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To the Development of a System for the Integration of Disciplines - Combinatorial Analysis, Graph Theory, Mathematical Modeling in the Formation of Competencies of the Bachelor of "Biomedical Engineering"

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Abstract

Background. For students to successfully master the necessary knowledge, skills and professional competencies, and their implementation in future practical activities, a flexible system of effective training (study) of the relevant training modules is needed based on the development of their special integrated computer knowledge base and database, using ideas and methods of discrete mathematics and artificial intelligence.

Methods. Structural and functional schemes are proposed: development of a system for integrating elements of disciplines - combinatorial analysis, graph theory, mathematical modeling in the implementation of problems and tasks of the components of the field of professional activity, objects of professional activity, types of professional activity of the bachelor of "Biomedical Engineering"; compiling a knowledge base and a database of a system for integrating these disciplines in designing and solving problems of biomedical engineering, medical and biological sciences for healthcare.

Results. In the areas of biomedical engineering research, examples of already implemented integrations with the disciplines of combinatorial analysis, graph theory, mathematical modeling (from literary and Internet sources and our own developments) are compiled. For diagnostics, monitoring, treatment methods, examples of their already implemented integrations with the disciplines of combinatorial analysis, graph theory, mathematical modeling (from literary and Internet sources and own developments) are also compiled. As a result, a database of integration systems is compiled, on the basis of which students will be able to get an idea about existing integration systems.

Conclusion. Note that all of the above will form the basis: firstly, the creation of a general system model for solving a number of scientific research or practical problems; secondly, to optimize the decision-making process; thirdly, to evaluate the quality of such a solution, and so on. Based on all of the above, it is planned to create a special system for integrating disciplines - combinatorial analysis, graph theory, mathematical modeling in the formation of competencies of the bachelor of "Biomedical Engineering".

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INTRODUCTION

Biomedical engineering is a field of science and technology that studies and develops the application of engineering principles and concepts to medicine and biology.

The research areas of biomedical engineering in general are: neuro engineering; pharmaceutical technology; technology of tissue and organ transplantation; Genetic Engineering; medical equipment; medical imaging; implants; bionics and others.

Medical engineering combines the design and problem-solving skills of engineering and the medical and biological sciences to improve health care, including diagnosis, monitoring, and therapies based on fundamental principles of molecular and cellular biology.

From the above, it follows that the areas, objects and types of professional activities of bachelors - "Biomedical Engineering", can cover almost all aspects of human life. For successful learning (mastering) of the necessary knowledge, skills and competencies, and their implementation in practice, a flexible system of effective learning (study) of the relevant training modules is needed based on the development of their special computer knowledge base and database, using ideas and methods of mathematical modeling and artificial intelligence [4].

Given all of the above, it is of great interest to create computer-based educational and methodological support for teaching general professional modules in the training of specialists in biomedical engineering. We took the following disciplines as such modules: combinatorial analysis, graph theory and mathematical modeling. It should be noted that all elements of these disciplines are optimized. In addition, the use of the apparatus of these disciplines, both individually and in one or another combination of them, entirely depends on the essence, meaning, nature, features of the biomedical-technical task (problem) under consideration (investigated).

METHODS

Here is a brief description of the disciplines: combinatorial analysis, graph theory and mathematical modeling.

Combinatorial analysis, combinatorial mathematics, combinatorics, a branch of mathematics that studies issues related to the placement and mutual arrangement of parts of a finite set of objects of an arbitrary nature (as well as infinite sets that satisfy some finiteness conditions) [10,16].

Ideas of a combinatorial nature are most widely used in mathematics, in such sections as probability theory, number theory, algebra, etc. The problems of combinatorial analysis have been known since ancient times. Many mathematicians have made a great contribution to the development of combinatorial analysis. However, combinatorial analysis began to take shape as an independent scientific discipline only in the 20th century.

Combinatorial analysis is closely related to graph theory, the theory of finite automata, and other branches of mathematics. Its results are used in the planning and analysis of scientific experiments, message coding, linear and dynamic programming, mathematical economics, and many other areas of science and technology.

There are three types of combinatorial analysis problems [18-20].

Listing tasks. In problems of this type, one is interested in the number of possible placements, satisfying various conditions, of a finite set of objects. One of the typical examples of this kind of problem is the problem of placing some n particles in N cells; both particles and cells can be distinguishable and indistinguishable, and this leads to different answers to the problem. Powerful methods have been developed to solve a variety of enumerative problems encountered in practice. Among them, the main ones are the method of generating functions and the Polya enumeration method [18].

Problems about existence and construction. In problems of this kind, one is interested in whether there is a configuration of parts of a finite set that has some given properties, and if so, how to construct it. For example, is there such a system of subsets (blocks) of a given finite set that any two different elements of the set meet together in these blocks a given number of times. Such systems are called block diagrams. They and similar configurations are intensively studied in combinatorial analysis. In this case, number-theoretic and algebraic methods play an important role.

Choice tasks. In problems of this type, conditions are studied under which it is possible to make such a choice of a subset or a certain set of parts of a set in order to satisfy certain requirements that are most often of an optimal nature. For example, suppose a set is given and there is some system of subsets; under what conditions is it possible to choose one element in each subset so that all these elements are pairwise distinct? This is the problem of a system of distinct representatives for a system of subsets. When solving problems of choice, along with purely combinatorial considerations, the algebraic apparatus is also essentially used.

Recently, graph theory has become a hot topic of science. It allows solving many practical problems of economics, technology, biology and ecology. As is known, graph theory is a mathematical model of any system containing binary relations [19,20].

Mathematical modeling [2,3] is the process of creating and using a mathematical model to obtain information about a real object. The model is necessary: 1) to understand how this or that object is located, its structure, main characteristics, laws of development and interaction with the surrounding world; 2) learn to manage an object or process and determine the best management methods for given goals and criteria; 3) predict direct and indirect consequences of the specified methods and forms of impact on the object. A mathematical model is a set of mathematical objects — numbers, symbols, sets, etc., and relations between them — reflecting the most important properties of the modeled object for the researcher. Mathematical models are called structural if they reflect the processes occurring during the operation of the object, if they reflect the functional or topological or geometric properties of the object. Topological mathematical models show the composition and interconnection of the elements of an object. Geometric mathematical models show the geometric properties of objects: in addition to information about the relationship of elements, there is information about their shape.

Now let us sequentially present the constituent elements of combinatorial analysis, graph theory, mathematical modeling and the competencies of the bachelor of biomedical engineering.

Now let's present the components of the field of professional activity, objects of professional activity, types of professional activity of the bachelor of "Biomedical Engineering".

combinatorial analysis

The subject and meaning of mathematical logic

Elements of mathematical logic

Sets and actions on them

combinatorial analysis

The role of combinatorial analysis in the discrete space of elementary phenomena of probability theory

graph theory

Graph theory. Basic concepts and types.

Counts. Their types and algorithms of actions on them

Graphs as a data structure

Types of vertices and edges of graphs. Routes, schemes, cycles in graphs

Decision tree method and other graph-based methods

Incidence and adjacency in graphs, adjacency matrices, incidence matrices, incidence lists.

Areas of practical application of graphs

Math modeling

Three-stage scheme of the process of mathematical modeling

1. Translation of the proposed problem from natural language into the language of mathematical terms, i.e. create a mathematical model of the problem (formalization)

2. Solution of the problem within the framework of mathematical theory

3. Translation of the obtained result (mathematical solution) into the language of the original problem (interpretation of the obtained solution)

Competences of the Bachelor of Biomedical Engineering

Modern trends in the development of medical devices; mechanisms, methods and tools for designing, developing and using medical and technical means, biological and technical devices and systems, including devices and systems for replacing lost organs and functions of the human body; methods and means of managing technological processes in the development, production and use of biotechnical means for the prevention, diagnosis and treatment of the needs of patients.

Area of professional activity of bachelors [23]:

- to design biomedical technical systems, devices for various purposes, complexes together with computer technology tools;

- design and implement production technology and operation of bio-medical technical elements, devices and systems for various purposes;

- conduct scientific and practical research, development, adjustment and testing, as well as organize the operation and maintenance of biomedical technical devices and systems for various purposes.

The field of professional activity of bachelors includes [23]:

--carrying out work on the use of equipment based on physical and physico-chemical methods in the study of the characteristics of biological objects for biological research and diagnosis, treatment, restoration of processes and prevention of human diseases;

– receives and processes biomedical data, creates and uses a medical database, an expert system and a monitoring system, provides a database of diagnostic and treatment processes, uses a package of modern applications;

– study special literature in the field of medical equipment and methods for studying biological objects, scientific and technical information, achievements in the field of science, engineering and technology abroad and in our country;

– carries out adjustment and maintenance of professional and household biomedical devices;

– carrying out verification using standard samples after adjusting biomedical equipment and facilities;

– use of computer technologies and programs;

- organization of the work of the team of performers;

– organizing the development and implementation of technologies for the creation of biomedical equipment;

– development of guidelines on methods, conditions and procedures for the use of biomedical methods, as well as other regulatory and technical documents.

Objects of professional activity of bachelors [23].

The objects of professional activity of the bachelor in the direction of "Biomedical Engineering" are devices, systems, complexes, and medical equipment and technology, as well as methods for studying therapeutic effects, analysis and processing of medical information in practical healthcare. The types of professional activities of bachelors are [23]:

– scientific and experimental research;

- design and construction;

- repair and service; – organizational and managerial;

- production and technological.

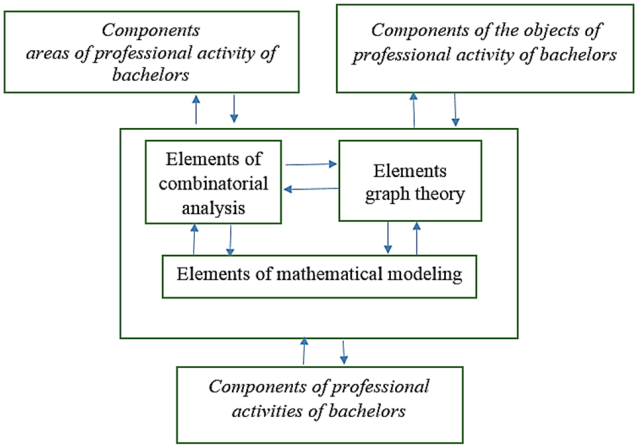
RESULTS

Taking into account the above, the structural and functional scheme for developing a system for integrating elements of disciplines - combinatorial analysis, graph theory, mathematical modeling in the implementation of problems and tasks of the components of the field of professional activity, objects of professional activity, types of professional activity of the bachelor of "Biomedical Engineering" has the following form (See Scheme 1).

Taking into account all of the above, for the successful formation of students' skills in designing and solving problems of engineering and medical and biological sciences in health care, we propose the following structural and functional scheme for compiling a knowledge base and a database of a system for integrating disciplines of combinatorial analysis, theory graphs, mathematical modeling in design and problem solving in engineering and medical and bio-

logical sciences (see Scheme 2).

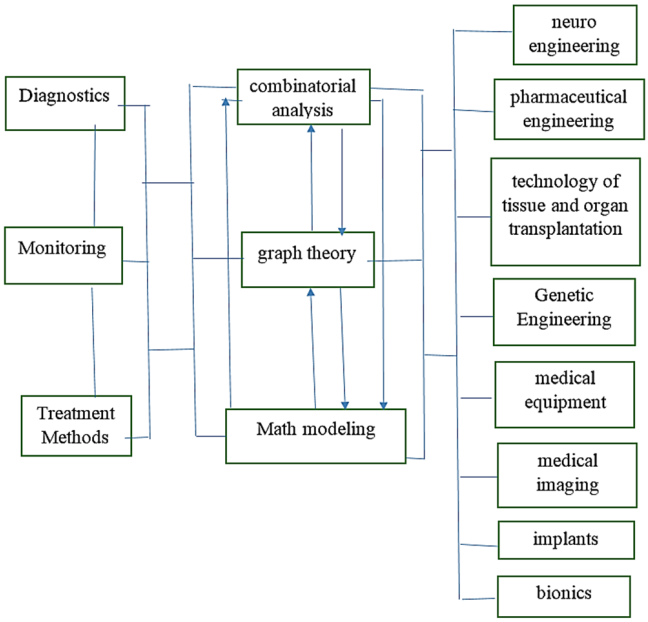
Scheme 1.



Scheme 2.

Structural-functional diagram of compiling a knowledge base and a database of a system for integrating the disciplines of combinatorial analysis, graph theory, mathematical modeling in the design and solving problems of engineering and medical and biological sciences

Areas of Biomedical Engineering Research



For each block of the research area of this scheme 2, examples of already implemented integrations with the disciplines of combinatorial analysis, graph theory, mathematical modeling (from literary and Internet sources and own developments) are compiled. For the blocks of diagnostics, monitoring, treatment methods, examples of already implemented integrations with the disciplines of combinatorial analysis, graph theory, mathematical modeling (from literary and Internet sources and our own developments) are also compiled. As a result, a base of integration systems will be compiled, on the basis of which students will be able to get an idea about existing integration systems.

When considering one or another biomedical-technical problem, at first an appropriate integration system will be determined from the existing database of integration systems. In the absence of a suitable integration system for the considered biomedical-technical problem, on the basis of a research project, together with the relevant specialists, an appropriate new integration system will be compiled.

DISCUSSION

Examples of the use of elements of combinatorial analysis, graph theory, mathematical modeling in the formation of professional competencies of a bachelor of biomedical engineering can be works [2-5, 8,10,16] and many others.

In [22], the problem of obtaining all possible outcomes of the corresponding combinatorial schemes in explicit form is studied. To obtain such qualitative information about the outcomes of schemes and convert it into quantitative information, an enumerative method for analyzing combinatorial schemes in the pre-asymptotic range of their parameters is proposed, based on: - building their probabilistic mathematical model; - representation for each scheme is an iterative random process of sequential non-repetitive formation of all its outcomes; - a certain order of their numbering; - a single addition of certain elements of the scheme to the value given in it. Due to the importance for a number of studies of the scheme of non-repeating enumeration of its outcomes, if it does not lie in its nature, it can be achieved by introducing some restrictions into the scheme that do not lead to a change in their set, do not change their probabilities, and must be taken into account.

The design of the process under the appropriate conditions of each scheme is visually depicted by a graph with the probabilities of iterative transitions specified in it, which determine the final distribution on the set of its outcomes. On this basis, the following tasks are solved: - determining the number of outcomes of the scheme; - establishing a one-to-one correspondence between numbers and types of its outcomes, called the numbering problem in direct and inverse formulations; - finding the probabilistic distribution of all its final outcomes, which makes it possible to model them with the found distribution of playing the number of the outcome and then determine its modeled form based on the result of solving the direct numbering problem. If there is no explicit formula for the number of outcomes of the scheme, under certain conditions, based on the results of their modeling, its estimate can be obtained with subsequent refinement by the numbering problem.

The study of models of combinatorial schemes on random processes with the introduction of probabilistic parameters expands the possibilities of their use in biomedical engineering. The results of circuit analysis can range from numerical methods and algorithms to analytical ones in the form of recurrence relations and explicit formulas.

In [14], it is noted that the formation of the ability to build mathematical models and work with them is one of the main goals of mathematical education at a university. This is also relevant for future specialists in biomedical engineering, for whom it is important to be able to formulate the problems of their

"own" field of knowledge and/or practice in mathematical terms, as well as interpret the results obtained.

Learning aids are objects selected by the teacher for better understanding and solving the task. Graphs can be an excellent (mathematical) model for solving biomedical engineering problems that reveal data and conditions that are invisible at first glance. As is known, graph theory is a mathematical model for any system containing binary relations.

A graph is a collection of many vertices and many edges. When constructing a model, it is convenient to take any objects as vertices, and relations between these objects as edges. Depending on the type of relation, we obtain undirected graphs or directed graphs. If we are talking about a symmetric relation, it is natural to use undirected graphs, in the case of an antisymmetric relation, directed graphs. In some cases, additional structures appear on the graph, for example, when solving discrete optimization problems, so-called loaded graphs can serve as models, in which a certain number ("length" or weight) is associated with each edge. When solving logical problems, graphs with colored edges or graphs with colored vertices, etc., can be used.

The method of mathematical modeling is widely used in all areas of human activity, including in education. Acquaintance of students with the elements of mathematical modeling contributes to the formation of not only a scientific worldview, but also makes their learning activities more meaningful and productive.

Modeling, as one of the universal educational and research activities, goes beyond the scope of mathematics, but it is precisely when creating mathematical models that its components manifest themselves most clearly [15]. It is clear that for the formation of this action, like any other, it is not enough to study its ready-made samples - it is also necessary to have one's own activity for the "production" of mathematical models from various task situations, for the translation of real life constructions into the language of mathematics.

An analysis of scientific sources shows a significant amount of various developments devoted to the use of mathematical modeling in engineering research. Such works include developments [1,6,7,9,11,12,13,21] and others. All of them are important for their study when teaching students - future engineers. Foreign scientists such as G. Kaiser, S. Brand [24], P. Frejd, C. Bergsten [25] and others also come to the conclusion that it is necessary to teach methods of mathematical modeling to form the professional competence of students in their research.

An engineer using mathematical modeling must understand the basic qualitative behavior of the system (for example, how the system reacts to an increase in the load on any subsystem). Such a deep understanding of system behavior can be important for the quality of the engineering product being created. The development of real-time control strategies for these systems relies on mathematical and computational tools and representations.

From the above, according to [15], it follows that:

• applications of mathematical modeling arise in all aspects of the production cycle and in the technological base of engineering processes;

• applications of applied mathematics arise from various areas of mathematical sciences, they depend on the activity of research in the field of mathematical sciences and use this research as the technological basis of modern engineering;

• mathematical modeling is used as a fundamental basis in applied research of systems engineering, is the main way of technology transfer of mathematical sciences;

• the transfer of technology from the research segment to the industrial sector is critical to improve the competitiveness of engineering;

• in the mathematical sciences, as well as in related branches of knowledge, technology transfer is significantly below its potential due to insufficient knowledge of mathematical modeling methods by engineering workers in the context of industry digitalization;

• in the higher technical school teaching mathematics, applied mathematics and professional training of a future engineer using mathematical modeling are of decisive importance for the formation of the competitiveness of a modern engineer;

• in the didactics of mathematical modeling for engineering students, there is a need for cooperation between industrial and academic sectors, in which the participants in the process are clearly aware of the central importance of technology transfer;

• teaching mathematical modeling to students of technical universities should be aimed at narrowing the gap between academic mathematics and the industrial use of mathematics, expanding the intellectual horizons of students, and increasing their potential usefulness in future professional activities.

From all of the above, the relevance of our chosen research topic follows.

CONCLUSION

Note that all of the above will form the basis: firstly, the creation of a general system model for solving a number of scientific research or practical problems; secondly, to optimize the decision-making process; thirdly, to evaluate the quality of such a solution, and so on.

Based on all of the above, it is planned to create a special system for integrating disciplines - combinatorial analysis, graph theory, mathematical modeling in the formation of competencies of the bachelor of "Biomedical Engineering".

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BIOTIBBIYOT MUHANDISLIGI" BAKALAVRIATINING KOMPETENSIYALARINI SHAKLLANTIRISHDA – KOMBINATORIAL TAHLIL, GRAFLAR NAZARIYASI, MATEMATIK MODELLASHTIRISH FANLARI INTEQRATSIYASI TIZIMINI ISHLAB CHIQISH

A.F.Marasulov, X.A.Marasulova

Annotatsiya

Dolzarbligi. Talabalar zarur bilim, ko'nikma va kasbiy malakalarni muvaffaqiyatli o'zlashtirishlari hamda ularni kelgusidagi amaliy faoliyatiga tatbiq etishlari uchun ularning maxsus integratsiyalashgan kompyuter bilimlari bazasini rivojlantirish asosida tegishli o'quv modullarini samarali o'qitish (o'rganish)ning moslashuvchan tizimi zarur. diskret matematika va sun'iy intellektning g'oyalari va usullaridan foydalangan holda ma'lumotlar bazasi.

Tadqiqod. Strukturaviy va funktsional sxemalar taklif etiladi: fanlar elementlarini integratsiya qilish tizimini ishlab chiqish - kombinatoryal tahlil, grafiklar nazariyasi, kasbiy faoliyat sohasi tarkibiy qismlarining muammolari va vazifalarini amalga oshirishda matematik modellashtirish, kasbiy faoliyat ob'ektlari, kasbiy faoliyat turlari. "Biotibbiyot muhandisligi" bakalavrining faoliyati; sog'liqni saqlash uchun biotibbiyot muhandisligi, tibbiyot va biologiya fanlari muammolarini loyihalash va hal qilishda ushbu fanlarni integratsiyalash tizimining bilim bazasi va ma'lumotlar bazasini shakllantirish.

Natijalar. Biotibbiyot muhandisligi tadqiqotlari sohalarida kombinatorial tahlil, grafiklar nazariyasi, matematik modellashtirish fanlari bilan allaqachon amalga oshirilgan integratsiya misollari (adabiy va Internet manbalaridan va o'z ishlanmalarimizdan) tuzilgan. Diagnostika, monitoring, davolash usullari uchun kombinatorial tahlil, grafiklar nazariyasi, matematik modellashtirish fanlari bilan allaqachon amalga oshirilgan integratsiya misollari (adabiy va Internet manbalaridan va o'z ishlanmalaridan) tuzilgan. Natijada integratsiya tizimlarining ma'lumotlar bazasi tuziladi, uning asosida talabalar mavjud integratsiya tizimlari haqida tasavvurga ega bo'ladilar. Biotibbiyot muhandisligining muayyan muammosi yoki vazifasini ko'rib chiqishda avvalo integratsiya tizimlarining mavjud ma'lumotlar bazasidan tegishli integratsiya tizimi aniqlanadi. Agar biotibbiyot muhandisligining ko'rib chiqilayotgan muammosi yoki vazifasi uchun mos integratsiya tizimi mavjud bo'lmasa, tadqiqot loyihasi asosida tegishli mutaxassislar bilan birgalikda tegishli yangi integratsiya tizimi tuziladi.

Hulosa. E'tibor bering, yuqoridagilarning barchasi asos bo'ladi: birinchidan, bir qator tadqiqot yoki amaliy muammolarni hal qilish tizimining umumiy modelini yaratish; ikkinchidan, qaror qabul qilish jarayonini optimallashtirish; uchinchidan, bunday yechimning sifatini baholash va boshqalar. Yuqorida aytilganlarning barchasidan kelib chiqib, "Biotibbiyot muhandisligi" bakalavriatining kompetensiyalarini shakllantirishda fanlarni integratsiyalashning maxsus tizimini – kombinatoryal tahlil, grafiklar nazariyasi, matematik modellashtirishni yaratish rejalashtirilmoqda.

Kalit so'zlar: biotibbiyot muhandisligi, bilimlar bazasi, diskret matematika fanlari, integratsiya

К РАЗРАБОТКЕ СИСТЕМЫ ИНТЕГРАЦИИ ДИСЦИПЛИН - КОМБИНАТОРНЫЙ АНАЛИЗ, ТЕОРИЯ ГРАФОВ, МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ В ФОРМИРОВАНИИ КОМПЕТЕНЦИЙ БАКАЛАВРА «БИОМЕДИЦИНСКОЙ ИНЖЕНЕРИИ»

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Аннотация

Актуальность. Для успешного освоения студентами необходимых знаний, умений, навыков и профессиональных компетентностей, и их реализации в будущей практической деятель-ности, необходима гибкая система эффективного обучения (изучения) соответствующих учебных модулей на базе разработки их специальной интегрированной компьютерной базы знаний и базы данных, с использованием идей и методов дискретной математики и искусственного интеллекта.

Методы. Предлагаются структурно-функциональные схемы: разработки системы интеграции элементов дисциплин - комбинаторный анализ, теория графов, математическое моделирование в реализации проблем и задач составляющих области профессиональной деятельности, объектов профессиональной деятельности, видов профессиональной деятельности бакалавра «Биомедицинской инженерии»; составления базы знаний и базы данных системы интеграции указанных дисциплин в проектировании и решении проблем биомедицинской инженерии, медицинских и биологических наук для здравоохранения.

Результаты. По областям исследований биомедицинской инженерии составляются примеры уже реализованных интеграций их с дисциплинами комбинаторный анализ, теория графов, математическое моделирование (из литературных и интернет источников и собственных разработок). В результате, составляется база интеграционных систем, на основе которых студенты смогут получать представления об существующих системах интеграции. В случае отсутствия подходящей системы интеграции для рассматриваемой проблемы или задачи биомедицинской инженерии, на основании исследовательского проекта совместно с соответствующими специалистами, будет составляться соответствующая новая интеграционная система.

Выводы. Отметим, что все вышеперечисленное ляжет в основу: во-первых, создание общей модели системы для решения ряда научно-исследовательских или практических задач; во-вторых, оптимизировать процесс принятия решений; в-третьих, оценить качество такого решения и так далее. На основе всего вышеперечисленного планируется создание специальной системы интеграции дисциплин – комбинаторного анализа, теории графов, математического моделирования в формировании компетенций бакалавра «Биомедицинская инженерия».

Ключевые слова: биомедицинская инженерия, база знаний, дисциплины дискретной математики, интеграция.