

Developing methods for solving typical professional tasks for students of medical and biological majors based on integration of natural science subjects

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Abstract. A higher school course in physics determines three main areas of training students of medical and biological majors. Professional tasks for biologists and doctors solved on the basis of physical and chemical knowledge are established, methods for their solving are developed. Examples of typical professional tasks and an algorithm of the method for their solving are given.

Keywords: professional task; general professional competence; generalized method of solving.

1. INTRODUCTION

National project “Education” aims to ensure the global competitiveness of Russian universities’ graduates. It means that university students should not specialize in only one type of activity but undertake multi-level training based on the integration of multidisciplinary knowledge. For this purpose, modernization of professional higher education is provided through the introduction of flexible practice-oriented educational programmes. Completing them will allow graduates to independently develop methods for solving various applied problems to address regional challenges, applying the knowledge they acquired.

The development strategy of modern universities is focused on changing the structure and content of the learning process, aimed at students’ mastering the skills in research, project and entrepreneurial activities. Physics is a compulsory subject in the training of various specialists like doctors, biologists, programmers and engineers of various profiles [1, 2], since it has a huge potential for the formation of graduates’ relevant competencies for the modern economy. This study shows the role of knowledge of physics for training doctors and biologists.

1.1. Evolution of Physical Knowledge Application in Medical and Biological Practice

Biologists, biotechnologists, bioengineers, doctors, veterinarians, etc. are trained at state classical and medical universities of the Caspian region. Having graduated, they face problems in their practical activities, many of which are solved with the help of physical knowledge. Let us consider the evolution of the physical knowledge application in the human and animal treatment practices.

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In the era of prehistoric medicine, when people’s ideas about the origin of diseases and treatment methods were very primitive, contribution to the creation of physical therapy methods, which are still used today, had already been made. That was when the first version of dry air cans, based on the use of atmospheric pressure force, was invented. The grounds of modern surgery appeared as a result of observation of people working with pets.

Once natural science empirical methods were approved, studies on the structure of human and animal organs based on anatomical dissection began. Some surgical techniques that became part of medicine of all the subsequent periods (for example, Caesarean section) appeared.

The next stage in the application of physical knowledge to solve medical problems was the appearance of knowledge about the influence of environmental factors to identify the causes of the diseases and treat them. That is how the first physical models of biological systems appeared. As early as in the 11th century, glass models of lens were made and the idea of vision correction using biconvex lenses was put forward in Egypt. In the 16th century, models of artificial limbs and joints were developed in France.

Then various physical instruments for examining the physiological state of the body started to be developed. The first one was the Galileo thermometer. At the beginning of the 17th century, a lot of original thermometers were invented in Europe.

Nowadays, the role of physical knowledge in solving medical problems has become particularly relevant. Diagnosis of any disease is based on physical models describing the processes in biological systems from the submolecular level to the organ system and the whole organism.

The development of physics has had an impact on the methods of examining the state of the body, it became possible to measure physical quantities using various physical methods and equipment, for example, evaluating the concentrations of various trace elements and substances in the body fluids, biopotential recording, auscultation. Physical methods of diagnosis and treatment, like diathermy, inductothermy, ultrahigh frequency treatment, X-ray, ultraviolet, infrared, gamma radiation, etc., are widely used in physiotherapy. Laser radiation is widely used in modern surgery.

2. CONTENT AND STRUCTURE OF MEDICAL AND BIOLOGICAL PHYSICS COURSE AT CASPIAN REGION UNIVERSITIES

Students of the training areas under study do a physics course during two semesters in the first study year.

In medical universities, a biological physics course is studied by first-year students for two semesters. A biophysics course is taught to the biology students during one semester [5]. Within the study in these courses, physical knowledge is included in all sections, allowing to understand the manifestation of various physical laws in living systems. The Mechanics section considers the issues of biomechanics – oscillatory and self-oscillatory processes in biological systems, mechanical properties of biological tissues, biomechanics of blood circulation. This knowledge is necessary for successful mastering of such subjects as Human Anatomy, Normal Physiology and Cytology. The Acoustics section examines physics of hearing and the relationship between the characteristics of auditory sensation and physical characteristics, and studies the physical basis of sound examination methods. In this course, special attention is paid to the study of physical processes at the cellular level. The physical aspect of considering the structure and models of biological membranes, modern methods of their studying, mechanisms of metabolic processes at the cellular level and biopotential formation allows students to further apply this knowledge when mastering courses in physiology and histology [4, 8, 9].

While studying electrodynamics, the physics of electrocardiography, rheography, the influence of currents and electromagnetic fields on body tissues and person’s own electromagnetic fields are considered along with physical issues. The Optics section studies the physics of vision, physical basis of microscopy and its special techniques, fiber optics and its wide application in diagnosis, as well as the physics of thermography. Studying the elements of quantum biophysics, students get acquainted

with the latest methods of laser therapy and radio spectroscopy [17]. Such topical issues as the ionizing radiation effect on human, usage of radionuclides and neutrons in medicine, usage of charged particle accelerators in therapy and dosimetry are also included in the course.

Therefore, the aim of physics as a subject is to form students' systemic knowledge of physical properties and processes and the ability to apply a physical approach to solving medical and biological issues. The following tasks should be solved in implementing the physics course in the educational process of biological, medical and veterinary majors: 1) learning the general physical laws, underlying the physiological processes in the body of human, animals and other biological objects; 2) identifying characteristics of physical factors and the mechanism of their effect on living organisms; 3) developing the students' ability to process information obtained with the help of medical appliances and determine changes in the physical properties of the objects in a specific condition [10, 11]. Solving the above-mentioned tasks allows students to form the following knowledge, skills and abilities:

- knowledge of basic laws of physics, physical phenomena and patterns underlying the processes occurring in the human body, physical aspects of physiological processes at the molecular, cellular, tissue and organ levels, physical principles of medical device functioning;
- skills of applying physical concepts and patterns to explain biomedical processes in the human body, using recorders, measuring physical and biophysical parameters;
- abilities of making calculations and presenting research results in graphical and tabular forms, of applying elementary physical methods of obtaining and analyzing medical data when solving standard professional tasks.

2.1. Established Training Areas for Studying Physics by Students of Medical and Biological Majors

Let us consider the established ways of solving the specified tasks. It should be noted most researchers and teachers emphasize the necessity of high-quality physical education for students of all training areas, since any graduated biologist, doctor or veterinarian should be able to work with both models of their professional world and real biological objects [16, 18].

The main training area in physics of the specialists under review is the integration of physical, biological and medical knowledge through the study of special academic subjects like Biophysics for biologists and veterinarians-to-be, Medical and Biological Physics, Medical Equipment for the main medical majors in medical universities [3].

Another area is related to the inclusion of additional professional topics and issues in the physics course. For example, Dynamics studies such issues as human body weight, weight distribution between the human body parts, the role of friction force in walking, in the work of joints, and in various sports. Molecular physics considers such additional issues as diffusion during respiration, lung processes, the effect of humidity on human, water vapor during anesthesia, blood pressure, systolic and diastolic blood pressure, etc. [17].

3. RESEARCH RESULTS

How effective are the results of these areas of work in teaching natural sciences? The authors carried out a student survey among biology and medical students who had previously completed a physics course. They were asked to complete two tasks: the first one was to identify physical phenomena, processes, and effects in specific situations; the second one proposed some challenges arising in the professional activities of biologists, doctors and veterinarians. The authors were interested in whether students used physical knowledge in the proposed situations and whether they could plan their actions. It required the development of tasks that the students had to perform in specific medical and biological situations. I.A. Krutova and N.V. Zhukova [6] described pedagogical requirements for the development of tasks for recognition and reproduction of specific practically significant situations requiring the use of physical knowledge. Let us give an example of the survey that includes two tasks developed in accordance with these requirements:

Task 1. Specify the physical knowledge that can explain the changes in the condition of a biological object in the following situations:

1. Mud poultice applications are used in balneological practice to improve metabolic processes;

2. Several tourists of a tourist group experience dizziness and tachycardia, when climbing to a height of 3500 meters;
3. Death can happen when a diver rapidly ascends from the deep water;
4. A skier has got plugged ears when he/she descends sharply from a high mountain;
5. When the cabin of an aircraft is depressurized, passengers develop otic barotrauma;
6. The tumor size in a patient with brain cancer changes under the CyberKnife effect up to its complete disappearance;
7. The heart rate of a passenger with a cardioaccelerator may be abnormal when passing through an electromagnetic frame at the airport;
8. Blooming of water is observed in artificial reservoirs and canals in the hot summer climate.

Task 2. Put your actions in the right order in the following situations and explain them:

1. A plot of land was chosen to build a kindergarten. It is necessary to make sure that the land does not contain chemical contaminants. Make a technological map of soil purification of the land plot chosen.
2. A botanical laboratory received a sample of a part of a tree from the urban vegetation. Carry out a biological examination of the condition of this sample.
3. Microscopy of a crop revealed various types of pathogenic bacteria. Develop an efficient method of sterilizing crops to kill pathogens.
4. Efficiency of biotechnological research of stem cell cultivation depends on nutrient medium. Make a composition of a nutrient medium solution for this study.
5. Permissibility of using water from the reservoir is determined by the total threshold limit value (TLV). Suggest a method for analyzing a water sample to determine the TLV.

The study results presented in Figure 1 clearly demonstrate that the majority of respondents could not cope with the task of the first type.

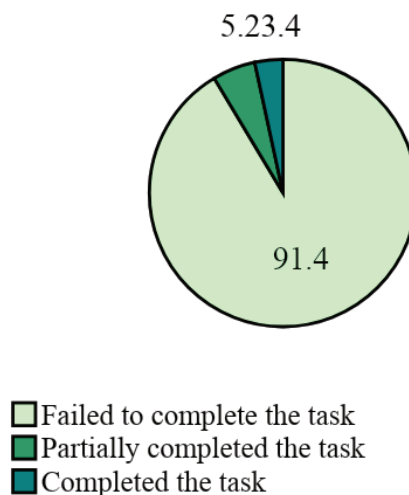


Figure 1. Results of the first stage of the ascertaining experiment, %.

The results of Task 2 show that students cannot plan their actions when solving professional practical tasks (Fig. 2). The conducted ascertaining experiment showed that the physical knowledge acquired by students is not used by them when analyzing specific situations. Students do not understand the importance of studying physics course for their future professional activities.

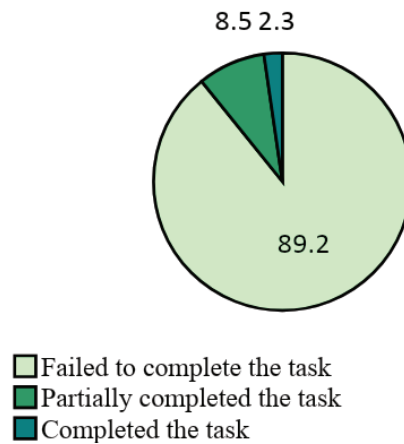


Figure 2. Results of the second stage of the ascertaining experiment, %.

4. DISCUSSION OF THE STUDY RESULTS

The question arises of how to make the physical knowledge and knowledge of natural sciences acquired by students the basis for the development of professional competencies of graduates, future biologists, doctors and veterinarians.

N.F. Talyzina established that the goals of training specialists of any profile should include their typical professional tasks and generalized methods of their solving [15]. Based on this idea, the authors identified the types of professional activities of future biologists and doctors. For this purpose, a large number of biologists and medical workers who deal with various biological objects both in natural and experimental conditions were interviewed. As a result, a fairly large list of such activities was obtained, for example: 1) identifying and classifying physical and chemical phenomena and processes occurring in a biological object; 2) modeling phenomena and processes occurring in biological objects exposed to external factors; 3) implementing physical, chemical and other effects on biological objects; 4) normalizing the properties of biological objects; 5) performing calculations of physical and chemical parameters of the condition of biological objects changing as a result of certain effects; 6) mathematical modeling of biological processes; 7) selecting basic physical and chemical laws to explain the properties of biological objects obtained as a result of certain effects; 8) statistical processing of results; 9) systematizing biological objects; 10) using modern equipment for experimental studies of the properties of biological objects; 11) storing and processing information about the properties of biological objects and processes occurring in them; 12) monitoring, protecting and restoring biological resources; 13) creating prototypes of biological and medical objects with specified properties, etc.

Analysis of the identified activities and their generalization by end product allowed to narrow them down to four types of tasks:

1. Creating prototypes of biological and medical objects with specified properties.
2. Identifying or assessing the values of physical, chemical and biological quantities describing the properties of a biological object in a certain condition.
3. Eliminating anomalies of the values of bio-object's condition parameters.
4. Operating modern medical and biological equipment.

In order to form the selected types of activities in biology bachelor students, it is necessary to supplement them with methods of task completion. G.P. Stefanova developed a mechanism for identifying generalized methods of solving typical tasks set to specialists [12, 14].

Eliminating anomalies of the values of bio-object's condition parameters is the most significant task for these specialists. The method of solving this problem consists of eight actions aimed at practical implementation of the conditions eliminating the phenomenon causing it [13].

Let us specify this method to solve a specific problem.

Task. In Southern Russia, when the ambient temperature rises in summer, the water on sturgeon farms heats up to $+32^{\circ}\text{C}$; as a result, sturgeons stop eating and can die. Suggest a way to ensure normal living conditions of the sturgeon population.

1. The biological object is the sturgeon population which must live in conditions corresponding to the normative.
2. Normative parameters of the water condition for keeping the sturgeons: water temperature - $+23^{\circ}\text{C}$, oxygen concentration in water - 8–10 mg/l, nitrogen concentration in water - up to 2 mg/l, permanent aeration of water.
3. Water condition parameters that differ from the normative ones: temperature - $+32^{\circ}\text{C}$, oxygen concentration in water - 14 mg/l, nitrogen concentration in water - up to 2.9 mg/l.
4. The reasons for these deviations are the following: in Southern Russia, the air temperature in summer reaches $+40^{\circ}\text{C}$ during the day and $+28^{\circ}\text{C}$ at night; a decrease in oxygen concentration and an increase in nitrogen concentration in water occurs due to an increase in water temperature.
5. The reason for the deviation from the norm of these parameters is high ambient temperature.
6. To avoid overheating of water in the pond, it is advisable to cover it with a shell with a reflective surface. It is also possible to increase the evaporation of water by ventilating the air above the pond. When water evaporates, energy will be released, which will lead to a decrease in water temperature. It is necessary to improve aeration for greater oxygen saturation of the water in the ponds.
7. Equipment: a light-tight shell to protect from sunlight and installation of pumps for aeration improvement.
8. To install an oxygen concentration sensor in the ponds; to develop a principal scheme of switching on the pumps depending on the sensor readings.

5. CONCLUSION

Therefore, changes in the educational process, which will be aimed at developing professional skills of future specialists, consist in the development and inclusion of competence-oriented tasks in the process of students' mastering of each subject of the curriculum of the corresponding training area. The development of such tasks is a new activity for university teachers, and it requires competencies in both subject and digital technologies [7]. To organize the systematic work of students aimed at mastering the methods for solving professional tasks, there is a need in special didactic tools, like drill books, training cards and electronic educational resources.

AUTHORS' CONTRIBUTIONS

G.P. Stefanova developed the idea and research methodology, identified the mechanism of the development of typical tasks and generalized methods of their solving, and wrote the article.

S.K. Kasimova specified the mechanism of the development of typical professional tasks of doctors and biologists, carried out the pedagogical experiment, and wrote the article.

E.I. Kondratenko developed a system of competence-oriented exercises and tasks, implemented them in the educational process of Astrakhan State University, and wrote the article.

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