PROGRAMMING OF PEDAGOGICAL TECHNOLOGY FOR FORMATION OF PROFESSIONAL COMPETENCE WHEN STUDYING NATURAL AND GENERAL TECHNICAL DISCIPLINES

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Abstract. Introduction of new state educational standards into the educational process, orientation towards a competent learning paradigm, and increase in the amount of independent work of the students necessitated the improvement of the existing approaches to modelling the integration processes in the system of higher agro-technical education. Unfortunately, under modern conditions, the educational potential of physics and general technical disciplines in the integrative version of their content and methodological aspects is not realised at the required level. The purpose of this work is to study the problem of the formation of professional competence of the future engineers in the process of integrating natural (physics) and general technical disciplines. Efficiency of the models for the formation of professional competence of the future engineers by integrating physics and general technical disciplines, which are based on personal activity, competence-based, problem-integrative, contextual and system approaches, is substantiated and experimentally tested. There are determined the psychological and pedagogical conditions for implementation of these models in the process of studying physics, technical mechanics, hydromechanics, technical thermodynamics and electrical engineering. The positive dynamics of the results of the formation of professional competencies of models and their impact upon the components of professional competence are recorded. This was carried out by applying a frame approach to the assimilation of scientific knowledge, using integrative learning technologies, as well as increasing their cognitive activity, motivating students to study physics and general technical disciplines, and developing educational reflection.

Keywords: competence, physics, professional orientation, agricultural engineer.

Introduction

At present, the most important tasks of the agro-technical universities are the quality of professional training, strengthening of confidence between the subjects of education, and strengthening their competitive ability in the domestic and foreign markets. Modern socio-economic conditions, characterised by the transition of mankind to new techniques and technologies, the growth of knowledge about the transformation of materials, energy and information in the interests of man, pose new educational and educational tasks, the implementation of which should ensure the formation of professional and cultural competence of a person capable to live in a technocratic society [1].

The current state of the organisation of the educational process in physics and general technical disciplines in the higher agro-technical school is based mainly on fundamental approaches, and the principle of professional orientation of education is not always fully implemented [2]. The knowledge, formed by the students of agro-technical universities in the classes of physics and general technical disciplines, should be the basis for studying the disciplines of professional and practical training, as well as for mastering agricultural machinery and technologies of the new generation. A change in technology during the productive life of a person occurs almost every 10 years. Therefore, the course of physics and general technical disciplines for the future specialists in the agro-engineering areas should contribute to the formation of the students' concept about the modern physical picture of the world, about trends in the development of engineering and technologies [3- 6].

Education in general technical disciplines should be based on a consideration not only of fundamental relationships but also specific physical processes and phenomena that will manifest themselves in the professional activities of the future specialist in agro-technical industry.

The issue of the content of physical education in higher educational institutions, based on a competent approach, and updating of didactic systems, methods and technologies for its implementation have been thoroughly studied by many scientists [7-13]. In the system of vocational education there are processes of reorientation towards the formation of professional competence. As the studies by E.F Zeer, Yu.A. Konarzhevsky, V.P. Kosyrev, E.V. Tkachenko and other scientists show, under the condition of modernisation of the education system, professional competence is the goal of training at a professional educational institution. In more detail competence was studied by such researchers as G. Hall, M. Mulder, T. Hyland, D. Clelland, J. Raven, W. Rothwell, G. Ryle, D. Kaittani, V. Derri, E. Kioumourtzoglou and others. J. Raven regards competence as a specific ability, necessary to efficiently perform a certain action in a specific subject area, including highly specialised knowledge, specific subject skills, a way of thinking, as well as understanding of responsibility for one's actions [13]. M. Mulder studies the concept and practice of professional and practical training, including research traditions and educational positions, associated with it [14]. Studies [5] describe the problem of using various teaching methods in universities to achieve the best training of the future specialists. In this context engineering education should be more inclusive, having a complex of knowledge and skills, based on the main relevant competencies, such as competencies in the core subject area, as well as general competencies in the activities and entrepreneurial and social contexts, and understanding of the characteristics of the future specialists [10; 11; 14]. However, the specifics of teaching physics and general technical disciplines to the future engineers have not been so far sufficiently studied.

The purpose of the study: to scientifically substantiate and experimentally test the efficiency of the proposed models for the formation of professional competence of the future engineers by integrating physics and general technical disciplines.

Materials and methods

One of the main tasks for the teachers of higher agrarian and technical educational institutions in the process of training the future specialists in the agro-technical industry is integration of their fundamental, general technical and professional knowledge. The efficiency of integrated learning (that is, based on the idea of integrating fundamental, general technical and professional knowledge) implies preliminary modelling of the educational process, which is the process of creating, research and using models. In the context of the research modelling was carried out at the level of the concept of integrated education, the methodological system of education and its components.

Next, we present a model of the concept of integrated learning (Table 1), a model of the target component (Table 2), a model of the content component (Table 3) and a model of the technological component of the integrated learning methodological system (Table 4).

Table 1

Model of the concept of integrative learning

Purpose of integrated learning:	**Main features of the models of integrated learning:**	**Integrated learning technologies:**
• formation of a holistic view of the world around, systems of knowledge and skills among the students; • achievement of high-quality, competitive education; • creation of optimal conditions for the development of the students' thinking in the process of studying general technical disciplines and disciplines of the professional cycle; • activation of the students' cognitive activity; • efficient implementation of the functions of developmental learning	• consistency; • complexity; • integrity • synthesis	• modular • cyclic

The presented models act as blocks of the integrative model of the methodological system of integrated training of the future specialists in the agro-technical industry. A comparative analysis of the professional activities of the future specialists in the agro-technical industry and the didactic units of the physics course indicates the existence of deep interdisciplinary relationships.

Table 2

Model of the content component of the methodological system of integrated training of the future engineers of natural, general technical and professional disciplines

Goal: formation of a competent engineer		
Task: formation of subject, inter-subject, key competencies and personal qualities		
Formation of the cognitive component	Formation of the activity component	Formation of the personal component

Table 3

Model of the content component of the methodological system of integrated training of the future engineers of natural, general technical and professional disciplines

Invariant component	**Variable component**
of the program of disciplines of natural-mathematical, general technical and professional cycles	courses of the choice of an institution and courses of the choice of students; individual assignments and learning projects

Table 4

Model of the technological component of a methodological system for integrated training of the future engineers

Methods of learning	**Forms of learning**	**Means of learning**
Reproductive, productive Explanatory and illustrative Partly search, search, research Active and interactive	General, frontal, group, individual Full-time, part-time, external learning. Distant, computer-oriented learning	Curricula and programs Educational textbooks and manuals Teaching aids, the computer Packages of applied computer Educational and material base, training simulator

The models for implementing the integrated approach to training the future specialists in the agro-technical industry can be as follows (Table 5).

- Establishment and implementation of interdisciplinary links between physics and general technical disciplines, studied separately according to the curriculum (Model 1). In such a model the elements of general technical disciplines are introduced into the course of physics as additional messages, problem situations, tasks of an interdisciplinary content.
- Establishment and implementation of interdisciplinary links between physics and general technical disciplines, studied separately according to the curriculum (Model 2). In such a model the elements of physical knowledge are introduced into the general technical disciplines by means of basic knowledge as a stage of "Actualisation of basic knowledge" during lectures, practical and laboratory classes.
- Implementation of deep integration of physics and general technical disciplines through their mutual penetration (Model 3). In view of the importance of separate sections of physics for training the future engineers, the material that is not basic for mastering general technical disciplines and professional disciplines is removed from the general physics course. There remain sections that serve as the foundation for general technical and professional training of the future specialists in the agro-technical industry.

The course of general physics is being transformed into the discipline "Technical Mechanics", which contains sections that are relevant for professional training of the future specialists in agricultural and technical educational institutions. Information about the relationship of its individual sections, related to general technical and professional disciplines, is included into the content of "Technical Mechanics" as introductory blocks that motivate students – the future specialists in the agro-technical industry to study physics as a basic discipline for further mastering the academic disciplines of general technical and professional cycles (Model 3).

- Removal of physics as a separate discipline according to the curriculum and inclusion of its sections through introductory information blocks into the corresponding sections of general technical and professional disciplines (Model 4).

Table 5

Models of integration of physics and general technical disciplines

Model 1	**Model 2**	**Model 3**	**Model 4**	
Physics	Physics	Physics	Physics	general technical disciplines
↑	↓	⇕		
general technical disciplines	general technical disciplines	general technical disciplines		

Each of these models can be implemented in the educational process of a university in various ways. Implementation of the first model is carried out in most educational institutions according to the traditional classical program. The advantage of this model is the possibility of studying physics as a discipline according to its classical structural-logical scheme. Such teaching is more focused on the study of “physics” as a means of forming the scientific worldview of the students, their intellectual development, duplicating the process of mastering the physical knowledge according to the school curriculum. The interrelation between physics and general technical and professional disciplines is implemented by means of such a model at the level of interdisciplinary connections between them, and, due to unpreparedness of the students to perceive information of a professional content, it is inefficient. It should also be noted that the time, allotted for the study of fundamental disciplines, is not enough for full acquisition of general physics; therefore, most teachers of professional educational institutions distribute it in such a way that the “lion’s share” of hours is devoted to studying the issues, necessary for further study of general technical and professional disciplines. The rest of the issues are presented in an overview.

In our opinion, such a model does not allow to implement interdisciplinary integration to the full extent. The second model assumes inclusion of the elements of physical knowledge about the selected issues of the course of physics into the content of general technical and professional disciplines as basic knowledge and skills. Following the principle of continuity, the teacher agrees on the designation and interpretation of physical concepts and terms of general technical disciplines. Such a model makes it possible to update the physical knowledge acquired at school and in the course of physics studied within the framework of the university, deepening and expanding it, before studying the relevant discipline, which makes it possible to implement integration of the academic disciplines at the level of topics or blocks of separate content modules. It should be noted that such a model makes it easy to distribute the selected questions of physics among the professional disciplines, and it can be used at the initial stage of transition from the classical system of a specialist training to the modern one. The third model is based on the implementation of interdisciplinary integration between natural (physics) and general technical disciplines in two opposite directions, which allows creating conditions for the introduction of contextual, problem-integrated and interactive approaches to their study, which will contribute to the development of cognitive processes, intellectual skills, professional competence. The fourth model assumes a deep integration of physics and professional disciplines, including physical knowledge as the basic elements of each of the topics of the corresponding professional discipline, which allows not only to update physical knowledge but also to unify approaches to the interpretation of concepts, terms, regularities, and so on. In such a way physics acquires an applied and professional orientation that is necessary for the formation of professional competence of the future specialists in the agro-technical industry and allows to create integrated courses in the field of physics and technology, that is, to implement integration at the level of integrated disciplines.

Considering the peculiarities of each of the described models, we can conclude that integration in them may be effected in various ways.

- In the case of Model 1, acquaintance of the students with the basic general technical and professional disciplines may be realised by:

a) giving examples of the possibilities of further application of physical knowledge in specific academic disciplines of the general technical and professional cycles at lectures;
b) involving the students in solving problems of interdisciplinary content during practical classes;
c) including the tasks of professional content into laboratory works in physics;
d) providing an opportunity for the students to join the implementation of the research tasks of interdisciplinary content within the framework of an independent work;
e) combining all the above types of implementation of interdisciplinary connections between physics and general technical and professionally oriented disciplines.

- In the case of Model 2 the students may be introduced to the basics of general technical and professional disciplines in the ways indicated above (a - e), yet in more detail, since this model does not involve studying all the sections of the physics course but only those that are most related to the future professional activities. For these reasons the number of hours allotted for their study increases, and, accordingly, more time the teacher can spend on their implementation.
- In the case of Model 3 the students are introduced to physics while studying general technical disciplines, and this can be executed by:

a) including an introductory block of physical content before studying a specific academic discipline of the general technical cycle (carried out by the teacher during the lectures);
b) introducing introductory blocks of physical content into each section of a specific general technical academic discipline (carried out by the teacher during the lectures;
c) combining the input of the introductory block and the introductory blocks (in order to update the basic knowledge in physics; this is necessary for the perception and acquisition of the educational material in a general technical academic discipline);
d) expanding the boundaries of application of the physical knowledge by including them into tasks for practical and laboratory classes in the disciplines of general technical content.

Implementation of these models required the following tasks of the pedagogical experiment:

1. To study the educational process in agrarian and technical institutes in order to find ways how to form professional competence of the future engineers in the research of natural (physics) and general technical disciplines.
2. To implement models for the formation of professional competence of the future engineers by integrating natural and general technical disciplines.
3. To take into account and fix changes in the process of the pedagogical experiment on the formation of professional competence of the future engineers.

Altogether 150 students took part in the experiment, of which 57 were in the control groups, 93 were in the experimental ones. In the first group, where the integration Model 1 was introduced, 30 students were engaged; in the second group, where the integration Model 2 was introduced, there were 31 students; in the third group, where the integration Model 3 was introduced, 32 students participated. The efficiency of experimental training was determined by indicators of the formation of the components of subject competencies (in physics and general technical disciplines), and professional competence, in general. Besides, the research hypothesis was an assumption that an integrative approach to teaching physics and general technical disciplines would positively influence the degree of mastering by the students of both academic disciplines, which, in turn, would increase the level of formation of professional competence, in general. Since at the beginning of the experiment it was practically impossible to select the control and the experimental groups with the same distribution of students according to the level of formation of each type of competence, we judged by the changes that had taken place in their distribution due to introduction of corresponding intergrative approaches. Distributions of students by the levels of professional competence formation were calculated as weighted arithmetic averages.

Taking this into account, we identified three experimental groups, training of physics and general technical disciplines of which took place according to the indicated models – experimental Group 1 (according to Model 1), experimental group 2 (according to Model 2), and experimental Group 3 (according to Model No. 3). A control group was also selected for comparison (Fig. 1).

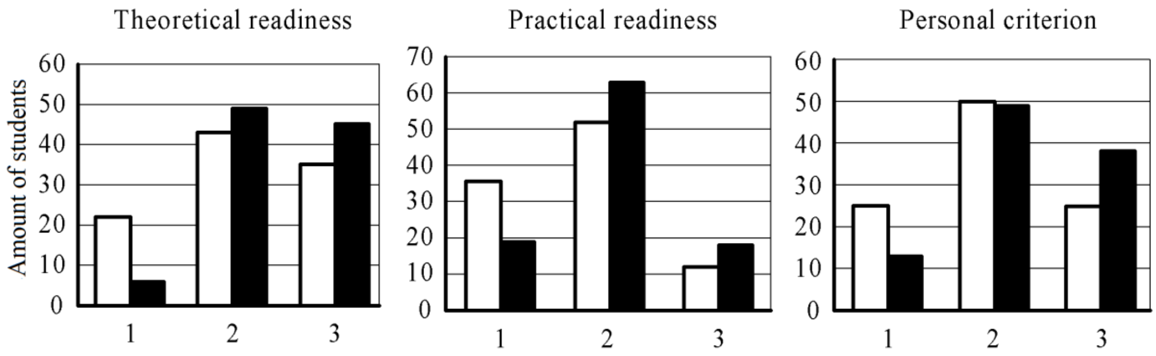

Fig. 1. **Levels of formation of the criteria of professional competence of the future engineers:** 1 – low; 2 – medium; 3 – high; □ – control group; ■ – experimental group

The distribution into groups was based on the comparison of the academic performance results of the second-year students in the discipline “Physics”, which is the base for the general technical disciplines involved in the experiment (technical mechanics, technical thermodynamics, hydromechanics, electrical engineering) and has a significant impact upon the results of their acquisition. Considering that such distribution of students by their academic performance levels, absence of differences of which is statistically proved, can be considered equivalent, determination of groups for the experimental and control samples was carried out, first, on the basis of a comparative assessment of the results of the students’ success in physics (general education course) with subsequent statistical verification of the reliability of the existing differences. Selection of the control and the experimental groups of students according to their grades in physics was insufficient to determine further changes in the practical and experimental conditions for the formation of professional competence of the future engineers. Therefore, additional research was made of the condition of the development of indicators of the practical and personality criteria of the 2nd year students at the beginning of the academic year when they start studying natural and general technical disciplines. During the experiment there were compared the results of the final control of knowledge of the students, trained according to the three models in the experimental and control groups. The input data of the experiment, as noted earlier, were the results of knowledge in physics (general education course) for the assessment of the efficiency of formation of the physical component of professional competence; while for the general technical components of professional competence, the basis was the knowledge of the general course of physics. The initial data were: for the physical component of professional competence – knowledge of physics after its study, and for the general technical component of professional competence – knowledge of the basics of hydromechanics, as a general technical discipline upon completion of its study.

During the experiment, there were accomplished the input, intermediate and final cuts of students’ learning results according to theoretical, practical and personality criteria. The number of models for the implementation of the research, experimental groups and their diversity, the number of criteria by which estimates and comparisons were made complicate statistical calculations of the experimental data. Therefore, we compared the results of the experiment according to the changes in the levels of formation of the components of professional competence by each criterion.

Results and discussion

Comparison of the percentage values of the indicators of the theoretical criterion for the experimental and control samples made it possible to establish the nature of the changes that have occurred in the distributions of students as a result of introduction of the developed models. Statistical data processing shows that the differences in the distributions of students in the experimental and control groups according to the theoretical criterion are essential and reliable.

Comparison of the results of questioning the students from the control and the experimental groups gave grounds to assume that positive changes have occurred in the distributions by levels of each indicator of the personality criterion. The most significant changes seem to have occurred in the students’ motivation for learning and in expression of a sense of responsibility.

Determination of the mean arithmetic values of the students' distribution according to the levels of formation of the theoretical, practical and personal criteria gave grounds for comparison of the changes that occurred in them under the influence of the proposed methodology for studying the subject "Fundamentals of hydromechanics"). The obtained data indicate positive changes in the groups of the future engineers as a result of introduction of the three models for the integration of physics and general technical disciplines (Table 6).

Table 6

Changes in the distribution of students in the control and the experimental groups according to the levels of formation of the physical and general technical components of professional competence

Group (model)	Qualitative changes in the levels of formation of the physical component of the students' professional competence as a result of the experiment						Qualitative changes in the levels of formation of the general technical component of the student' professional competence as a result of the experiment					
	Low		Medium		High		Low		Medium		High	
	Number of students	%	Number of students	%	Number of students	%	Number of students	%	Number of students	%	Number of students	%
Model 3	-24	-18.5	+ 13	9.9	+ 11	8.6	-22	-17.4	10	7.6	12	9.8
Model 2	-7	-5	+ 4	2.9	+ 3	2.1	-10	-7.9	2	1.3	8	6.6
Model 1	-7	-5.8	+ 3	2.8	+ 4	3	-2	-1.7	-7	-6.1	9	7.8
Control group	-6	-2.9	+ 2	1	+ 4	1.9	-6	-2.7	-1	-0.4	7	3.1

The greatest changes in the distribution of the students by the levels of physical and general technical components of professional competence occurred in groups where the third integration model was introduced. In the experimental group 3, the number of students with high and medium levels of formation of the physical and general technical component of professional competence increased by 6.3%, but in the control groups - only by 2.7%. The experiment also showed that the number of students with a low level of knowledge decreased by 19% in the experimental groups while in the control groups only by 6%. In groups, in which integration models No. 1 and No. 2 were introduced, the differences in the distributions of students are small. However, changes in them occur due to the number of students with different levels of formation of physical and general technical competencies. The obtained results testify to the positive dynamics of the growth of the levels of formation of the studied indicators in the experimental groups, compared with the control ones. This confirms the efficiency of the introduced models and pedagogical conditions for the formation of professional competence of the future engineers.

Conclusions

1. Ensuring the integrity, fundamental and professional orientation of training of the future agricultural engineers is possible on condition of didactic integration of natural (physics) and general technical disciplines as a way and means of improving the quality of professional training of the future engineers. As a result of introduction of the third experimental model for the integration of natural and general technical disciplines: duplication of educational material is eliminated; professional orientation is increased; the motivational side of learning is improved by emphasizing the practical significance of theoretical knowledge; the information capacity of scientific knowledge increases; an integral system of integrative knowledge of the students is formed; the quality of their preparation for assimilation of special disciplines improves.
2. In the experiment, with a change in the distribution of students by levels of formation of professional competence, an increase in the level of the students' knowledge with high (by 6%) and medium (by 11%) levels of the physical and general technical components of professional competence was stated. The practical readiness of the students in the experimental group 3 has grown. This is confirmed by an increase in the number of students with a high degree of practical

skills by 13%. At the same time, the personal characteristics of the future engineers have improved, as evidenced by the increase in the number of students with high (by 10%) and medium (by 6%) levels of personal formation criterion.

Author contributions:

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