RESEARCH ON INTER-DISCIPLINARY LINKS TRAINING ENGINEERS-DESIGNERS FOR AGRICULTURAL MACHINERY AT AGRICULTURAL UNIVERSITIES

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Abstract. There are studied and analysed peculiarities of inter-disciplinary links of the course of theoretical mechanics with general technical and special disciplines when training engineers-designers of agricultural machinery. The topicality of the problem of inter-disciplinary links in education is determined by objective processes in modern education, in particular, in training engineers-designers for agricultural machinery. The purpose of this study is theoretical substantiation of the didactic efficiency of establishing and implementation of inter-disciplinary links between theoretical mechanics, general technical and professional disciplines in order to improve the professional knowledge of the engineers-designers of agricultural machinery. As research methods there are accepted theoretical (comparative analysis of the scientific-methodical and pedagogical literature) and empirical (observation, analysis and generalization of pedagogical learning experience) methods. The comparative analysis of the results of studying theoretical mechanics, the disciplines of natural sciences, general technical and professional cycles, based on statistical processing of the results of the experiment, showed an increase in the level of formation of inter-disciplinary knowledge links and, accordingly, a 17% increase in the level and cognitive activity of future engineers-designers of agricultural machinery. The results of this research allow drawing a conclusion that ensuring integrity, fundamental and professional orientation of education is possible only if inter-disciplinary links are introduced.

Keywords: theory, mechanics, inter-disciplinary links, engineer-designer of agricultural machinery.

Introduction

Higher education is an important link in the system of professional training of personnel who solve the main tasks of the agricultural sector in the context of creation of market relations in Ukraine. Among the main socio-economic landmarks of higher education, defined by the Government’s program of activities “Towards the People”: the creation of appropriate conditions for providing the country with high-quality labour potential through professional self-realization of the individual, meeting his needs for professional educational services, providing high-quality professional training, taking into account the requirements of the labour market, ensuring labour resource safety in the country. In recent years the quality of the labour potential in Ukraine continues to deteriorate, the degree of aging of the workforce is growing. In addition, the quality of the labour force in most cases does not meet the modern requirements for its training, mobility and economic activity, in general. Improving the quality of training specialists in the agricultural sector needs improvement of the educational process. Among the ways of reforming higher education, the leading place is allotted to the improvement of the educational process, based on the introduction of new pedagogical technologies. Therefore, in order to solve this complex of tasks that are set for higher education, inter-disciplinary links, implemented in the cycle of fundamental disciplines are of great importance [1; 2]. The didactic theory of inter-disciplinary links is widely reflected in the publications of many scientists, which define the types of inter-disciplinary links, their functions, place in the modern school, means of their implementation, etc.

The problem of inter-disciplinary integration can be attributed to the number of traditional ones, which have already become classic problems of pedagogy. The works by J.J. Rousseau, I.G. Pestalozzi, J. Dewey, P.R. Atutova, S.Ya. Batisheva, O.F. Fedorova, V.A. Kondakova, P.N. Novikova, I.D. Zvereva, V.N. Maksimova, N.A. Sorokina, P.G. Kulagin, and others have been devoted to its study. I.G. Pestalozzi, using large didactic material, revealed the variety of interrelations of educational subjects. He proceeded from the requirement: “Bring in your mind all essentially interconnected objects in exactly the same connection in which they really are in nature.” I.G. Pestalozzi noted the particular danger of separation of one object from another [3].

In the scientific and methodological literature there are many definitions of the concept of “inter-disciplinary communication”: “inter-disciplinary communications are a reflection in the course, built, taking into account its logical structure, features, concepts, to be disclosed in the classes of other disciplines”, or this: “inter-disciplinary communications are a reflection in the content of academic disciplines of those dialectical relationships that objectively operate in nature and are known by modern sciences” [4-7].

Inter-disciplinary education is aimed to support the development of skills to overcome disciplinary boundaries and integrate the knowledge of two or more disciplines to explain a phenomenon, to solve a problem, to create a product, or pose a new question in ways that would be impossible or unlikely to be in one discipline (V. Boix Mansilla, C Lyall, L. Meagher, J. Bandola, A. Kettle, C. Manathunga, P. Lant, G. Mellick, E. Spelt, H. Biemans, H. Tobi, P. Luning, M. Mulder, A. Corbacho). While most inter-disciplinary courses are offered at the undergraduate or graduate level [7], it remains critical for undergraduate students to experience an integrative learning environment that maintains an open view of other disciplinary areas [6].

Taking into account such possibilities of inter-disciplinary links from T. Nilsen research [8], he came to the conclusion that the combination of concepts in physics with mathematical symbols affects the interpretation of physical quantities. K. Mwangala and O. Shumba in their study [9] arrived at a conclusion that difficulties in understanding physical and mathematical concepts explain the statistics of failures in the physics courses. The reason may be misunderstanding of physical and mathematical concepts. These studies have shown that even students who score high in typical introductory physics courses often fail to apply basic physical principles to real situations, to solve a real world problem, or organize the ideas of physics hierarchically. Based on this, one can make a definition: inter-disciplinary links is a pedagogical category to designate synthesizing, integrative relations between objects, phenomena and processes of the reality, which find their reflection in the content, forms and methods of the educational process and perform educational, developing and upbringing functions in their limited unity.

As regards teaching theoretical mechanics, P. Ho [10] expressed his opinion that the students should first be introduced to the relevant physical and mathematical skills, so that later they can give to theoretical mechanics their full attention without struggling with physical and mathematical concepts. Similar pedagogical approaches have been used in other studies [4; 11; 12].

The diversity of statements about the pedagogical function of inter-disciplinary links is explained by the versatility of their manifestation in the real educational process. The purpose of this research is to present the view on the peculiarities of inter-disciplinary links of the course of theoretical mechanics with general technical and professional disciplines to the future engineers-designers of agricultural machinery.

Materials and methods

In order to achieve the goal, set by the present article, there were used data from theoretical and empirical studies, psychological and pedagogical analysis of the educational process in the system of higher education, peculiarities of the educational-cognitive and educational-practical activities of the future engineers-designers of agricultural machinery.

Observations, conversations, questioning of teachers and students of the “Podolsky State University” were used. At the first stage the methodological foundations of the study were clarified; at the second, inter-disciplinary links of the discipline “Theoretical Mechanics” were established, and their content was revealed; at the third, the potential of the identified inter-disciplinary links in the formation of technical thinking was analysed.

The main task of studying theoretical mechanics is to form in the students a system of deep and strong knowledge of the foundations of modern engineering and production technology, labour organization in an amount, necessary for strong mastery of the profession and further growth of their creative attitude to work, and an active position in life. The need for inter-disciplinary integration in the teaching of theoretical mechanics at an agrarian technical university is dictated, firstly, by the content of this discipline, its goals and objectives. A peculiarity of the study of theoretical mechanics is that this process should not only provide a high level of training natural science but also to have a clear focus on the future profession, taking into account inter-disciplinary links. The curriculum should provide an opportunity to specialize education in the chosen specialty.

The main elements of introduction of the inter-disciplinary links in training of specialists are:

1. Providing a logical link in the study of all subjects of the curriculum, types of training in accordance with the requirements of the educational and qualification characteristics.
2. Establishing concrete links between the subjects of natural science, general technical and professional training cycles.
3. Finding the most efficient means, ways and forms of disclosure of links in the process of studying each subject, as well as the links of theoretical and industrial training with life, allowing the graduates of agrarian and technical institutions to solve skilfully, creatively the production problems, to master the necessary practical skills in accordance with modern requirements.

Regardless of the specifics of various higher educational institutions and the accumulated experience, the study of theoretical mechanics needs to meet the following mandatory requirements:

1. the course of theoretical mechanics should be consistent in order to enable the students to determine and trace the cause-and-effect relationship of phenomena and patterns of the objective world;
2. the course of theoretical mechanics should ensure an integrated use of the knowledge and skills, obtained during the study of the educational material from different disciplines, while avoiding duplication of the educational material;
3. the course of theoretical mechanics should ensure the unity of terminology in the study of different disciplines;
4. the course of theoretical mechanics should be clearly focused on the needs of a graduate of a particular profession.

Results and discussion

It is possible to determine the content of the course, based on the analysis of inter-disciplinary links between theoretical mechanics and the disciplines of natural science, and professional training. The inter-disciplinary links provide orderliness, systematic knowledge, broad generalization of knowledge, focus on a specific profession (Fig. 1).

Theoretical mechanics is one of the most important disciplines, studied in an agrarian technical university. It is based on such general educational disciplines as physics and mathematics. Theoretical mechanics is united with physics by the use of the same concepts in describing the corresponding processes of the objective laws of nature, which are considered in the course of studying physics. For example, the study of the discipline "Theoretical Mechanics" is based mainly on the laws of kinematics and the dynamics of a material point, studied in the course of physics. When considering various types of movement, kinematic and dynamic characteristics are used, which are introduced into consideration as early as within the framework of the school curriculum. Theoretical mechanics also provides a logical link between physics and mathematics by applying the mathematical apparatus to the description and study of physical phenomena. Therefore, in order to successfully master the course of theoretical mechanics, the student must have a solid knowledge of mathematics. Examples from theoretical mechanics make it possible to understand better the meaning of differential quantities. Very often the students admit that they understand more completely, meaningfully the functional dependencies, i.e. links between the variables, studied in the course of mathematical analysis, only in the process of solving kinematics problems for the study of various types of movement. The theory of differential equations is used to full extent to analyse dynamical systems in theoretical mechanics. Therefore, the insufficient level of mathematical training, received by the student in the first years, can lead to significant difficulties in teaching him technical and special disciplines at an appropriate level. The result is low quality of calculation and graphic works, performed by him, the course projects, the final qualifying work, and, in the future, this leads to problems in his professional activities.

Theoretical mechanics is closely linked with other general technical disciplines: the basics of descriptive geometry and engineering graphics, engineering mechanics, the theory of mechanisms and machines, etc. The laws and conclusions of theoretical mechanics are widely used in a number of general technical disciplines: technical mechanics, strength of materials, engineering mechanics, mechanics of materials and structures. The inter-disciplinary links of the course of theoretical mechanics with the disciplines of professional and practical training have been of a leading and perspective nature. The system included the tasks that took into account both the leading and the accompanying links of the course of theoretical mechanics with such disciplines as “Introduction to the specialty”, “Material science and TCM”, “Interchangeability, standardization and technical measurements”; promising connections with the disciplines, “Agricultural machines”, “Mechanical and technological properties of agricultural materials”, “Machinery and equipment of the agro-industrial complex”, etc.

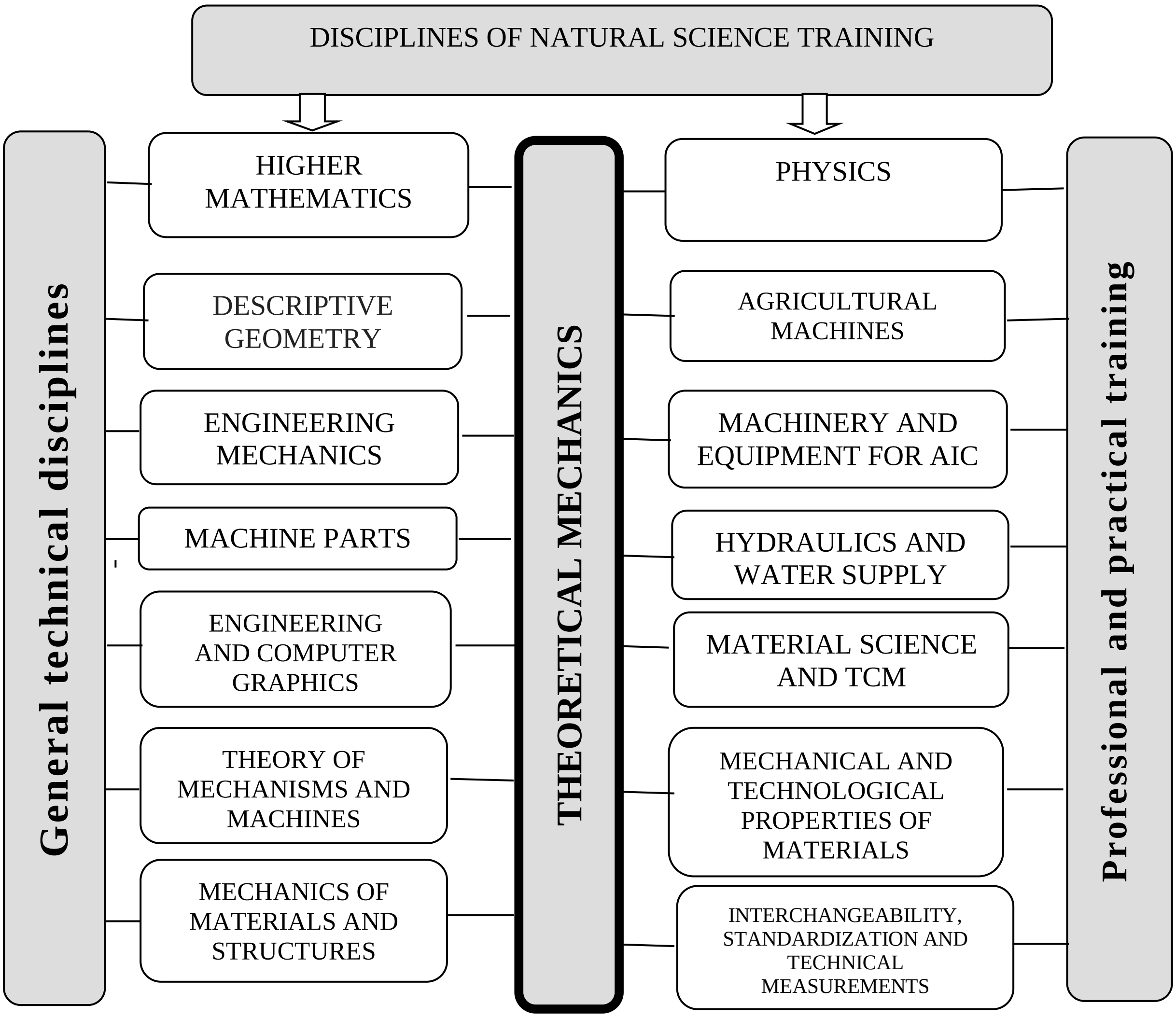

Fig. 1. **Link of the course of theoretical mechanics with general technical disciplines and disciplines of professional and practical training**

The course ‘Material Science and TCM” is studied on the basis of already studied in the course of theoretical mechanics topics “Rotation of a rigid body around a fixed axis” (moment of force, moment of inertia, the basic law of dynamics for rotational motion, etc.) and “Forces of elasticity” (deformations, relative and absolute elongation).

The curriculum of Specialty 208 “Agroengineering” provides for the study of the discipline “Theoretical Mechanics” from the second semester (term) of the first year. Theoretical mechanics is the science of general laws of mechanical movement and interaction of material bodies, which is the scientific basis for many applied areas. Secondly, the transition to a two-level system of higher education required significant changes in educational technologies, a need to revise the main conceptual approaches to the development of educational and methodological support in a number of fundamental natural science and professional disciplines. This is due to an increase in the volume and degree of complexity of knowledge, required for training bachelors, and a simultaneous decrease in the number of hours, devoted to the study of corresponding disciplines. In the course of theoretical mechanics, the students study its three sections: statics, kinematics and dynamics. In the first section of theoretical mechanics “Statics” equilibrium of material bodies under the action of forces is studied. The main objective of this section is to teach the student to perform operations with various systems of forces in space and on a plane. This knowledge is necessary to study the courses of technical mechanics, strength of materials, engineering mechanics and other disciplines in order to determine the reactions of the bonds of various structures. The calculation apparatus of statics is widely used in the statics of devices and disciplines, related to the design of various agricultural structures. The purpose of studying section “Kinematics” are the basic laws and methods for studying the movement of material points and bodies, which in general technical and professional disciplines will be used to study the mobility and instantaneous variability of various structures. “Kinematics” contains tasks for the mathematical description of the movement of mechanical systems and the study of its characteristics without taking into account the causes (forces), this is the movement of the callers. This task is related to the concepts of the school geometry course, since its solution takes into account the time of movement of geometric images (shapes) of real objects.

The subject of “Dynamics” is a study of the movement of material bodies in connection with the forces, acting upon them. “Dynamics” involves the study of the following tasks:

- according to the pre-set characteristics of the movement of a mechanical system, find the forces under the action of which this movement occurs;
- according to the pre-set forces, acting upon the points of the mechanical system, and the characteristics of the movement, corresponding to a certain moment of time t_0, find the characteristics of the movement of the system for time $t > t_0$.

To study dynamics, one has to be able to find integrals of the simplest functions, calculate partial derivatives and the total differential of the functions of several variables, and also be able to integrate first-order differential equations with separable variables and second-order linear differential equations (homogeneous and inhomogeneous) with constant coefficients.

For example. Under the impact of the horizontal force F_1, the movement of a material point with mass m = 8 kg occurs along the smooth horizontal plane OXY according to equations: $X = 0.05 \cdot t^3$ and $Y = 0.3 \cdot t^2$. Determine the modulus of the resultant of forces, applied to the point at a moment of time $t_1 = 4 \cdot$s (Fig. 2). To solve such problems, it is important to have skills both from the course of physics and from the course of higher mathematics. For this it is necessary:

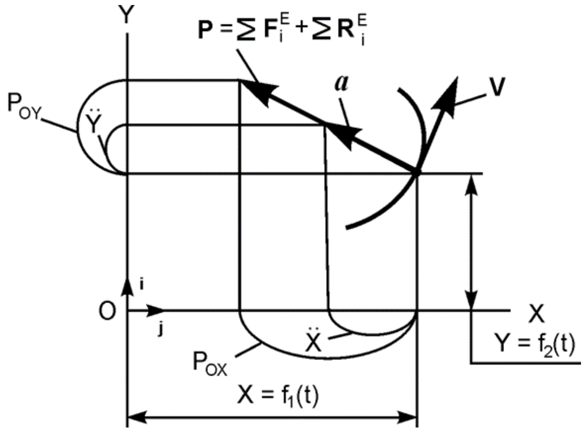

Fig. 2. **Graphical representation of the condition of the problem**

1. To choose the OXY reference system.
2. To draw a point on the trajectory of its movement at an arbitrary moment in time. According to the known provisions of kinematics, speed V of the point is directed tangentially to the trajectory of the movement, and its acceleration a is directed towards the concavity of the trajectory of movement.
3. Since the initial conditions for the movement of the point are not specified, in Fig. 2 they are not shown.
4. According to the condition of the problem, the active forces F_1 and G are applied to the point. Since the surface on which the point moves is smooth, only the normal reaction N acts upon the point. The basic equation of dynamics for the problem under consideration has the form:

$$ma = \Sigma F_i^E + \Sigma R_i^E = G + F_1 + N.$$

Since Fig. 2 is shown in an orthogonal projection, the force of gravity G and the normal reaction N are not shown.

5. Let us write down the differential equations of movement of the point.

$$m\ddot{X} = \sum F_{iOX}^{E} + \sum R_{iOX}^{E} = F_{1OX} = P_{OX} , \tag{1}$$

$$m\ddot{Y} = \sum F_{iOY}^{E} + \sum R_{iOY}^{E} = F_{1OY} = P_{OY} , \tag{2}$$

$$m\ddot{Z} = \sum F_{iOZ}^{E} + \sum R_{iOZ}^{E} = F_{1OZ} = P_{OZ} . \tag{3}$$

6. According to these equations of movement $X = 0.05\,t^3$, $Y = 0.3\,t^2$ define projections $\ddot{X}$, $\ddot{Y}$, $\ddot{Z}$ acceleration of the point on the coordinate axes.
7. The obtained values $\ddot{X}$, $\ddot{Y}$, $\ddot{Z}$ we substitute into equations (1), (2), (3).

$$m\cdot(0.3\cdot t) = F_{1OX} = P_{OX},$$

$$m\cdot(0.6) = F_{1OY} = P_{OY},$$

$$m\cdot(0) = F_{1OZ} = P_{OZ} = 0.$$

8. We determine module P of the resultant active forces and reactions of external links.

$$P = \sqrt{(F_{1OX})^2 + (F_{1OY})^2} = \sqrt{(0.3\cdot m\cdot t)^2 + (0.6\cdot m)^2} .$$

9. We calculate values F_{1OX}, F_{1OY}, P for the moment in time $t_1 = 4$ s.

$$F_{1OX}(t_1) = 0.3\cdot m\cdot t_1 = 0.3\cdot 8\cdot 4 = 9.6\text{ N},$$

$$F_{1OY}(t_1) = 0.6\cdot m = 0.6\cdot 8 = 4.8\text{ N},$$

$$P(t_1) = \sqrt{(9.6)^2 + (4.8)^2} = 10.733\text{ N}.$$

10. Let us define the direction cosines and angles, formed by the directions of the coordinate axes and the force.

$$\cos(P(t_1), \mathbf{i}) = F_{1OX}(t_1)\cdot[P(t_1)]^{-1} = 9.6\cdot(10.733)^{-1} = 0.894;\ \alpha = 26.563^{\circ},$$

$$\cos(P(t_1), \mathbf{j}) = F_{1OY}(t_1)\cdot[P(t_1)]^{-1} = 4.8\cdot(10.733)^{-1} = 0.447;\ \beta = 63.434^{\circ}.$$

11. We determine the coordinates of the point on the trajectory of its movement at the moment of time t_1, and the resulting information we show in Fig. 3: $X(t_1) = 0.05\cdot 4^3 = 3.2$ m; $Y(t_1) = 0.3\cdot 4^2 = 2.4$ m.

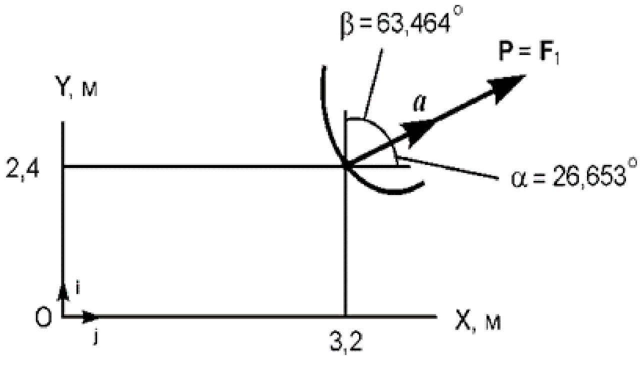

Fig. 3. **Determining the coordinates of a point on the trajectory of its movement at a moment in time t_1**

In such a way the problem is solved, the answers to the questions posed are received.

It can be seen from the solution of the problem that for it there is used the knowledge of the course of theoretical mechanics on differential equations, which is based on inter-disciplinary links with the course of physics, and links with mathematical analysis (the course of higher mathematics).

The content of such tasks clearly demonstrates the need, firstly, for integrated application by the students of knowledge from various branches of mathematics and physics. Secondly, it illustrates the fact that the links of theoretical mechanics with mathematics and physics help develop general subject skills, skills in computational, visual-graphic, measuring activities, in modelling and a versatile study of concepts and their properties. Based on the analysis of the inter-disciplinary links between theoretical mechanics and other disciplines of the natural sciences, general technical and professional cycles, one can suggest several ways how to implement inter-disciplinary integration. One of them is to develop in the students a sense of importance of studying theoretical mechanics by emphasizing their practical significance of this discipline for training agricultural engineers. Taking into account the experience of conducting classes in theoretical mechanics, we can conclude that this discipline is quite difficult for understanding and perception by the students of initial courses. Initially the students are not sufficiently interested in studying it because, in accordance with the curriculum, it does not belong to the special disciplines. Therefore, a teacher of theoretical mechanics should be able to explain to the students from the first lessons that without knowledge of the basic laws and principles of theoretical mechanics there cannot be a successful engineer-designer of modern agricultural machinery, who has a systematic approach to explaining physical phenomena and processes, occurring in the space, surrounding a person. A good incentive for a conscientious attitude of the student to the study of the discipline is not only persuasion but also the control of knowledge. The traditional knowledge control methods ignore inter-subject and inter-disciplinary links. The control method, based on an inter-disciplinary approach, is more efficient. Therefore, along with the current and final control of knowledge of the discipline, it can be proposed to control the residual knowledge, for example, in the form of testing subjects that have been studied earlier and have an applied nature or logical development of this discipline.

When starting the study of theoretical mechanics, we can test elementary knowledge in physics (section of mechanics), higher mathematics, descriptive geometry and graphics; in the strength of materials – to check the ability of the students to compose and solve equations of equilibrium, to determine the centre of gravity; in engineering mechanics – to test the knowledge on theoretical mechanics and strength of materials.

Such an inter-disciplinary knowledge control has several important aspects:

1. it enables the teacher at the earliest stage of studying the discipline by the students to identify the least studied topics, weak points of the students and, taking this into account, to adjust the teaching of their discipline. The test results will also be useful for the students who will have to fill in the gaps in their knowledge of the previous discipline, to strengthen self-training under the guidance of a teacher;
2. inter-disciplinary control of knowledge will invariably lead to the emergence and development of inter-departmental and inter-disciplinary interaction. Implementation of inter-disciplinary integration in the process of inter-departmental interaction will make it possible to bring correspondence, to inter-connect the working programs in related disciplines, which will help avoid duplication in the presentation of the same material, and will make it possible to unify the designations of related terms and concepts in different courses. Joint development of tasks for inter-disciplinary knowledge control will allow to agree on the minimum requirements for the students' knowledge in the transition to the study of subsequent disciplines;
3. clear understanding by the students of the inevitability of control of the residual knowledge in the previous discipline before studying the next one, despite the presence of a final exam or credit; it serves as a reliable incentive to improve the level of knowledge, focusing on the issues, related to the residual knowledge.

The main objective of the experiment was implementation of the experimental research into the teaching practice. At this stage of the study a scheme was formed for the specificity of teaching theoretical mechanics, the introduction of inter-disciplinary links with the disciplines of the natural sciences, the general technical and professional cycles.

Besides, the experimental research work was performed in the following order: the initial level of first-year students in specialty 208 "Agroengineering" was clarified. This made it possible to form experimental and control groups of students. 150 students, 7 teachers in technical disciplines and physics took part in the experimental work. A multi-stage test of the knowledge and skills of the applicants for higher education throughout the entire period of the research enabled obtaining objective data about the assimilation of educational material on an inter-disciplinary basis.

Analysis of the results of the experiments showed that the average performance in the experimental group in theoretical mechanics increased by 17.02%, the quality of knowledge by 33.89%; in technical disciplines – performance in the experimental group increased by 3.4%, the quality of knowledge by 11.82%. In the reference group the academic performance in theoretical mechanics increased by 11.83%, the quality of knowledge by 10.15%; in technical disciplines – the academic performance increased by 5.34%, the quality of knowledge by 8.44% (Fig. 4). The results of the students' learning activities are confirmed by archival data, which confirms the methodology of inter-disciplinary teaching.

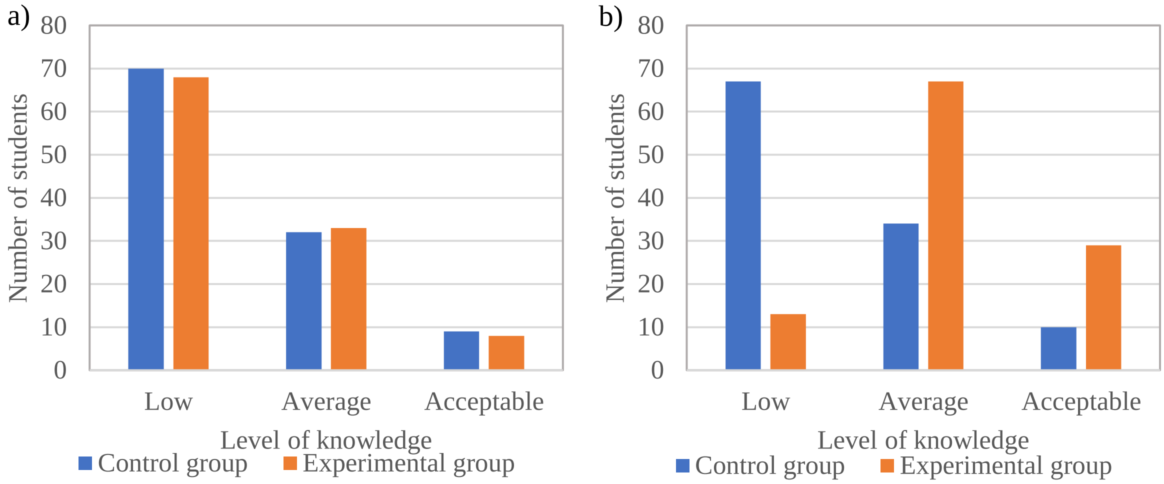

Fig. 4. **Results of student knowledge at the beginning of the experiment (a) and at the end of the experiment (b)**

Analysis of the results of the students' educational achievements (Fig. 4b) gave grounds to confirm the hypothesis about the need to build inter-disciplinary links in teaching theoretical mechanics to improve the professional knowledge of the students of agrarian and technical educational institutions. The results of the experiment confirm the working hypothesis of the study. This indicates the efficiency and potency of the proposed methodology for teaching theoretical mechanics.

Conclusions

The conducted research allows to conclude that ensuring the integrity, fundamental and professional orientation of education is possible only if inter-disciplinary links are introduced. The stepwise formation of a scientific picture of the world, using inter-disciplinary links during training, contributes to qualitative transformation of all the aspects of the students' cognitive activity. When using this method, an increase in the level of formation of the inter-disciplinary knowledge links was revealed, and, accordingly, by 17%, an increase in the level and cognitive activity of future engineers-designers of agricultural machinery. Consequently, implementation of inter-disciplinary links into the course of theoretical mechanics increases the efficiency of professional orientation of education; deepens the knowledge of the fundamental sciences; contributes to the organic combination of theoretical and practical components in training a future specialist; intensifies the search for new approaches to designing and organizing the educational process.

Theoretical mechanics is one of the most fundamental sciences that studies the movement of bodies and the interaction between them. The main purpose of studying theoretical mechanics is to understand the physical laws that determine the motion of objects, as well as the ability to apply these laws to solve various technical, engineering and scientific problems.

The main reasons why the study of theoretical mechanics is important:

Understanding the fundamental laws of motion: Theoretical mechanics provides the fundamental laws that describe the motion of objects in space and time. Understanding these laws allows to understand the physical principles that underlie more complex systems.

Applications in engineering and technology: Theoretical mechanics allows to develop mathematical models that help solve various technical and engineering problems related to the movement of bodies.

Development of mathematical skills: The study of theoretical mechanics requires a high level of mathematical training. It helps develop math skills and prepare students for more complex math problems.

Development of critical thinking: The study of theoretical mechanics helps develop critical thinking and analytical skills, as it requires analyzing and solving complex problems.

Exploring the world: Understanding the physical principles underlying theoretical mechanics helps us better understand and explore the world around us. For example, knowledge of the laws of motion can be useful in understanding how the various mechanisms we use every day, from cars to robots, work.

Development of scientific research: Theoretical mechanics is one of the main disciplines and is the basis for many other scientific fields. The development of new theories and methods in theoretical mechanics can open the door to new scientific discoveries and technological innovations.

Therefore, the study of theoretical mechanics is important not only for the development of physical science, but also for the development of technical and engineering sciences, mathematics and other scientific disciplines. It helps understand the world around us and solve various technical and scientific problems.

Prospects for further research of this issue lie in a systematic approach to the study of the complex problem of inter-disciplinary links between natural and professional disciplines, and the development of new teaching methods.

Author contributions

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

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