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Formation of biophysical concepts in the process of training biology students

Orazkul Tursymatova*

Korkyt Ata Kyzylorda University
120000, 29A Aiteke Bi Str., Kyzylorda, Republic of Kazakhstan

Kalampyr Zhumagulova

Abai Kazakh National Pedagogical University
050010, 13 Dostyk Ave., Almaty, Republic of Kazakhstan

Saltanat Ibadullayeva

Korkyt Ata Kyzylorda University
120000, 29A Aiteke Bi Str., Kyzylorda, Republic of Kazakhstan

Aitmaganbet Urganishbekov

Korkyt Ata Kyzylorda University
120000, 29A Aiteke Bi Str., Kyzylorda, Republic of Kazakhstan

Gulzhan Balykbayeva

Korkyt Ata Kyzylorda University
120000, 29A Aiteke Bi Str., Kyzylorda, Republic of Kazakhstan

Abstract

Relevance. The relevance of the study is determined by changes in science and trends in the social development of modern society, since there is an increase in the amount of scientific information in the information society. In the context of the informatization of science and education, an important role in the formation of common concepts about life and the organization of its stages.

Purpose. This article explores ways of introducing biophysical concepts into the content of the biology course in the training process of university biology students in order to improve their biophysical knowledge, skills, and professional competence. Training in biology and physics in the experimental group were carried out based on a work program that provides an intersubject relation. Training in the control group was organized in the traditional form of lectures and practical classes. The experiment involved 104 second-, third- and fourth-year students enrolled in "5B011300 – Biology" and "5B011000 – Physics". The experimental group (EG) consisted of 67 students, and the control group (CG) – of 37 students. The experiment was carried out in three stages.

Methodology. The research process was carried out with the help of such research methods as monitoring during classes, analysis of the teacher's actions and students' performance, dialogue between the teacher and students.

Results. The study demonstrated that to achieve high performance in biology and physics among students at pedagogical higher education institutions, further improvements are needed in the developed methodology for integrating interdisciplinary relations between biology and physics to form biophysical concepts.

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*Corresponding author



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Conclusions. There is a need to expand, supplement and systematize the content of biophysical concepts used in updated educational programs. In order to improve the biophysical knowledge of future specialists one should determine and systematize biophysical concepts in terms of the content of biological knowledge.

Keywords: biophysics; biophysical knowledge; development; intersubject relation; concept “energy”.

Introduction

The new paradigm of education is aimed at the basic principles of didactics that provide in-depth explanations of the goals and objectives of education. This is the basis for the development of a new vision of education and for the implementation of positive trends in the global educational space, such as expanding the concept of the quality of knowledge and raising its level. Improving the quality of knowledge is aimed at the formation of human capital. The theoretical knowledge of biophysical concepts is provided in the biological educational material of senior classes. However, the lack of special studies concerning the issue under consideration that could be taken for guidance causes contradictions between the insufficient exploration of integrated approaches to the development of concepts from a methodological point of view and the formation of biophysical concepts in the training of biology students. The solution of these contradictions in the formation of biophysical concepts from an individual theoretical and methodological point of view determines the relevance of the study.

Biophysical concepts as such are complex, multi-element and interdisciplinary, therefore, they are formed in a certain order, systematically, based on the basic knowledge of natural disciplines, such as biology and physics. While studying the role of these concepts in the systemic knowledge of individual biology courses, methodological biologists, such as E.P. Brunovt [1; 2], N.M. Verzhilin [3], B.V. Vsesvyatsky [4], I.D. Zverev [5], B.D. Komissarov [6] and N.A. Rykov [7], paid great attention to the interdisciplinary connection in their formation.

In the course of studying the preparedness of biology students to improve their biophysical knowledge and skills, the need emerged for the introduction of accurate biophysical concepts in the content of the biology course, as well as for the search of effective ways to further improve it. In this regard, the need arose to expand, supplement and systematize the content of biophysical knowledge in the structure of updated educational programs. In the opinion of modern researchers, such as O.N. Golubeva [8], L.Ya. Zorina [9], V.S. Stepin [10], natural-science education has acquired personal and social significance due to huge ideological, methodological, informational and cognitive opportunities. L.Ya. Zorina [9] in her studies identified the main reasons for the lack of systemic knowledge among students in the formation of general physical concepts. One of them is the weak development of the conceptual framework in didactics, which is connected with the lack of tools that implement systemic knowledge.

The competitiveness of developed countries is the result of fundamental natural scientific research that ensures scientific and technological innovations and their safety. In the course of our research, when determining the place of biophysical knowledge in the content of natural disciplines, it was necessary to determine the role and place

of biophysical knowledge in the cycle of natural disciplines. In the scientific literature, the category of “knowledge” is defined as the result of human social, material, and spiritual activity [11-15]. Since the whole world can be represented as a set of certain systems put in order, it can be argued that the creator of the system can be considered the pillar of systematicity in science, which makes it possible to identify interrelated properties and qualities, combined in the structure of a natural, universal, simulated and modular system. They are interconnected, but each fulfills its mission.

Materials and Methods

Studying the place and role of biophysical knowledge in teaching general natural disciplines in higher educational institutions, as well as in determining the content of biophysical knowledge in the disciplines of natural sciences, we first focused on the composition and structure of the content of education. The content of education is comprised of general and professional knowledge. The general educational content is the basis for the formation of the general personality culture, worldview, civic orientation, views on work and social life. The content of professional knowledge is focused on activities, as well as on application in practice.

In pedagogical science, there are certain criteria for selecting the content of knowledge. The basis of the selection criteria for the content of education is the content of knowledge:

- ensuring the development of personality and providing a complete and holistic solution of problems for the formation of basic education;
- scientific and practical significance of the educational material;
- compliance of the content of the educational material with the real capabilities of students, ensuring compliance with other requirements.

Given these requirements, when determining the content of biophysical knowledge in the disciplines of natural sciences, we relied on the criteria for selecting the content of knowledge provided by I.Ya. Skatkin [16] and V.I. Zagvyazinsky [17]. In higher pedagogical educational institutions, the structure and content of students’ training from a methodological point of view in different disciplines is based on educational recommendations, textbooks, as well as on the content of curricula. But, recently, some significant changes have been taking place in this direction. The updated content of the biology course in secondary schools proves the need to turn interdisciplinary relations into a mandatory factor in the educational process. We think that such a structure of the educational content is efficient. This in turn will reveal the relevance of our research on the scientific and methodological foundations of the formation of biophysical concepts in the training of biology students in higher pedagogical educational institutions [18-21].

Unfortunately, in the description of the biophysics course taught in higher pedagogical educational institutions, interdisciplinary relations are not mentioned at all. Therefore, we believe that for scientific research, it is necessary to revise the content of the integrated biophysics course, which would show the role of interdisciplinary relations for students enrolled in biology and physics. For these purposes, training in biology and physics in the experimental group was carried out on the basis of a work program that provides an intersubject relation. Training in the control group was organized in the traditional form of lectures and practical classes.

The experiment involved 104 second-, third- and fourth-year students enrolled in “5B011300 – Biology” and “5B011000 – Physics”. The experimental group (EG) consisted of 67 students, and the control group (CG) – of 37 students. The experiment was carried out in three stages:

1. The definition experiment; the defining stage.
2. The formation experiment; the formative stage.
3. The control experiment – the verification of research results.

The methodological approaches in the field of biology and physics in the proposed contents of various biophysical definitions provide a deep understanding of our choice of studies of biological and physical fundamental concepts in the process of interdisciplinary training [22-28]. Our point of view coincides with the point of view of A.B. Rubin [29], who also understands the need to establish fundamental relations between biology and physics. Thus, as a result of studying textbooks and manuals on biology, it was found that interdisciplinary relations in the formation of biophysical concepts are not carried out at the proper level and need to be improved.

For the purpose of training through the formation of biophysical concepts among students, the organization of the conducted practical experiment consisted of three stages. Practical and experimental work was carried out during the 2017-2020 academic years at the Korkyt Ata Kyzylorda University to verify the correctness and effectiveness of the proposed methodology. In 2017-2018, the refinement stage of the experiment was conducted. Its main goal was to determine the state of the formation of biophysical concepts in university practice and its impact on students' educational achievements. In this regard, the following tasks were addressed:

- to determine the level of students' educational achievements and their relationship with the formation of biophysical concepts in the educational process;
- to determine the characteristics of the formation of biophysical concepts used in university practice.

The solution of these specific tasks was based on the example of “Biophysics” course, introduced into the curriculum. At the initial stage of the control experiment, the indicators of knowledge acquired by students of the experimental groups were divided into three levels. During the selection experiment, an analysis was conducted to test students' knowledge and skills in “Biology” and “Physics” courses, and their compliance with the curriculum requirements. The analysis of curricula content was conducted as well. This period of the experiment was carried out with the help of such research methods as monitoring during classes, analysis of the teacher's actions

and students' performance, dialogue between the teacher and students.

The defining period of the experiment is the initial stage in the diagnosis of the formation of skills for the effective use of biophysical concepts by students. The goal is to determine indicators and criteria for the level of these skills in experimental groups, and the possibilities of their implementation in the biophysics curriculum. In this regard, during the experiment, an analysis of students' knowledge in the basic disciplines “Biology” and “Physics” was first conducted.

The purpose of the pedagogical experiment is to integrate the development of biophysical concepts, to introduce the principles of interdisciplinary relations, as well as to test the impact of the applied methodology on the quality of the assimilation of concepts. Among students of pedagogical educational institutions, an experiment was conducted to study the state of the realization of interdisciplinary relations in the formation of biophysical concepts, which consisted of three stages.

To assess the quality of the assimilation of biophysical concepts, we used A.V. Usova's [30; 31] elemental analysis, which makes it possible to calculate the following values:

- the average coefficient of completeness of the student's assimilation of knowledge elements (C), when studying the concept of energy;
- the profit ratio from the formation of knowledge elements – (μ);
- the methodology's efficiency ratio – (β).

For the statistical evaluation of the experimental results, we used the following indicators:

1. The formula (\bar{C}) with the average coefficient of completeness of students' knowledge assimilation (Eq. 1):

$$\bar{C} = \frac{1}{nN} \sum_{i=1}^N n_i, \quad (1)$$

where n is the total number of knowledge elements defined by the teacher; n_i is the number of knowledge elements correctly learned by the student, N is the total number of students done the assignment. The largest value of \bar{C} is 1.

2. The ratio of success from the formation of knowledge elements (Eq. 2):

$$(\mu): \mu = \frac{\bar{C}_1}{\bar{C}_0}, \quad (2)$$

where \bar{C}_0 is the average coefficient of the formation of knowledge elements at the beginning of learning, \bar{C}_1 is the average coefficient of the formation of knowledge elements at the end of learning. With the value of the formation of knowledge $\mu > 1$ is considered effective.

3. The methodology's efficiency ratio when calculating by the formula (Eq. 3):

$$(\beta): \beta = \frac{\mu_e}{\mu_c}, \quad (3)$$

where μ_e is the coefficient of success in assimilating knowledge elements by students of the experimental groups; μ_c is the coefficient of success in assimilating knowledge elements by students of the control groups.

With the value of the formation of knowledge $\beta > 1$ is considered effective.

The following groups of both specialties participated in the experiment: 16 (CPh) – the control group enrolled in physics, 17 (EPh₁) – the 1st experimental group enrolled in physics, 18 (EPh₂) – the 2nd experimental group enrolled in physics, 13 (CB) – the control group enrolled in biology, 14 (EB₁) – the 1st experimental group enrolled in biology, 15 (EB₂) – the 2nd experimental group enrolled in biology.

The definition experiment includes:

- the need to specify the methodology for the formation of biophysical concepts among students of pedagogical higher educational institutions in the development of such a physical concept as energy in the context of the realization of interdisciplinary relations between biology and physics;

- the need to develop a working curriculum that implements an interdisciplinary relation between the courses of physics and biology in teaching the biophysics course;

- identification of the need to develop intersubjective control tasks of the developed methodology for implementation in the educational process.

To assess the efficiency of the developed methodology, we made two observations on the formation of the concept of energy. The first observation was carried out in the introductory lecture at the beginning of the course, and the second – during the test lesson before the exam.

Results and Discussion

Textbooks on biology and physics used in universities were analyzed in the context of the realization of interdisciplinary relations in the formation of natural-scientific concepts. It can be noted that they mainly focus on a university's direction. This trend is observed at the faculties of biology, chemistry, and physics in agricultural, medical, and pedagogical higher educational institutions. In this regard, students' training in pedagogical universities involves mainly textbooks and manuals intended for classical universities [32-38]. Currently, there are no textbooks and manuals for the development of fundamental physical and biological concepts in disciplines that implement intersubject relations and form a holistic worldview, knowledge, and skills [39-44]. Based on this, it can be concluded that a systematic solution to these problems can only be achieved by creating curricula and textbooks that can realize intersubject relations.

During the analysis of the questionnaire, we noted the lack of biophysical concepts that are formed during training in higher educational institutions, as well as the fact that they are partially formed through the media (social science journals, educational literature, periodicals). Based on the foregoing, we can call positive the results obtained by identifying students' interest and abilities in the biophysics course and their ideas about their future profession, as well as by determining the degree of the content of biophysical concepts in "Biology" and "Physics" courses.

The results obtained during the research work are shown in Table 1.

Table 1. The coefficient of formation of the concept of "energy" (at the initial control stage) among students of experimental (E₁, E₂) and control (C) groups

Groups	17, EPh ₁ N ₁ = 17		16, CPh N ₂ = 21		18, EPh ₂ N ₃ = 17		14, EB ₁ N ₁ = 16		13, CB N ₂ = 16		15, EB ₂ N ₃ = 17	
	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁
\bar{C}	0.45	0.71	0.40	0.49	0.31	0.58	0.28	0.39	0.25	0.30	0.26	0.35
μ	1.58		1.23		1.87		1.39		1.20		1.35	
μ_e	1.73						1.37					
μ_c	1.23						1.20					
β	1.41						1.14					

The above table shows the comparative coefficient of the completeness of assimilating the concept of energy in the experimental and control groups at the beginning and end of the experiment (first and second control). The coefficient of completeness (C) in the experimental groups enrolled in physics (E₁, E₂) varies from 0.58 to 0.71 (in the control group – 0.49), while the result of those enrolled in biology varies from 0.35 to 0.39 (in the control group –

0.30). The profit ratio from the assimilation of the concept of energy (μ) by students of the experimental groups enrolled in physics was 1.73 (in the control group – 1.23), while in the experimental groups enrolled in biology this figure was 1.37 (in the control group – 1.20). The methodology's efficiency ratio, in turn, was higher than one. The results obtained are shown in Figure 1.

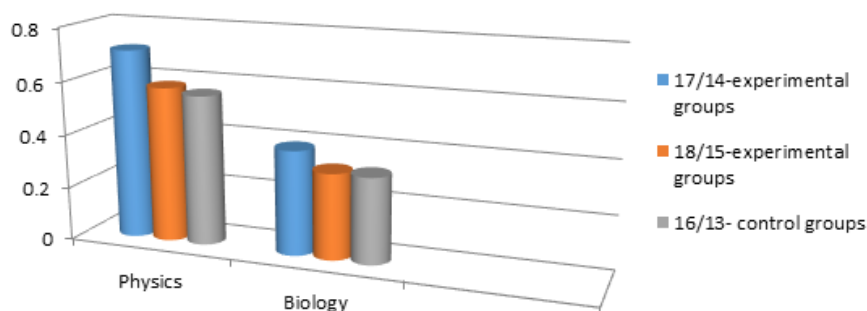


Figure 1. The coefficient of completeness of formation of the concept “energy” (at the initial control stage) among students of experimental (E₁, E₂) and control (C) groups

As Table 1 shows, the indicators of the control and experimental groups on the concept of energy at the first control stage on the formation of the concept “energy” showed a high level of the quality of knowledge. The results of assignments completed by students of the experimental groups far exceeded the results of the control groups. Analyzing the answers of students to the tasks of the first control test, we were able to determine their capabilities: whether they know the meaning of the quantities and what signs (or phenomena) characterize these quantities, can write formulas and provide

explanations. Along with this, we saw that during the experiment our students acquired certain skills, for example, they were able to determine the place of a number of biophysical concepts in the general system of scientific concepts, to show and use the scientific industry, to determine phenomena and processes, to reveal the relationship between physical and biological phenomena and their scientific development, to transfer knowledge from the branch of biology to the branch of physics, to find the place of the concept of energy in the knowledge system in physics and biology.

Table 2. Elemental analysis of the assimilation of the concept of energy by students enrolled in physics and biology (the first control period)

Control questions No. 1	Total number of participants %					
	Physics			Biology		
	17, EPh ₁ N ₁ = 17	18, EPh ₂ N ₂ = 17	16, CPh N ₃ = 21	14, EB ₁ N ₁ = 16	15, EB ₂ N ₂ = 17	13, CB N ₃ = 16
I	88.2	76.5	71.4	56.3	64.7	56.3
II	76.5	70.6	66.7	46.9	47.0	43.8
III	73.5	58.8	59.5	34.4	35.3	31.3
IV	64.7	47.1	28.6	31.3	17.6	12.5
V	52.9	35.3	19.1	21.9	8.8	6.3

These results were obtained during the analysis of answers to determine the relationship of biological, physical phenomena and their development. When calculating the percentage of the quality of the proposed tasks, it was found that students of the experimental groups enrolled in physics and biology showed good results – 64.7% and 31.3%, respectively. In turn, students of the

control group enrolled in physics showed a result of 28.6%, while those enrolled in biology – 12.5%. The answers to the fifth question on determining the place of the concept “energy” in physical and biological science showed similar results (Table 2). The data obtained are shown in Figure 2, 3.

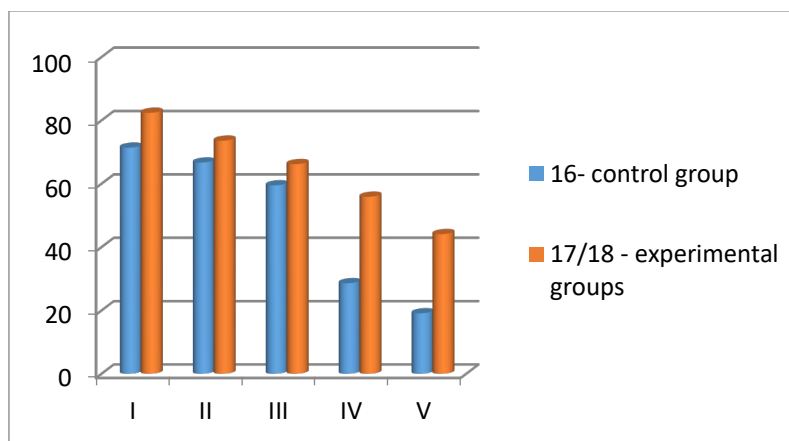


Figure 2. Elemental analysis of the assimilation of the concept “energy” by students enrolled in physics (the first control period)

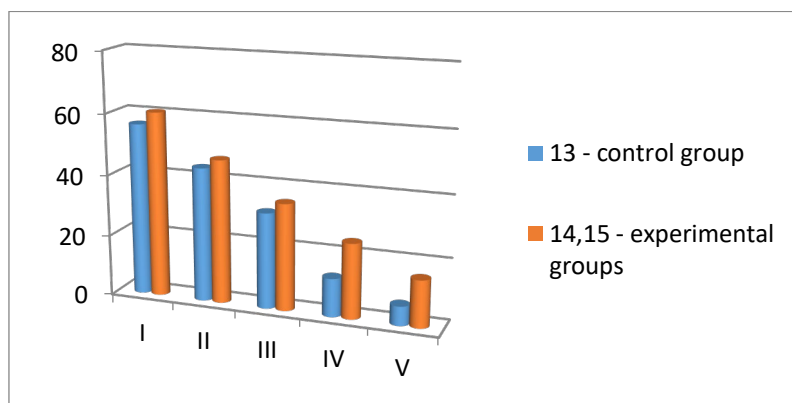


Figure 3. Elemental analysis of the assimilation of the concept “energy” by students enrolled in biology (the first control period)

Table 3. Comparative analysis of the coefficient of completeness of forming the concept “energy” by students enrolled in biology and physics

Concept characterization	Total number of participants %					
	Physics			Biology		
	17, EPh ₁ N ₁ = 17	18, EPh ₂ N ₂ = 17	16, CPh N ₃ = 21	14, EB ₁ N ₁ = 16	15, EB ₂ N ₂ = 17	13, CB N ₃ = 16
Content	0.88	0.76	0.71	0.56	0.64	0.56
Volume	0.69	0.59	0.51	0.38	0.35	0.29
Relation	0.53	0.35	0.19	0.22	0.11	0.06
Average value	0.70	0.57	0.47	0.39	0.37	0.30

Comparing the results of the first test, one can talk about the effectiveness of forming the content of the concept of energy, including its relationship with other concepts, and the volume. Table 3 shows that the level of students’ knowledge in the experimental groups is higher than that in the control groups. The reason for this is that we presented the concept of energy not separately but as a

complex concept, identifying its relations with other physical and biological concepts. The results of the second control stage are shown in Tables 4, 5 and Figures 4, 5, 6. To determine the completeness of assimilating the concept of energy, a number of tasks were given, showing the relationship between the concepts.

Table 4. The coefficient of completeness of forming the concept of energy among students of the experimental and control groups

Selection and group volume	17, EPh ₁ N ₁ = 17		16, CPh N ₂ = 21		18, EPh ₂ N ₃ = 17		14, EB ₁ N ₁ = 16		13, CB N ₂ = 16		15, EB ₂ N ₃ = 17	
	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁	C ₀	C ₁
Indicators												
\bar{C}	0.43	0.72	0.39	0.48	0.42	0.68	0.28	0.37	0.23	0.27	0.27	0.36
μ	1.67		1.23		1.62		1.32		1.17		1.33	
μ_e	1.65						1.33					
μ_c	1.23						1.17					
β	1.34						1.14					

Based on the data in Table 4, one can compare the coefficient of the completeness of assimilating the concept of energy in the experimental and control groups at the beginning and end of the experiment. While among students of the experimental groups enrolled in physics (EPh₁, EPh₂) the coefficient \bar{C} varied from 0.68 to 0.72 (in the control group – 0.48), among students of the experimental groups enrolled in biology this value was in

the range of 0.36 to 0.37 (in the control group – 0.27). In this regard, while the coefficient of completeness in the experimental and control groups enrolled in physics was 1.62 and 1.23, respectively, in the experimental and control groups enrolled in biology the coefficient was 1.33 and 1.17, respectively. These results, in turn, prove that the proposed methodology is more effective than traditional.

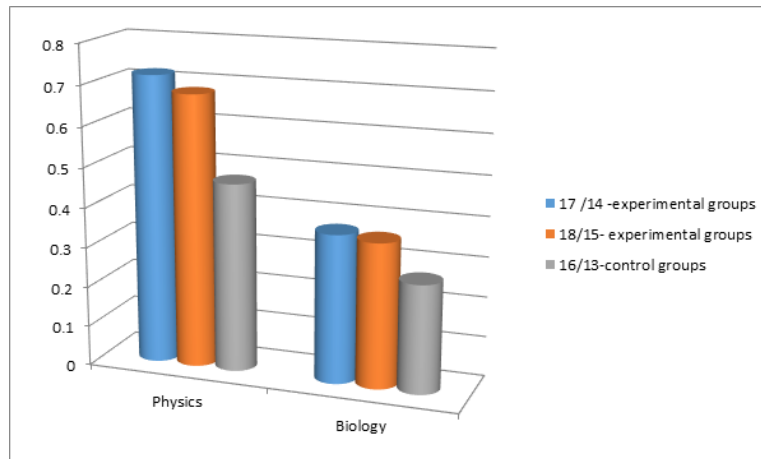


Figure 4. The coefficient of completeness of formation of the concept “energy” among students of experimental and control groups

Table 5. Elemental analysis of the assimilation of the concept of energy by students enrolled in physics and biology (the second control period)

Control questions No. 2	Total number of participants %					
	Physics			Biology		
	17, EPh ₁ N ₁ = 17	18, EPh ₂ N ₂ = 17	16, CPh N ₃ = 21	14, EB ₁ N ₁ = 16	15, EB ₂ N ₂ = 17	13, CB N ₃ = 16
I	91.1	85.3	64.3	59.4	61.8	53.1
II	85.3	79.4	59.5	65.4	52.9	34.4
III	79.4	73.5	54.8	46.9	44.1	28.1
IV	61.8	53.0	40.5	21.9	20.6	15.6
V	41.2	32.4	21.4	0.0	0.0	0.0

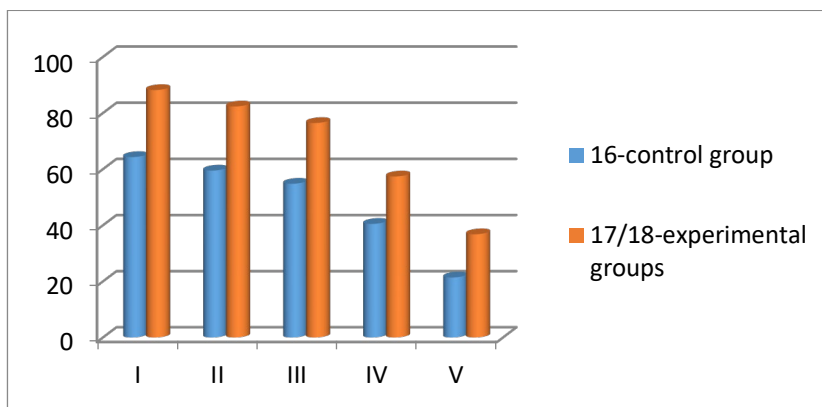


Figure 5. Elemental analysis of the assimilation of the concept “energy” by students enrolled in physics (the second control period)

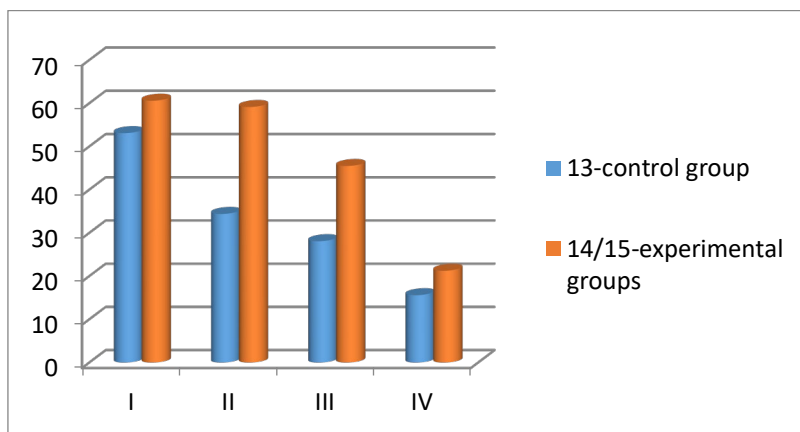


Figure 6. Elemental analysis of the assimilation of the concept “energy” by students enrolled in biology (the second control period)

Analyzing the students' answers to the proposed tasks, we concluded that the students understand that "concept" is a philosophical category: they associate the content and the volume with physical quantities, understand its functions and the difference between a material state and a process, they can also systematize concepts by special criteria (through the example of concepts, energy, work, amount of heat and entropy) and know the limit of the application of physical concepts to characterize biological systems. Thus, the proposed methodology for the formation of the concept of fundamental energy is effective from a methodological point of view, since the formation of the concept has increased by 1.5 times. However, the students enrolled in biology in comparison with those enrolled in physics when characterizing the biological systems, could not answer the question "show the limit of application of physical concepts", and at the comparative experimental stage they answered only a few questions (Table 5). But due to the fact that nobody could answer the fifth question "What is the significance of the qualitative irreducibility of the application of fundamental physical concepts in biology?", we have concluded that it is necessary to further improve the content and methods of teaching the subject of biophysics for biology specialty.

Conclusions

Thus, the following conclusions can be drawn from the experimental results:

1. For the implementation of interdisciplinary relations between biology and physics and the formation of biophysical concepts, the proposed methodology can be used in the educational process of pedagogical higher educational institutions.
2. The high results of the pedagogical experiment on the coefficient of the complete assimilation of the concept of energy show that the method of implementing interdisciplinary relations in the formation of biophysical concepts and its main steps were chosen correctly.

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3. In order for the results of students enrolled in biology to reach the results of students enrolled in physics, when implementing an interdisciplinary relation between biology and physics for the formation of biophysical concepts among students of pedagogical higher educational institutions, the developed methodology is required to be introduced into the educational process.

The physical and chemical processes that occur in the biological system nowadays, firstly, provide an opportunity to expand the scientific and natural-scientific worldview of students and, secondly, enable them to work with 21st century technologies and to master the skills of using modern technologies. The study proved that in order to achieve the high performance of students enrolled in biology and physics, when implementing an interdisciplinary relation between biology and physics for the formation of biophysical concepts among students of pedagogical higher educational institutions, the developed methodology needs further improvements.

A structurally substantive model of the formation of biophysical concepts can be used to enhance students' natural-scientific competencies, including the students' biophysical literacy and culture. The selected content of knowledge and the system of concepts from a methodological point of view is effective for use in the educational process by future biology teachers. The obtained theoretical and practical results can be introduced into the educational process of pedagogical higher educational institutions and senior classes of secondary schools.

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None.

Conflict of Interest

The authors declare that there is no conflict of interests.

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Формування біофізичних концепцій у процесі навчання студентів біології

Оразкул Турсиматова

Кизилординський університет імені Коркит Ата
120000, вул. Айтеке Бі, 29А, Кизилорда, Республіка Казахстан

Калампир Жумагулова

Казахський національний педагогічний університет імені Абая
050010, вул. Достик, 13, Алмати, Республіка Казахстан

Салтанат Ібадуллаєва

Кизилординський університет імені Коркит Ата
120000, вул. Айтеке Бі, 29А, Кизилорда, Республіка Казахстан

Айтмаганбет Ургенішбеков

Кизилординський університет імені Коркит Ата
120000, вул. Айтеке Бі, 29А, Кизилорда, Республіка Казахстан

Гульжан Балыкбаєва

Кизилординський університет імені Коркит Ата
120000, вул. Айтеке Бі, 29А, Кизилорда, Республіка Казахстан

Анотація

Актуальність. Актуальність дослідження визначається змінами в науці та тенденціями у соціальному розвитку сучасного суспільства, оскільки в інформаційному суспільстві збільшується обсяг наукової інформації. У контексті інформатизації науки та освіти важлива роль у формуванні загальних концепцій про життя та організацію його етапів.

Мета. У цій статті досліджуються способи введення біофізичних концепцій у зміст курсу біології у процесі навчання студентів університету з метою покращення їх біофізичних знань, навичок та професійної компетентності. Навчання біології та фізики в експериментальній групі проводилося на основі робочої програми, яка передбачає міжпредметний зв'язок. Навчання в контрольній групі організовувалося у традиційній формі лекцій та практичних занять. В експерименті брали участь 104 студенти другого, третього та четвертого курсів, які навчаються за спеціальностями “5В011300 – Біологія” та “5В011000 – Фізика”. Експериментальна група (ЕГ) складалася з 67 студентів, а контрольна група (КГ) – з 37 студентів. Експеримент проводився в трьох етапах.

Методологія. Дослідницький процес здійснювався за допомогою таких методів дослідження, як моніторинг під час занять, аналіз дій викладача та результатів студентів, діалог між викладачем та студентами.

Результати. Дослідження показало, що для досягнення високої успішності у біології та фізиці серед студентів педагогічних вищих навчальних закладів необхідні подальші вдосконалення в розробленій методології інтеграції міждисциплінарних відносин між біологією та фізикою для формування біофізичних концепцій.

Висновки. Існує потреба у розширенні, доповненні та систематизації змісту біофізичних концепцій, що використовуються в оновлених освітніх програмах. Для покращення біофізичних знань майбутніх спеціалістів необхідно визначити та систематизувати біофізичні концепції з урахуванням змісту біологічних знань.

Ключові слова: біофізика; біофізичні знання; розвиток; міждисциплінарний зв'язок; концепція “енергія”.