Didactic Criteria For Selecting And Systematizing Medical Mathematical Modeling Problems

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ABSTRACT

The thesis presents the criteria for selecting and systematizing mathematical modeling problems with medical content for future physicians. Scientific validity, clinical relevance, progression, systematization, interdisciplinary integration, visualization, and the possibility of digital verification are combined into a unified didactic system. A seven-stage sequence is proposed, consisting of formulating a medical situation, identifying indicators and parameters, constructing a model, performing calculations, checking the result, providing a professional interpretation, and evaluating the limitations of the model. This system forms the scientific and methodological basis of a set of problems developed for the sections of equations and inequalities, derivatives, definite integrals, exponential and logarithmic functions, probability, and statistical modeling.

KEYWORDS: Medical education, mathematical modeling, applied problem, clinical relevance, interdisciplinary integration, didactic criterion.

INTRODUCTION

The main task of teaching mathematical modeling in higher medical education is not to make students memorize ready-made formulas, but to teach them to translate a biological or clinical process into mathematical language, explain the obtained result in medical terms, and recognize the limits of the model's applicability. Theoretical models of population dynamics, epidemiological processes, physiological regulation, and pharmacokinetic systems are widely discussed in the literature on mathematical biology and medicine [1–3]. However, transforming these models into applied problems appropriate to students' professional training requires a separate didactic selection.

In existing educational materials, medical content often remains merely an external context in the problem statement: the formula is given in advance, while the biological meaning of the parameters and the clinical interpretation of the result are not sufficiently explained. Such a task may assess computational skills, but it does not fully develop the student's competence in independently formalizing a medical situation. The purpose of the study is to clarify the criteria for selecting and systematizing mathematical modeling problems with medical content for future physicians and to substantiate a didactic structure that transforms them into a consistent learning activity.

Materials and Methods

The research materials included qualification requirements for medical specialties, the syllabus of the course "Mathematical Modeling in Biology and Medicine," the content of biology, physiology, biophysics, pharmacology, epidemiology, and biostatistics, as well as applied tasks presented in local and foreign educational literature [1–6]. The comparative analysis assessed the proximity of the problem to a professional task, the accuracy of the model, stages of reasoning, interdisciplinary connections, and the possibility of verifying the result.

Table 1. Criteria for Selecting Applied Problems with Medical Content

Criterion	Requirement for the Problem	Expected Learning Outcome
Scientific validity	The model should correspond to a biological or medical regularity, and its parameters and units should be justified.	The student explains the content of the model and the assumptions adopted.
Clinical relevance	The situation should be close to a process or indicator encountered in the professional activity of a future physician.	The student relates the mathematical result to a professional task.
Progression and systematization	The tasks should become progressively more complex, from applying a ready-made model to independently constructing a model, and should form an interconnected set.	Independence in formalization and integrated modeling activity are developed.
Interdisciplinary integration	The mathematical content should be connected with biology, physiology, pharmacology, epidemiology, or biostatistics.	The student is able to transfer theoretical knowledge to another discipline and a clinical situation.
Visualization and verification	It should be possible to verify the result using a table, graph, simulation, or applied software package.	Skills in calculation, visual analysis, and error detection are developed.

In didactic design, the chain “medical situation – mathematical formalization – calculation – professional interpretation” was taken as the basis. The principles of scientific validity, ease of assimilation, visualization, systematization, and the connection of theory with practice identified in the dissertation were supplemented with the criteria of clinical relevance, gradual increase in complexity, interdisciplinary integration, and compatibility with information technologies.

Results

As a result of the analysis, a seven-stage didactic cycle for constructing an applied problem with medical content was developed: 1) clearly defining the medical situation; 2) identifying the observable indicator, variables, and parameters; 3) determining the necessary assumptions and limitations; 4) selecting or constructing a mathematical model; 5) performing analytical, numerical, or statistical calculations; 6) verifying the result using a table, graph, or software tool; 7) interpreting the result in medical terms and indicating the factors not taken into account by the model. This cycle transforms the problem from the level of “finding a numerical answer” into a task of professional analysis.

The set of problems was systematized according to the areas of mathematical training required for future physicians. For each section, the corresponding medical process, model-building activity, and final professional interpretation were determined. This made it possible to gradually increase the level of complexity while maintaining the same methodological chain in lectures, practical classes, and independent study.

Table 2. Systematization of Mathematical Sections and Problems with Medical Content

Mathematical Section	Medical and Biological Content	Student's Modeling Activity
Equations and inequalities	Drug dosage, body mass index, clinical limits	Determining the unknown quantity, checking conditions and constraints
Derivative and rate of change	Dynamics of heart rate, glucose, or physiological indicators	Assessing the rate of change and interpreting the critical condition
Definite integral	Amount of drug accumulated over time or physiological flow	Calculating the total amount and explaining its medical meaning
Exponential and logarithmic functions	Spread of infection, population growth, drug elimination	Estimating parameters, making predictions, and indicating model limitations
Probability and statistics	Blood pressure, hemoglobin, glucose, and demographic data	Describing the sample, comparing groups, and substantiating the conclusion

For example, in a task related to blood glucose indicators, the student does not simply compare values before and after meals. The student checks the measurement time, units, and observation conditions; distinguishes dependent and independent variables; selects an appropriate statistical or dynamic model; represents the result graphically; compares the observed change with the clinical norm; and indicates that the model does not fully account for food composition, physical activity, or individual metabolic differences. The same structure was also applied to problems related to heart rate, blood pressure, hemoglobin, body mass index, and the dynamics of infectious diseases.

Discussion

The proposed criteria prevent any mathematical task containing a medical term from being regarded as a professionally oriented problem. In a genuine mathematical modeling problem with medical content, the clinical problem must be clearly defined, the biological meaning of the parameters must be explained, the choice of model must be justified, the calculation result must be interpreted from a medical perspective, and the limitations of the model must be indicated. In this case, the problem creates a meaningful connection between mathematics and specialized disciplines [2, 4, 5].

The scientific significance of this result is not limited to compiling a set of separate examples. Criterion-based selection and the seven-stage cycle transform applied problems into a system that gradually develops competence. The digital tool is not the goal here, but a means of verifying calculations, visualizing graphical relationships, and analyzing the influence of parameters. In the pedagogical experiment of the dissertation, this system of problems was used as a component of the integrated methodology.

Conclusion

The criteria of scientific validity, clinical relevance, progression, systematization, interdisciplinary integration, visualization, and digital verification for selecting mathematical modeling problems with medical content for future physicians were clarified. A seven-stage didactic cycle was developed, ranging from formulating a medical situation to evaluating the limitations of the model. The system of problems developed for the sections of equations and inequalities, derivatives, definite integrals, exponential and logarithmic functions, probability, and statistical modeling serves to consistently develop students' skills in formalizing a medical process, verifying the result, and interpreting it in a professional context.

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