters of machines and aggregates, analysis of thermal processes in the grain dryers, and designing the energy-saving technologies. For example, application of the knowledge in physics allows optimizing the operation of the drip irrigation system which reduces the water consumption and energy costs. The laboratory experiments, such as studying the strength of materials, are also used in the development and testing of the agricultural machinery.

The integration of physics and professional disciplines develops in the students the skills of an interdisciplinary approach, analytical thinking and the ability to solve real engineering problems. This enhances their readiness for professional activities and increases their motivation to learn. Thus physics becomes not only the theoretical basis but also a tool for achieving practical results in agricultural engineering.

B. Problem-based learning

Setting tasks, based on real professional situations promotes the development of analytical and critical thinking.

For example, the students may be asked to develop a project to optimize the operation of a heat pump for heating a greenhouse, where it is necessary, to calculate the energy costs and efficiency of the system. It is also possible to create models of the operation of the wind turbines which are used to provide agricultural facilities with electricity, with calculations of the efficiency factor and the effect of the wind speed on the energy generation. Another example of the task might concern the design of a grain storage and separation system [15], where the students analyse the heat loss, the temperature distribution within the storage facility, and the energy efficiency of the ventilation system.

The drying chamber is used to remove moisture from various agricultural products, such as grain, vegetables, fruits, herbs and others. Diffusion is the key process that ensures the movement of moisture from the inner layers of the material to the surface, from where it evaporates. Such tasks require that the students applied the knowledge of physics, data analysis, design, and being aware of the consequences of their decisions "Fig. 1".

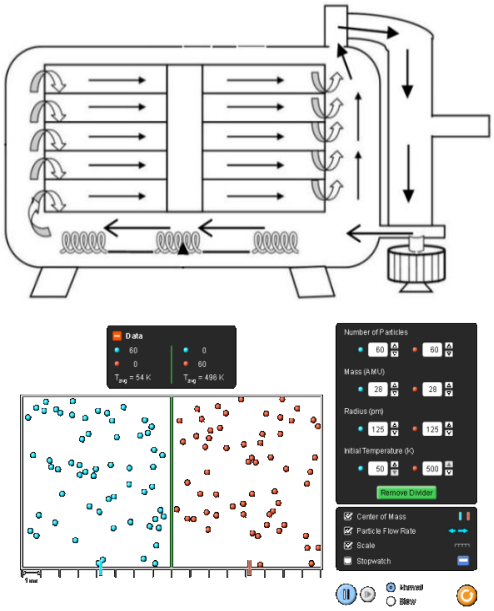

Fig. 1. Setting the tasks, based on real professional situations.

In the process of completing the tasks, the students learn to work in teams, to assign roles, and jointly to seek solutions. In addition, discussing the results with the teacher allows one to evaluate errors, suggest alternative approaches and deepen one's understanding of the material. This method helps to develop not only professional skills but also an ability to solve complex engineering problems, which is the key requirement in the field of agricultural engineering.

C. The use of modern technologies

The introduction of the computer modelling and laboratory work, using digital tools, allows for a deeper understanding of physical processes and their application in agricultural engineering. Computer modelling provides an ability to visualize the complex processes, such as the heat transfer, hydraulics and mechanics, making them easier to understand and analyse. For example, using software, such as MATLAB, SolidWorks, or ANSYS, the students can simulate pumps, the irrigation systems, the heating systems, or the designs of the agricultural equipment, giving them an insight into the behaviour of real objects under different conditions "Fig. 2".

The water pump of a car creates a pressure drop in order to force the coolant to circulate through the engine and radiator. The rotation of the impeller (curved blades of the pump) creates a centrifugal force that increases the kinetic energy of the liquid, causing it to move through the system.

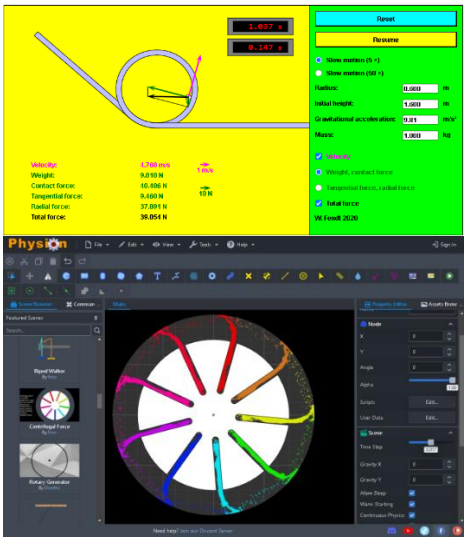

Fig. 2 Computer simulation of the operation of the pump of a car.

The laboratory work with digital instruments allows one to collect accurate data and analyse it with a high degree of detail. Using the temperature, pressure and humidity sensors in educational experiments allows for real-time measurements, which is particularly useful for studying the irrigation or ventilation systems. Virtual laboratories and simulators give the students access to perform complex experiments without the need for expensive equipment. Virtual labs and simulators give students access to perform complex experiments without the need for expensive equipment. Such technologies ensure flexibility and accessibility to learning, especially for the students in remote regions. In addition, the technologies of augmented and virtual reality make it possible to create interactive 3D models that the students can explore while learning about the structure and operating principles of the agricultural equipment. This increases their level of engagement and helps them better understand the theoretical aspects. Thus, the use of modern technologies not only deepens knowledge but also makes the students ready to solve real problems that they will face in their professional activities.

D. The project activities

The work on the projects, related to the solution of current problems in the industry of agricultural engineering, it helps the students develop the teamwork skills and independent search for solutions. Within the framework of such projects the students join into groups to complete the tasks that simulate real-life production situations. For example, one of the tasks might be to the develop an automatic soil moisture control system, where the team of students analyse data from the sensors; they develop a control algorithm, and test the prototype. Another project may involve designing an energy efficient agricultural storage system, using modern insulation and ventilation technologies. In the process of implementation of such projects, the participants distribute their roles: someone is responsible for the data collection, someone

else for calculations, and someone for programming or technical assembly.

The work with the project may also involve interaction with the local agrobusinesses, allowing the students to consider real market conditions and requirements. For example, a project to develop a mobile platform for monitoring the crop conditions could involve the use of unmanned aerial vehicles and data analysis, using neural networks. Discussion of the results and feedback from the teachers and external experts help improve the projects and increase their practical value. Such an approach not only develops the technical and analytical skills but also instils in the students a sense of responsibility for the final result, the ability of efficient interaction in the team and adapt to the changing conditions of the task.

III. Results and discussion

In the course of the research methodological conditions for the continuity of the formation of physical and technical concepts and their systems were established and formulated as an efficient approach to the implementation of the professional orientation of physics and the formation of special competence of students.

An experimental determination of the implementation efficiency of the designed system of professionally oriented teaching of physics in the formation of special competence of the future agricultural engineers was carried out at the institution of higher education "Podolsk State University" for specialty 208 "Agroengineering". Let us present the results of some experimental sections.

The influence of professionally oriented teaching of physics upon the students' motivation to study this discipline was determined by the comparison of the results of a survey of students (118 people) before studying physics and after their experimental training. At the same time there was determined the level of formation of such a personal factor in the upcoming professional and pedagogical activities of the students as "responsibility". The students were asked to rate on a 10-point scale the level of importance for them of studying physics in their professional and pedagogical training, and therefore in the formation of special competence and responsibility for the choice of the profession they are pursuing. One of the experimental sections revealed the level of development of the students' vision of the manifestation of physical laws in the engineering and technology of agricultural production as a component of special competence (direct connection: physics-engineering) and such a quality as "systematization". At the beginning and end of the physics course the students were given the task of providing a maximum number of examples of the use of physical laws in the industrial and household equipment and technology. The results of the experiment are presented in Table 1.

Table 1 Distribution of the students' answers by the number of examples of manifestation of physical laws in technology

Number of examples	**Before training (%)** (number of students)	**After training (%)** (number of students)
Less than 3 examples	40% (47 students)	15% (18 students)
From 3 to 5 examples	35% (41 student)	40% (47 students)
More than 5 examples	25% (30 students)	45% (53 students)

After the introduction of experiential learning a significant shift was observed in the distribution of the students' responses: the proportion of students who gave fewer than three examples decreased from 40% to 15%, while the proportion of the students who gave more than five examples increased from 25% to 45%. This indicates an improvement in the students' ability to systematize their knowledge and find numerous practical applications of the physical laws, which is an indicator of an improvement in the quality of assimilation of the theoretical material and the development of professional competencies.

The determination of the degree of development of the students' skills to justify the design and operation features of the agricultural machinery units, based on physical laws, as an integral part of special competence (the feedback: technology-physics) and such a skill in their future work activities as "using knowledge in solving professional problems" was carried out through a series of questions, asked to the students before and after experimental training in physics. The assessment of the answers was based on 5 generally accepted quality criteria of answers in pedagogy: correctness, completeness, practical orientation, logicality of the answer, literacy of the presentation, assessed on a five-point scale. The results of the experiment are presented in Table 2.

Table 2 Dynamics of development of the students' skills to substantiate the design features and operation of the agricultural machinery units, based on physical phenomena and regularities

Survey	Average level of the assessment of the responses according to criteria				
	Correct-ness	Complete-ness	Practical orientation	Logica - lity	Literacy of the answer
Before the experimental training	3.6	3.3	3.1	3.0	3.2
After the experimental training	4.0	3.9	4.2	4.1	4.3

Due to experimental learning, the indicators for such criteria as practical orientation, logic, and literacy increased by 1.1 points, and for the rest, on average, by 0.5 points. Such a result demonstrates the high efficiency of implementation of the system of professional orientation of physics in the formation of the students' special competence and an important skill in their future professional activity as "using their knowledge in solving professional problems".

As a result of the study there is noted the positive dynamics in the development of the students' ability to substantiate the design and operation features of the agricultural machinery units, based on physical phenomena and regularities. The systematic study of

physics contributes to the expansion of their knowledge, which is reflected in the increase in the number and quality of the given examples of practical application of the theoretical principles. This confirms that a deep understanding of physics not only deepens the understanding of fundamental laws but also develops skills to analyse and justify the operation of complex technical systems, which is of crucial importance for the future agricultural engineers.

Thus, the results of the experimental studies showed high efficiency in the formation of special competence of the designed and implemented system of professionally oriented training in physics of the future agricultural engineers.

CONCLUSIONS

An experimental determination of the efficiency of the designed system of professionally oriented teaching of physics showed that its implementation significantly increases the motivation of the future agricultural engineers to study this discipline. After the experimental training the students' average scores according to the criteria of practical orientation, logic and literacy increased by 1.1 points, which indicates a significant expansion of their knowledge and skills in applying the laws of physics. These results confirm that the systematic study of physics not only deepens the theoretical basis but also develops critical thinking, it contributes to the formation of a vision of the manifestations of physical laws in the engineering and technology of agricultural production, and also helps to substantiate the features of the design and operation of the agricultural machinery units, which significantly increases the students' professional competence.

Unlike other investigations in which the professional orientation of studying physics was often limited to a general mention of the problems of agricultural engineering, in our work we have developed a holistic teaching system, based on specific examples and scenarios from real agricultural practice. Each topic of the physics course is accompanied by professional cases demonstrating the link between the laws of physics and the operation and maintenance of the agricultural machinery, as well as the models of technological processes. This approach allows the future agricultural engineers not only to acquire theoretical knowledge but also to see immediately its practical significance, to analyse the peculiar features of the devices and operating principles of particular mechanisms, which significantly accelerates the formation of special competence.

Professionally oriented training in physics creates the basis for the formation of special competence of the future agricultural engineers. The introduction of an interdisciplinary approach, problem-based learning and modern technologies allows one to train specialists who are able to apply efficiently the acquired knowledge in their professional activities. Further research may be aimed at developing new educational technologies and methods that will help improve this process.

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