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THE EFFECTIVENESS OF IMPLEMENTING "HEART-LUNG MACHINE SORIN C5" SOFTWARE PRODUCT IN THE EDUCATIONAL PROCESS OF MEDICAL UNIVERSITY

Abstract. The article is devoted to the research of the effectiveness of formation of students' experimental competencies in hydrodynamics and hemodynamics at a medical university using the software "Heart-lung machine SORIN C5" [1]. On the basis of analysis of psychological and pedagogical literature, the professional experimental competencies of medical students are singled out and the role of virtual laboratory works in the development of students' professional experimental competencies in higher medical education institutions is determined. The authors consider the use of information resources in the educational process on the example of the software product "Laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5", which is an integral part of the discipline "Medical and Biological Physics". The paper describes the main structural elements and implementation of respective scenarios in the virtual laboratory work on hydrodynamics and hemodynamics. The article presents statistical check of the effectiveness of formation of students' experimental competencies in hydrodynamics and hemodynamics based on the use of Student's t-test. The authors analyze the results of the conducted experiment and show that visualization, the use of web resources in physics and virtual laboratory work contribute to the formation of the logical and epistemological structure of the teaching material and the strengthening of the role of fundamental generalizations of concepts and theories. It is proved that the difference in the knowledge acquisition coefficients in the experimental and control groups is significant and depends not on random samples, but on the difference in the formation of the material structure and teaching methods in medical and biological physics. It has been established that the system of virtual laboratory works contributes to students' training in general scientific methods of action, forms the proper professional, technological and experimental competence.

Keywords: virtual laboratory work; experimental competencies; hemodynamics; hydrodynamics; software "Heart-lung machine SORIN C5"; medical university students.

1. INTRODUCTION

Statement of the problem. The modern level of scientific and technological progress requires that medical specialists update and transform acquired scientific knowledge and technologies into practical skills essential for operating medical devices, choosing proper methods of treatment, conducting medical research and mathematical modeling of biological processes in a living organism to preserve patients' health and ensure their longevity.

Therefore, the ability of graduates of higher medical education institutions to independently acquire knowledge, skills and abilities on the basis of computer technology is an important competence that needs to be developed throughout the period of education in a higher education institution.

At the time of transition to a new content of education conditioned by the scientific and technological progress, the role of the experiment in learning is growing significantly. The system of demonstration, frontal and home experiments, experimental tasks, frontal laboratory works and physical workshop promotes deeper and more comprehensive assimilation of the program material, helps students to understand the principles of measuring physical quantities, master the methods and techniques of measurements, and methods of error analysis [2], [3], [4].

Formation of students' experimental competencies is conditioned by propaedeutics of research activity, the development of abstract thinking through hypotheses and deduction, the degree of self-determination and self-improvement, ability to overcome difficulties and succeed in solving tasks, etc.

Analysis of recent research and publications. Formation of students' experimental competencies is directly related to the development of education research methods. This is evidenced by the papers written by the following scientists: A. Aleksiuk, H. Andrieiev, V. Davydov, I. Lerner, A. Matiushkin, P. Pidkasystyi, M. Skatkin, M. Yarmachenko, L. Vyhotskyi, L. Rubinshtein.

Based on the principles of a developing educational environment, the problem of the formation of competences in the study of physics was considered from different positions, and the following types of competencies were singled out: professional (M. Veras, K. Pottie, D. Cameron, G. Dahal, V. Welch, T. Ramsay, P. Tugwell, P. Atamanchuk); subject (L. Blahodarenko, O. Lunhol, O. Nikolaiev, V. Sharko); educational-cognitive (S. Velychko, M. Halatiuk, V. Sharko); experimental (V. Vovkotrub, M. Sadovyi, V. Sliusarenko); key (M. Holovko, O. Liashenko); research (Ye. Korshak); methodological (O. Liashenko); informational and technological (M. Martyniuk); professional (V. Menderetskyi, V. Sharko); ecological (V. Sharko); information and communication (M. Shut).

Formation of students' professional experimental competencies in the study of physics is an essential condition for the quality education of medical students.

The use of virtual laboratory work in medical physics in the educational process makes it possible to achieve a high level of development of professional competencies of future specialists, since it optimizes the training time for the implementation of practical tasks, allows carrying out those experiments for which there is no equipment or reagents, and may partially replace a hospital visit for study of the algorithm of surgical interventions or other medical manipulations.

Significance of the implementation of laboratory works and experimental studies in the course of biophysics in higher medical education institutions is noted in the works of

V. Dotsenko, V. Lazarovych, V. Pylypchenko, M. Blokhina, I. Essaulova, H. Mansurova, E. Shvets, O. Nebesniuk, Z. Nikonova, A. Nikonova, V. Rudnieva and others.

The use of computer simulations in the study of biophysics and the implementation of experimental research is proposed by R. Hryhorian and T. Aksenova (simulation of hemodynamics of hypertrophied heart), N. Stuchynska and O. Hrybkov (creation of virtual simulators for electrography: electrocardiograph, electroencephalograph, electromyograph), O. Dats and B. Palasiuk (virtual training simulators: "Apparatus for electroplating and healing electrophoresis", "Electroson", "Darsonval Crown Violet Ray generator") and others.

The development and implementation of computer simulations in the educational process in the study of biophysics contributes to qualitative training and forms the professional qualifications of a future medical specialist based on three components: professional competence, subject competences in natural sciences (primarily medical and biological physics), technological competence [5] (knowledge of the principles and algorithms of working with medical devices and working with computer software).

Given the importance of this topic, as well as the fact that it has not been sufficiently studied in scientific circles, we devoted our research to the creation of virtual laboratory works in biophysics with computer simulations of medical devices.

The basis of our research is the following hypothesis: the introduction of virtual laboratory works in the educational process of institutions of higher medical education provides the formation of students' professional experimental competencies. Interactive visualization gives an opportunity to optimize students' perception of information and improve the memory of the sequence of stages in practical implementation of an experiment that reproduces the actual process of preparing and conducting medical manipulations; stimulates the activation of internal potential resources of the individual and the development of mental cognitive processes.

The aim of the article is to investigate the effectiveness of forming students' experimental competencies in hemodynamics on the basis of laboratory works placed in the virtual educational environment "System of laboratory works in medical and biological physics".

2. RESEARCH METHODS

In this article we used the following methods of research: a) theoretical – analysis of psychological, pedagogical and methodological literature; synthesis, comparison and juxtaposition of different views on the problem of the formation of experimental competencies; b) empirical – observation, survey (questioning, testing); pedagogical diagnostics for determining the effectiveness of the influence of the informational educational environment on the level of students' experimental competencies in conducting virtual laboratory work; c) statistical – methods of mathematical calculations for the study of the effectiveness of the formation of students' experimental competencies in hemodynamics on the basis of laboratory work.

3. RESEARCH RESULTS

To form subject experimental competencies while studying medical and biological physics at the Donetsk National Medical University (DNMU), we use our original series of laboratory works located in the virtual educational environment "System of laboratory works in medical and biological physics".

Virtual laboratory work is an effective information and communication tool, which in the process of training students of a medical university is an effective means of achieving an educational goal [6]. In particular, as an electronic means of training in biophysics classes at the DNMU, the authors created the software product "Laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5". This work is done within the theme "Hydrodynamics and Hemodynamics" [1]. This software product is oriented to the research and exploration character of the competencies formation in physics.

As a result, the knowledge and skills on this topic are better assimilated by students by increasing the impact on their internal potential resources by means of attracting most of the sensory organs, in particular through the use of video visualizations of learning material (animations), sound effects and practical professional-oriented activities [7].

In the course of an experimental study the effectiveness of the methodology of teaching medical and biological physics on the basis of computer technologies was determined. The criteria of the effectiveness of the developed methodology were the levels of students' academic achievement in the discipline, their ability to solve physical problems and to carry out laboratory and practical work on the basis of the use of information resources developed and recommended by the authors.

One of our information resources is a software product created for the students' lab work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5".

The study and understanding of the basic structural elements of the device "Heart-lung machine SORIN C5" is one of the ways of forming the technological competence of future physicians.

Let us outline the main methodological and structural components created by the authors of the virtual laboratory work on medical physics.

Topic. Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5".

The aim. To form professional competencies of using the apparatus "Heart-lung machine SORIN C5" (HLM) in clinical practice, interpretation of terms and concepts of hydrodynamics and hemodynamics.

Instruments and materials. A virtual laboratory using software that includes: a virtual patient model, a heat exchanger, apparatus "Heart-lung machine SORIN C5" with interactive monitors, an oxygenator, centrifugal blood pump, etc. (Fig. 1).

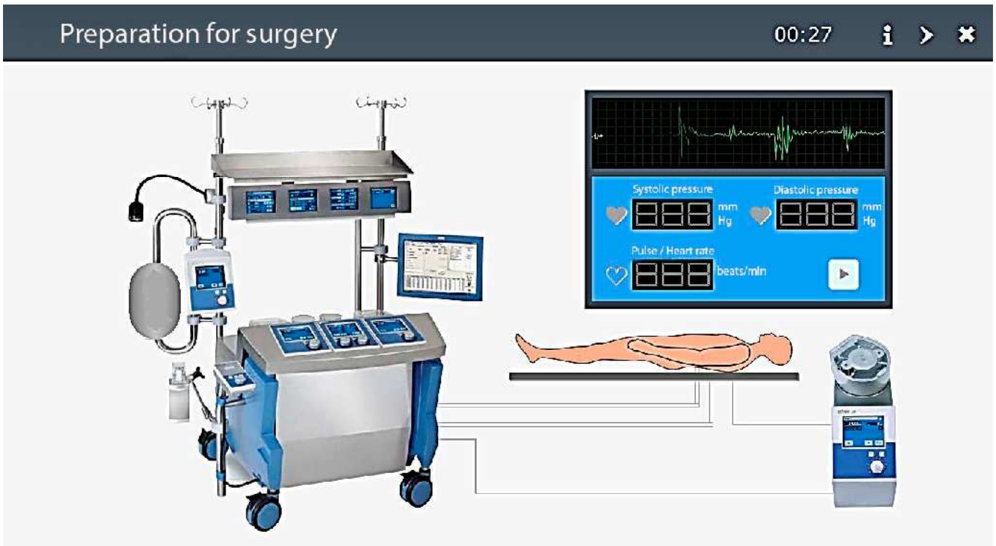

Fig. 1. Window of the virtual laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5"

Work instructions. Work with the software product "Laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5" begins with the launch of the file "Physics" in the folder "MedikLab".

After loading the software, the user is invited to review the list of laboratory works in biophysics and select one of them. When selecting laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5", the user can view the submenus, which contain the following items: "Theoretical Information", "HLM components", "Glossary of terms", "Web-Resources", "Laboratory work execution", "Start". Each of these items implements its virtual laboratory work scenario.

The item "Theoretical Information" implements a scenario of user's viewing of educational material on the topic "Physical bases of hydrodynamics and hemodynamics", the content of which reveals the main key issues of the content module "Biological physics" of the discipline "Medical and Biological Physics" [8], [9].

The "HLM components" item implements a script for studying the structure and operating principles of the apparatus "Heart-lung machine SORIN C5" [10].

"Glossary of terms" provides for the implementation of a scenario where the user can easily find the definitions of the basic terms and concepts of the topic "Physical bases of hydrodynamics and hemodynamics" of the content module "Biological physics" of the discipline "Medical and Biological Physics" [11], [12].

The "Web-Resources" item allows the user to switch to the script of viewing the recommended educational Web resources: video materials, textbooks and manuals, presentation material that is posted on the "Resource Center on Physics" site at the link: http://rcf-ptu.in.ua [13, p. 247].

The item "Laboratory work execution" reproduces the scenario of familiarizing students with instructions on the implementation of the created laboratory work, which specifies the purpose of laboratory work, devices and materials, input control questions, work procedure, literature used.

When selecting the "Start" item, the user enters the Virtual Laboratory Script, which involves training and simulation of actions with medical devices (with the "Heart-lung machine SORIN C5" apparatus) and measuring the patient's physical parameters before surgical intervention in the heart.

Below are the main points of the laboratory work.

1. Measure body weight m and patient's height h.

The weight of the patient's body m is automatically captured in the assigned cell of the program window (the program's result is limited in the range of 40-130 kg). Also, the height of the patient h is recorded (the result of the program is limited in the range of 140-210 cm).

2. Calculate the surface area of the body:

   1) Using the Dubois formula: $S = 0.107 \cdot \sqrt[3]{m^2}$ [m^2];
   2) By the Costeff formula: $S = \frac{4 \cdot m + 7}{m + 90}$ [m^2];
   3) Using the DuBois formula (in medical calculations): $S = 0.16 \cdot \sqrt{m \cdot h}$ [m^2].

3. Use the perfusion index k for adults 2.5 $\frac{\mathrm{l}}{\mathrm{min} \cdot \mathrm{m}^2}$ or for children 3 $\frac{\mathrm{l}}{\mathrm{min} \cdot \mathrm{m}^2}$ when calculating the volume velocity of perfusion (the value of the blood flow): $Q = S \cdot k$ [$\frac{\mathrm{l}}{\mathrm{min}}$].

4. Calculated values are put in cells of "Monitor 1. "Calculation of patient's body characteristics" (fig. 2).

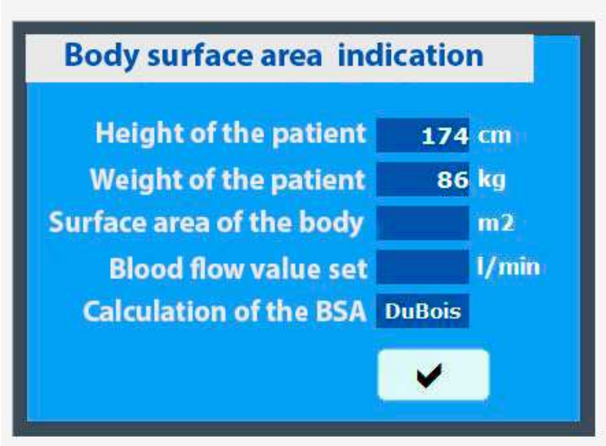

Fig. 2. Window of "Monitor 1. "Calculation of patient's body characteristics"

5. Measure the patient’s temperature with a temperature sensor, which is inserted into the mouth. Analyze the obtained value (the patient’ temperature *t* is automatically recorded (the program result is limited in the range of 35.5-38.5 ^{0}C). If the temperature values exceed the permitted limits for the operation (the program result is limited in the range of 36.2-36.9 ^{0}C) the program blocks the move to the next step. The measured value is placed in the "Temperature 1" cell of the "Monitor 2. "Patient" (fig. 3).

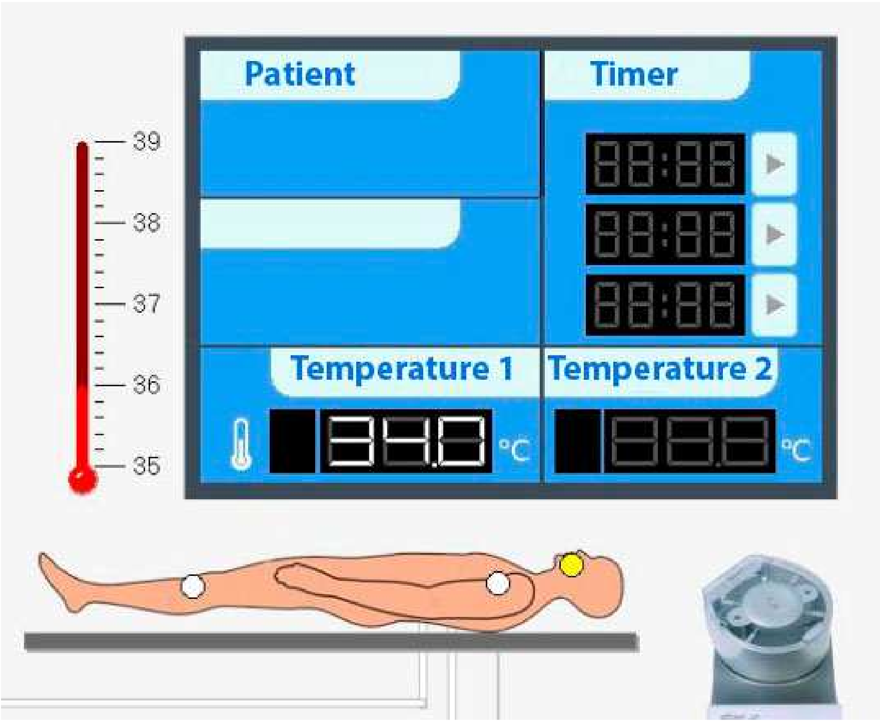

Fig. 3. Window of "Monitor 2. "Patient"

6. Connect the operating table with the heat exchanger. Install in the "Operating table" cell of "Monitor "Heat exchanger" temperature t_1 (the program result is limited in the range of 34.0-37.5 ^{0}C) in the range 35-36 ^{0}C for cooling the operating table (fig. 4).

Fig. 4. Window of "Monitor "Heat exchanger"

7. Install an invasive sensor for pressure control. Expose the correct values of systolic, diastolic, pulse / heart rate in the "Monitor "Pressure measurement" cells. Analyze the obtained values (fig. 5).

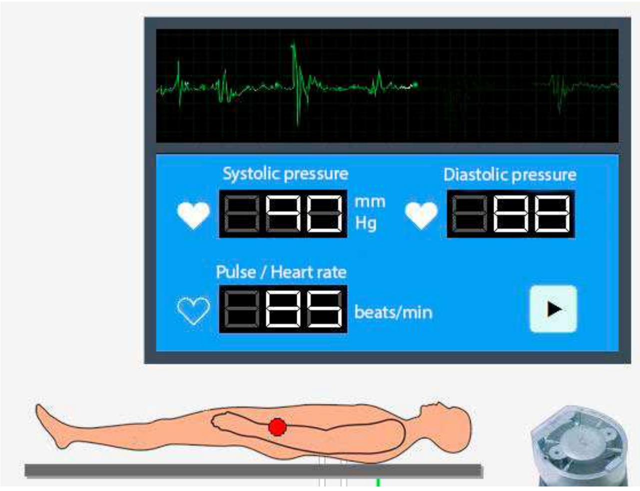

Fig. 5. Window of "Monitor "Pressure measurement"

In the cells "Systolic pressure", "Diastolic pressure", "Pulse / heart rate", the program generates the corresponding values (the program value is limited in intervals: systolic pressure 70-200 mmHg; diastolic pressure 50-100 mmHg; pulse / heart rate 50-95 beats / min).

If the values obtained exceed the permitted limits (the program values are limited in intervals: systolic pressure of 100-150 mmHg; diastolic pressure 60-80 mmHg; pulse / heart rate 60-80 beats / min) for the operation, the program blocks the move to the next step.

8. Connect the HLM with the heat exchanger. Insert in the "Oxygenator" cell of the "Monitor "Heat exchanger" the temperature t_2 (the program result is limited in the range 34.5-37.5 ^{0}C) in the range 35-36 ^{0}C for cooling the blood in the oxygenator (fig. 6).

Fig. 6. Window of "Monitor "Heat exchanger"

9. Attach a venous catheter for taking venous blood into the extracorporeal circuit of HLM.

10. Artificial blood circulation starts with the inclusion of the pump "Monitor "Pump" on the small productivity of 20-50% (rotating the wheel of the perfusion volume velocity). Synchronously increasing the productivity of the pump to 100%, within 1-2 minutes, increase the volume perfusion rate to the calculated. From the patient's body, venous blood enters the oxygen generator, where it is enriched with oxygen and cleansed of carbon dioxide, and then with the help of an arterial pump it returns to the bloodstream (fig. 7).

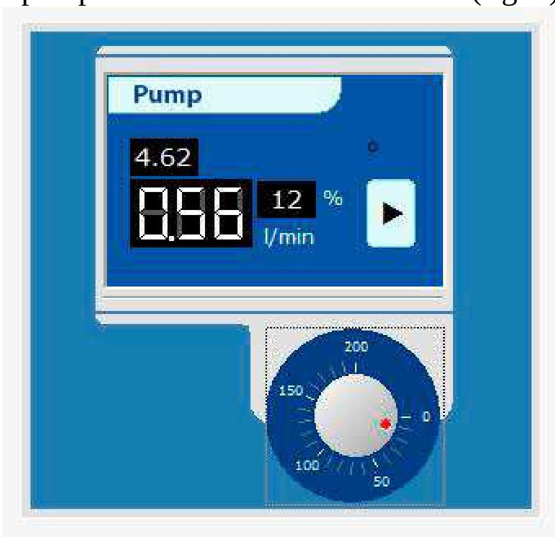

Fig. 7. Window of "Monitor "Pump"

11. Set the time of perfusion on "Monitor 2".

12. Analyze the results of the work done and draw conclusions.

Application of the created software product "Laboratory work "Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5" is an element of a new generation of educational information technologies, which made it possible to improve the quality of education, create new means of interaction with students and more effective teacher-student collaboration [14].

Application of the created software product “Laboratory work”. Studying the basics of hemodynamics using the SORIN C5 Heart-Lung Apparatus is an element of a new generation of educational information technologies that have improved the quality of instruction, created new means of interaction with students and more effective teacher-student collaboration [14].

Execution of laboratory work, in particular on hydrodynamics and hemodynamics, implies that students have a certain set of skills that ensure the achievement of the desired result.

In each case, this set of abilities depends on the content of the experiment and the set goal, as determined by the specific actions of students during the laboratory work. However, they are a reproduction of a generalized experimental skill, which is formed by the whole system of educational physical experiment.

Estimation of the level of students' potential resources [7] realization during the implementation of virtual laboratory works and experimental tasks was carried out through the specific levels and indicators:

a) knowledge of the observation algorithms;

b) the ability to plan the stages of the research;

c) conducting research;

d) registration of research results;

e) processing of the experiment data;

g) justification of the conclusions of the experiment.

Student's t-test was used for statistical verification of effectiveness of formation of the students' experimental competencies in hydrodynamics and hemodynamics.

The sample size was calculated by law of large numbers [7]:

$$n = \frac{t^2 pq}{\varepsilon^2}, \quad (1)$$

where n – number of students whose level of knowledge is to be established (sample size); t – argument of the function F(t), whose value is equal to the predetermined probability P (Student's coefficient); p – probability of the event occurrence; q = 1-p – the probability of the opposite event; ε – the error of the results obtained.

The effectiveness of the methodology was studied on the basis of comparison of educational achievements with two independent samples of students of experimental and control groups of a sufficiently large sample size.

The value of the average indicator of knowledge assimilation separately for control and experimental groups corresponds to the conditions of use – the Student's t-test. The processing of the data was carried out according to the method proposed by P. N. Volovyk [15] and Yu. V. Pavlov [16].

The coefficient of assimilation of knowledge elements (K) is determined by the ratio of the number of reproduced knowledge elements to the maximum possible number of elements and is calculated from the ratio:

$$K = \frac{N}{N_0}, \quad (2)$$

where N is the number of correct answers, is determined by the product of the number of correct answers and the number of students (n) who participated in the experiment; N_0 – the maximum possible number of answers to a question determined by the product of the number of knowledge elements and the number of students (n) who participated in the experiment.

During the analysis of the section content "Hydrodynamics and hemodynamics" we identified 39 physical concepts, phenomena, processes (Fig. 8).

The results of the conducted experiment showed that visualization, the use of web resources in physics and virtual laboratory work contribute to the formation of the logical and epistemological structure of the teaching material and the strengthening of the role of fundamental generalizations of concepts and theories. Fig. 8 summarizes the pedagogical experiment data on the implementation of virtual laboratory work on the topic

«Hydrodynamics and Hemodynamics» in the Donetsk National Medical University, which in general confirms the effectiveness of the developed methodology.

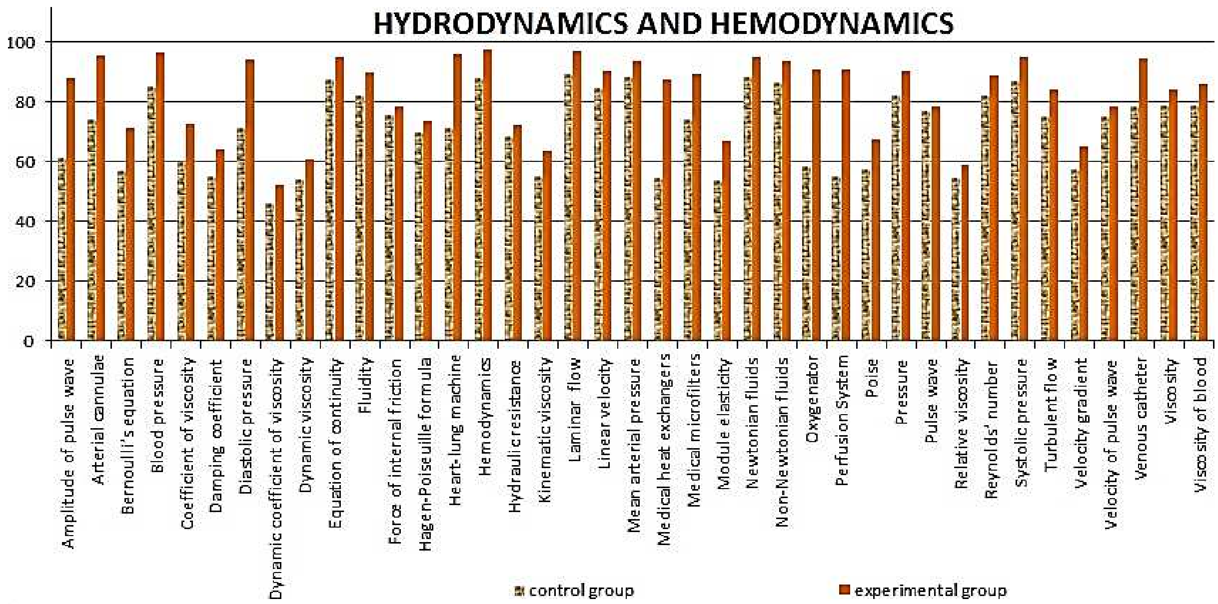

Fig. 8. Selective histogram of students' knowledge in medical and biological physics in the experiment

For control and experimental groups: the sum of elements is calculated as the product of the students number (n) and the total number of responses.

Total number of knowledge elements – 39.

The total number of knowledge elements for the control and experimental groups is respectively: $264 \cdot 39 = 10296$; $224 \cdot 39 = 8736$ (Table 1).

Table 1

Generalized results of pedagogical experiment

Groups	Number of students, *n*	Total number of elements, N_0	Elements restored, *N*	$K = \frac{N}{N_0} \cdot 100\,\%$
Control	264	10296	6451	62,66
Experimental	224	8736	6978	79,88

Difference in the coefficients of knowledge acquisition in experimental and control groups $d = K_E - K_C = 0{,}1722$.

During the pedagogical experiment, we calculated the average sample error in the experimental study.

The mathematical effectiveness of the teaching material structure and the methods of its study was verified due to the reliability of the obtained difference in the coefficients of knowledge elements assimilation.

$$P_C = \sqrt{\frac{K_C \cdot (1 - K_C)}{n_C}}, \quad p_C = 2{,}98 \cdot 10^{-2}, \tag{3}$$

$$P_E = \sqrt{\frac{K_E \cdot (1 - K_E)}{n_E}}, \quad p_E = 2{,}68 \cdot 10^{-2}, \tag{4}$$

where P_E and P_C; K_E and K_C; n_E and n_C – respectively, the average errors of correct answers; coefficients of knowledge assimilation; number of students in experimental and control classes.

The average probability of correct answers to questions is calculated by the average error of their difference:

$$P_\alpha = \sqrt{P^2{}_E + P^2{}_C}, \qquad P_\alpha = 4{,}005 \cdot 10^{-2}, \tag{5}$$

Thus, the error of the average probability of correct answers does not exceed 4.4%. Estimation of probability of obtained difference reliability is carried out with the help of normal deviation:

$$t_\alpha = \frac{K_E - K_C}{P_\alpha} = \frac{d}{P_\alpha}, \qquad t_\alpha = 4{,}30. \tag{6}$$

Since t >> 1.96, the difference in the coefficients of knowledge assimilation in the experimental and control groups is significant and depends not on random samples, but on the difference in the organization of the structure and methods of teaching medical and biological physics in the DNMU.

4. CONCLUSIONS AND PROSPECTS OF FURTHER STUDIES

The use of information resources in the educational process on the example of the software product "Laboratory work «Study of the hemodynamics fundamentals using the apparatus "Heart-lung machine SORIN C5" contributes to a more complete realization of students' potential resources: the development of interest, creativity and motivation of students to learn the discipline "Medical and biological physics". A system of virtual laboratory work can be used in the process of building students' new knowledge of basic physical principles and approaches to the study of processes in living nature, the physical and technological principles of the functioning of medical devices, the use of mathematical methods in biomedical research. All this forms the basis of subject competencies in medical and biological physics and is an integral part of the experimental competence of a future specialist in the field of health care. The resulting knowledge and skills form the basis for the study of professionally oriented natural sciences and clinical disciplines.

The pedagogical experiment conducted at the medical university confirmed the effectiveness of the proposed methodology for teaching biophysics using the system of virtual laboratory work. There was an improvement in the quantitative indicators of the students' content knowledge of axioms, principles, statistical approaches, hypotheses, postulates, phenomenological generalizations of biophysics.

The system of virtual laboratory work contributes to the students' knowledge and skills by general scientific methods of action, forms the proper professional and experimental competence.

We see the prospects for further research in the creation and implementation of a system of virtual laboratory work in the educational process of medical institutions of higher education on the topics: "Study of the dispersion of the biological tissue impedance", "Study of biological membranes using the Goldman-Hodgkin formula".

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ЕФЕКТИВНІСТЬ ВПРОВАДЖЕННЯ ПРОГРАМНОГО ПРОДУКТУ «ШТУЧНИЙ КРОВООБІГ SORIN C5» В ОСВІТНІЙ ПРОЦЕС МЕДИЧНОГО УНІВЕРСИТЕТУ

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Анотація. Стаття присвячена дослідженню ефективності формування експериментальних компетентностей з гідродинаміки та гемодинаміки у студентів медичного університету в процесі використання програмного продукту «Штучний кровообіг SORIN C5» [1]. На основі аналізу психолого-педагогічної літератури та власного педагогічного досвіду виокремлено професійні експериментальні компетентності студентів-медиків та визначено роль упровадження віртуальних лабораторних робіт для розвитку професійних експериментальних компетентностей студентів закладів вищої медичної освіти. Авторами розглянуто застосування інформаційних ресурсів в освітньому процесі на прикладі програмного продукту «Лабораторна робота «Вивчення основ гемодинаміки за допомогою апарату «Штучний кровообіг SORIN C5», яка є складовою частиною дисципліни «Медична та біологічна фізика». У роботі описано основні структурні елементи та реалізацію відповідних їм сценаріїв у віртуальній лабораторній роботі з гідродинаміки та гемодинаміки. У статті наводиться статистична перевірка ефективності формування експериментальних компетентностей у студентів з гідродинаміки та гемодинаміки на основі використання критерію Стьюдента. Авторами аналізуються результати проведеного експерименту та показано, що забезпечення наочності, використання вебресурсів з фізики та віртуальних лабораторних робіт сприяють формуванню логіко-гносеологічної структури навчального матеріалу і посиленню ролі фундаментальних узагальнюючих понять та теорій. Доведено, що різниця коефіцієнтів засвоєння знань в експериментальних і контрольних групах є суттєвою і залежить не від випадкових вибірок, а від різниці в організації структури й методики навчання медичної й біологічної фізики. Встановлено, що система віртуальних лабораторних робіт сприяє оволодінню студентами загальнонауковими способами дій, формує належну професійну, технічну та експериментальну компетентність.

Ключові слова: віртуальна лабораторна робота; експериментальні компетентності; гемодинаміка; гідродинаміка; апарат «Штучний кровообіг SORIN C5»; студенти медичного університету.

ЭФФЕКТИВНОСТЬ ВНЕДРЕНИЯ ПРОГРАММНОГО ПРОДУКТА «ИСКУССТВЕННОЕ КРОВООБРАЩЕНИЕ SORIN C5» В ОБРАЗОВАТЕЛЬНЫЙ ПРОЦЕСС МЕДИЦИНСКОГО УНИВЕРСИТЕТА

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Аннотация. Статья посвящена исследованию эффективности формирования экспериментальных компетентностей по гидродинамике и гемодинамике у студентов медицинского университета в процессе использования программного продукта «Искусственное кровообращение SORIN C5» [1]. На основе анализа психолого-педагогической литературы и собственного педагогического опыта выделены профессиональные экспериментальные компетентности студентов-медиков и определена роль внедрения виртуальных лабораторных работ для развития профессиональных экспериментальных компетенций студентов учреждений высшего медицинского образования. Авторами рассмотрено применение информационных ресурсов в образовательном процессе на примере программного продукта «Лабораторная работа «Изучение основ гемодинамики с помощью аппарата «Искусственное кровообращение SORIN C5», которая является составной частью дисциплины «Медицинская и биологическая физика». В работе описаны основные структурные элементы и реализация соответствующих им сценариев в виртуальной лабораторной работе по гидродинамике и гемодинамики. В статье приводится статистическая проверка эффективности формирования экспериментальных компетенций у студентов по гидродинамике и гемодинамике на основе использования критерия Стьюдента. Авторами анализируются результаты проведенного эксперимента и показано, что обеспечение наглядности, использование веб-ресурсов по физике и виртуальных лабораторных работ способствуют формированию логико-гносеологической структуры учебного материала и усилению роли фундаментальных обобщающих понятий и теорий. Доказано, что разница коэффициентов усвоения знаний в экспериментальных и контрольных группах является существенной и зависит не от случайных выборок, а от разницы в организации структуры и методики обучения медицинской и биологической физики. Установлено, что система виртуальных лабораторных работ способствует овладению студентами общенаучными способами действий, формирует соответствующую профессиональную, техническую и экспериментальную компетентность.

Ключевые слова: виртуальная лабораторная работа; экспериментальные компетентности; гемодинамика; гидродинамика; аппарат «Искусственное кровообращение SORIN C5»; студенты медицинского университета.