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Methodology Features of Teaching Stochastics to University Students of the Biology Specialization

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ABSTRACT

The purpose of the research is to build a methodological system for teaching stochastics to university students of the Biology specialization in the context of implementing a professional-applied orientation. The leading method of researching this aspect is the modeling of the conceptual basis of the methodological system for teaching stochastics, which allows to form a system of mathematical knowledge and skills necessary for understanding the fundamentals of the process of mathematical modeling and statistical processing of biological data in professional activity; to develop practical application skills of statistical methods in biological research. In this article, the authors' methodology of forming professional competence of future specialists of the Biology specialization through the implementation of professionally-applied teaching stochastics is presented. The specificity of our methodology for teaching stochastics to university students of the Biology specialization is that between the theoretical and practical aspects of stochastics, a deep content-methodological interrelationship has been established; the authors' system of professionally-applied tasks has been proposed, which includes, among other things, real tasks from the discipline of Biology that facilitates the integration of natural science knowledge based on the modeling method. The research carried out by the authors proved the effectiveness of the suggested methodology for teaching stochastics to university students of the Biology specialization. The article materials can be useful for lecturers of higher educational institutions and teachers of secondary schools with in-depth Biology studying when the suggested methodology for teaching the probability theory and mathematical statistics is applied.

Keywords: stochastics, methodological teaching system, professional and applied orientation.

INTRODUCTION

Relevance of research

Many ecological, genetic, cytological, microbiological, radiobiological phenomena are massive and random in their nature. The realization of events in the aggregate of cells, α-particles, bacteria, individuals of the species, families, etc., can be estimated using probabilistic methods, and their analysis requires the use of statistical methods.

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State of the literature

- We should underline the fact that in the literature on the theory and methodology of teaching mathematics, there are very few studies of stochastics training of university students of the Biology specialization within the framework of the concept of professional and applied orientation.
- Gradual introduction of professional standards into the system of higher education entails an increase in the level of quality requirements for preparing professionally oriented specialists. Meanwhile, the analysis of the state of the problem of teaching students of natural science specializations of higher education in Mathematics (in particular, stochastics) and the method of modeling in bachelor's degree programme made it possible to reveal that the currently existing methods of teaching mathematics (in particular, stochastics) at university do not fully provide the formation of modern professional knowledge, skills and competencies, adequate application of the modeling and statistical methods within the framework of the professional-applied orientation of teaching on the level required by the Standard.

Contribution of this paper to the literature

- The conceptual apparatus, the structural components of the methodological system for teaching stochastics to university students have been theoretically justified.
- The content of each component of the methodological system and their interrelation from the positions of professionally-applied orientation have been developed.
- The methodological system for teaching stochastics and a set of teaching materials have been developed.
- The system of professionally-applied tasks on stochastics for university students of the Biology specialization based on the modeling method within the framework of the concept of a professionally-applied orientation has been presented.

Meanwhile, a number of questions in Biology can be studied only with the help of mathematical-statistical methods. For example, the variability of morphological, physiological and ecological signs of animals and plants; determining the influence of external and internal factors on these; quantitative accounting of processes occurring in populations; studying the similarities and differences between species, subspecies and other systematic categories; individual growth and growth of populations, etc. In turn, understanding and accounting of statistical regularities allows one to methodically plan and conduct a scientific experiment in Biology, substantially improve the quality of scientific research, understand the processes underlying life activity more deeply, assess on them the influence of external factors, build mathematical models of biological processes.

Professional education of university students of the Biology specialization involves mastering a certain amount of systematic knowledge and skills in the field of a particular profession. The study of mathematical disciplines, in particular stochastics, is usually conducted in the first and second courses, when students do not have a system of professional knowledge and skills yet. The real application of mathematical and stochastic methods and models takes place in the study of special disciplines, mainly in the third and fourth courses. In order to form integrative ties, it is necessary to organize for teaching stochastics within the framework of a professionally-applied orientation, all this contributes to the formation of professional competence among students. The works of E. V. Alexandrova (2005), A. B. Dmitrieva (2004), A. A. Solovyova (2006), and others are dedicated to the applied orientation of education.

The current period of the development of the educational system is characterized by the practice of introducing information technology into teaching university disciplines. In recent years, the Ministry of Education and Science has repeatedly drawn attention to the need of using information technology as a means of teaching in all classes of the natural-mathematical cycle. In this direction, a lot of profound studies have been conducted, the content of which is reflected in a number of papers by M. P. Lapchik (1999), I. V. Robert (2010), and others. Due to a number of objective reasons, the problem of using information technologies in the course of probability theory and mathematical statistics, when organizing independent (especially out-of-class) work of university students in conditions of a professional-applied orientation turned out to be scarcely developed.

Meanwhile, the educational standards of higher education in Russia require drastic changes in attitudes towards studying outcomes. Assessing knowledge and skills, it is necessary to assess the level of professional and general competencies formation. General competencies can be expressed through certain qualities of personality: the ability to learn, the ability to make decisions, receive and transmit information in various ways, be communicative, have critical thinking (Buntod, Singseevo, & Suksringam, 2010; Minkina, 2000). We can note that the realization of a professional orientation in the process of teaching stochastics to university students of the Biology specialization promotes the transformation of fundamental knowledge and skills into professional ones, the formation of professional competence of future specialists among students, the development of thinking and the formation of a world outlook and a general scientific picture of the world.

Aims and objectives of the study

The aim of this study is to develop a methodology for teaching stochastics and to test its effectiveness experimentally.

Objectives: to design and implement a methodological system for teaching stochastics, to reveal the features of the methodology in teaching stochastics, to reveal the components of the methodological system for teaching stochastics, to prove the effectiveness of the methodology of teaching stochastics to university students of the Biology specialization.

LITERATURE REVIEW

Analysis of foreign studies

The problem of implementing the modeling method and solving tasks related to reality (in particular from the field of Biology) is currently relevant and studies in this direction continue: W. Blum (2011), S. Schukajlow et al. (2012), I. Biza & H. E. Vande (2014), A. K. Erbas et al. (2014), G. Kaiser & S. Brand (2015), I. Biza et al. (2016), P. Frejd & C. Bergsten, (2016), M. Mascaró, A. I. Sacristán & M. M. Rufino (2016), J. Tanevski, L. Todorovski & S. Džeroski, (2016), and others.

The analysis of the studies showed that the authors offer different approaches to mathematical modeling and related concepts, but despite their different views on the use of mathematical modeling in the educational process and studying mathematics in terms of determining models and modeling, most authors consider it necessary and natural to apply the modeling method for solving real-world problems at the stage of both secondary and higher education. So, for example, W. Blum (2011) not only substantiates the importance of using the modeling method in the learning process, but also gives examples of students' difficulties in solving problems through modeling, recommendations for teachers to improve the modeling competence of students engaged in modeling tasks. The study of A. K. Erbas et al. (2014) is dedicated to an attempt to develop a unified perspective of mathematical modeling, describes two approaches to the use of modeling in mathematical education, namely modeling as a means of teaching mathematics and modeling as the goal of teaching mathematics. I. Biza et al. (2016) carried out a rather thorough analysis of the published works, starting from 2014 through 2016 inclusive, on possible theoretical and methodological prospects of the development of mathematics, its relationship with other theories in higher education. In their work, the authors also disclose the role of Mathematics and mathematical methods, including the modeling method, taught on the higher level in other disciplines (engineering, science, economics, etc.). The work is mostly of a theoretical nature, does not contain any description of the methodology for teaching mathematics, in particular stochastics.

In his study, T. Koparan (2015) analyzes the emerging difficulties in the process of studying and teaching stochastics in secondary schools, and suggests possible ways to solve them. The author does not disclose the aspects of the methodology of teaching stochastics, including at the university level. In the works of I. Biza & H. E. Vande (2014), an evaluation of the project is presented, when senior students of Mathematics are involved in the development of methodological and educational resources for teaching stochastics to students of various profiles. This assessment concerns the participation of students in the project and its impact on their study of statistics,

characterized from the point of view of statistical reasoning, statistical thinking and statistical counseling skills, the participation of students was assessed from the point of view of communities. B. G. Silva Junior & C. E. Lopes (2016) reveal in their work the role of statistics in the preparations of professional engineers, their research showed the necessity of developing statistics in accordance with other constituents of the curriculum. Here, the method of teaching stochastics to university students of the Biology specialization is not given.

The study of M. Mascaró, A. I. Sacristán & M. M. Rufino (2016) is dedicated to a project that aims to improve the quality of teaching and studying the experimental analysis and statistics, to students of environmental and biological sciences, through computer program activities (using R-code). In this project, through integrative design, the authors developed sequences of R-code (ANOVA) that allow students to apply statistical methods and use computational tools such as R, according to their own data from the field of Biology, which allows them to deepen their understanding of biological phenomena. This work focuses on one of the means of teaching stochastics, it does not consider the teaching methodology as a unifed methodological system for teaching stochastics.

The book of N. S. Goel & N. Richter-Dyn (2016) contains a description of stochastic models in Biology, the analysis of biological systems and experiments of biological phenomena on various levels, from a molecular to an ecological one. This work is of a more theoretical nature, it is applicable for filling the content component of the methodological system for teaching stochastics students of the Biology specialization.

The work of the authors J. Tanevski, L. Todorovski & S. Džeroski (2016) is dedicated to the disclosure of modeling aspects for solving the current problem of the system approach to Biology. The modeling method is considered by J. Tanevski, L. Todorovski & S. Džeroski (2016) as one of the main methods for solving problems in the field of Biology, because the identification of the biological model with the optimal structure and parameters is taking place through the modeling process, the authors illustrate the usefulness of the proposed method with four stochastic modeling problems from two areas of Biology: gene regulatory networks and epidemiology. In the field of epidemiology, they were the first to formalize the knowledge that was used to create stochastic description models: Eyam plague outbreak, Tristan da Cunha influenza outbreak, based on the fundamental principles of polygamous modeling. Meanwhile, this study does not contain methodological aspects of applying the modeling method in teaching students stochastics.

Analysis of the Russian scientific-pedagogical literature

In the theory and methodology of teaching mathematics in higher educational institutions, there are studies dedicated to various issues related to the problems of teaching probability theory and mathematical statistics: B. V. Gnedenko (2005), S. A. Samsonova (2004), and others, they are aimed at solving stochastic problems of preparing future mathematics teachers (Vanyurin, 2003; Selyutin, 2002), students of the higher agricultural education institutions (Alexandrova, 2005), humanities students (Solovyova, 2006) etc., but all of them do not contain the method of teaching stochastics of the Biology specialization.

A. V. Vanyurin (2003) and S. A. Samsonova (2004) offer a method for teaching stochastics to university students using information technology, their work does not contain methodological aspects of the application of the modeling method in teaching students stochastics. E. V. Alexandrova (2005) has developed a teaching and methodological complex for the implementation of the professional orientation of probability theory and elements of mathematical statistics. The complex includes: a methodological model; modular programme and methodological comments to it; a system of professional assignments, based on the levels of cognitive activity. In the paper, the author gives the content and methodological recommendations for performing laboratory works on the module "Mathematical Statistics" using Excel and SPSS. The study does not contain methodological aspects and the application of the modeling method for teaching students stochastics, there is no methodology for teaching probability theory. A. A. Solovyova (2006) theoretically substantiated and experimentally confirmed the possibility of a professional orientation of teaching mathematics to students of humanities, in particular, she developed a methodological system of professionally oriented teaching Mathematics to students of humanities, relying on the concept of foundation of the student's personal experience. A. B. Dmitrieva's research (2004) is that she identified

the features of organizing independent work on mathematics in a military higher school, methodically grounded a set of military-applied tasks for independent work as a means of improving the quality of students' professional training. In particular, the author developed a methodology for teaching independent tasks of the applied content and a block of tasks of the military-applied content on the topic "Probability Theory". In her work, the author does not consider the methodological aspects of teaching mathematical statistics to students in a higher educational institution.

The analysis of the studies made it possible to conclude that the theoretical, methodological and practical aspects implementing the methodological system for teaching stochastics to university students in the Biology specialization within the framework of the professionally-applied orientation of teaching and the use of the modeling method remain insufficiently developed.

MATERIALS AND METHODS

Structure and content of the methodological system for teaching stochastics at university

The methodical system for teaching stochastics at university within the framework of the concept of a professionally-applied orientation is considered as an integrator and regulator in the conditions of the modern educational environment of the university. It is a reference point of the system organization of the educational process at university, as well as the lecturer's methodical tool aimed at fostering in students the professional competence of future specialists, developing their cognitive interest and stochastic thinking, and developing the statistical and mathematical culture of students. Here, under the methodological system, we mean a set of interrelated means, methods and processes necessary to create an organized, purposeful and deliberate pedagogical influence on the formation of a personality with given qualities (Bespalko, 1989).

The fundamental conceptual position underlying the development of all the components of the methodological system for teaching stochastics to university students of the Biology specialization is a systematic approach to its design and implementation. The methodological system for teaching stochastics consists of the following components: target, content, forms, methods and means of teaching, each of which acquires a certain methodological function (**Figure 1**).

The concept of the methodological system of teaching stochastics at university is based on the idea of implementing a professionally-applied orientation. The professionally-applied orientation of teaching in the methodological system of teaching stochastics at university is included in all the structural components of this system: target, motivational, content, administrative-procedural, control-evaluation and result.

The target component is represented by the target of teaching stochastics and involves forming students' general ideas about probability theory and mathematical statistics as adequate means of describing the phenomena and processes of real Biology, mastering complex activities through the use of specific methods and teaching means, developing their stochastic thinking and raising the level of mathematical culture. The target component is associated with the formation of professionally significant knowledge, practical skills, mastering the technology of solving professionally-applied tasks on the basis of the modeling method. Here, the requirements formulated in the Federal State Educational Standard of the Biology specialization, of the curriculum and the corresponding system of means that governs the studying process are taken into account. The motivational component is aimed at forming and developing cognitive interests of students within the framework of professional-profile teaching stochastics as a source of developing in them future professional competence. Here, the lecturer needs to build a process of teaching stochastics so that at each stage of introducing and working with a new stochastic concept, formula, or theorem they should demonstrate students the relationship with future professional activity.

The content-related component contains theoretical and practical constituents. The theoretical constituent contains a set of mathematical knowledge – concepts, theorems, methods of reasoning, which is determined on the basis of the principle of continuity, taking into account the current trends in the development of mathematical education and the requirements of the Federal State Standard of higher education for a graduate of the Biology specialization. The practical constituent of teaching mathematics is realized through the implementation of various

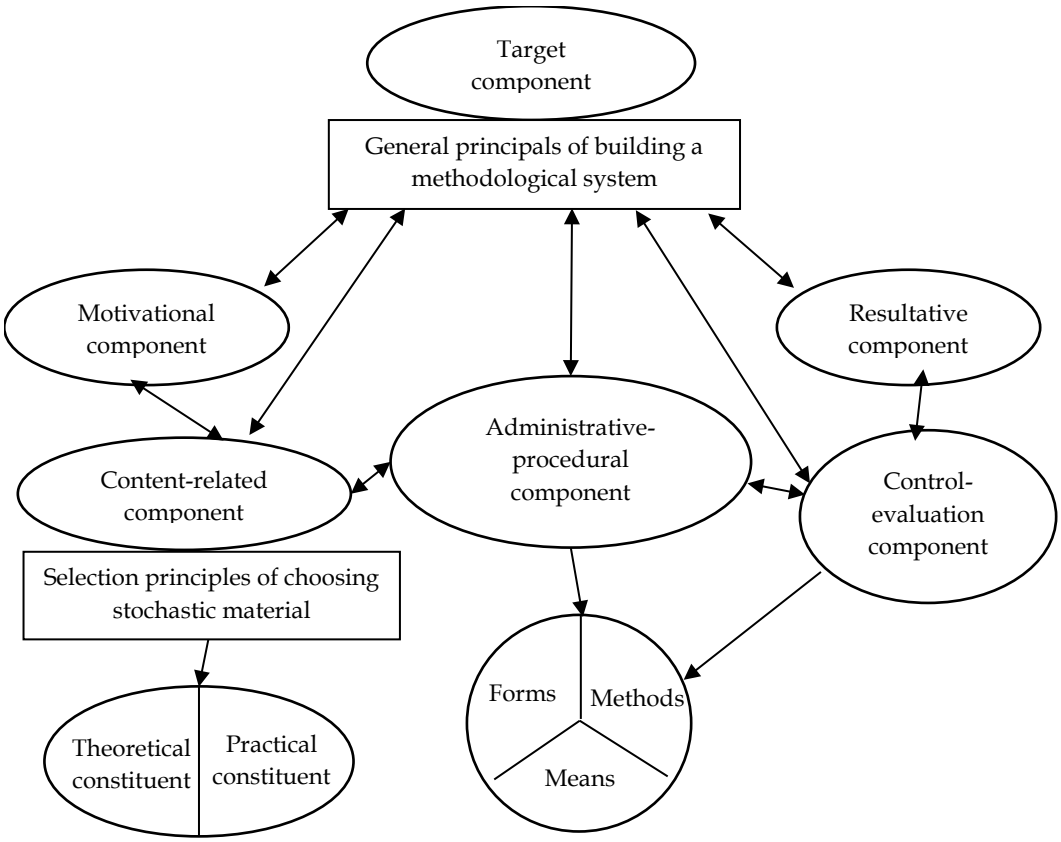

Figure 1. Methodological system for teaching stochastics to university students of the Biology specialization

practical tasks, through the use of a specially selected system of tasks that take into account students' specialization, their future profession. The tasks are close to professional ones as much as possible not only in form, but also in content, there are tasks containing real data or aimed at modeling real biological processes. In solving tasks, the choice of statistical methods is conditioned by a number of peculiarities, including the nature of the data (Khusainova, Shilova & Curteva, 2016). The diversity of the content-methodological support of the stochastic line for the Biology specialization (profile block of the shell) is achieved by the difference of methodological approaches, the degree of illustration, abstraction, the application of the system of professionally-applied tasks, etc. The selection of the material for the outline is carried out with the help of the following principles: the correspondence of the content component to the profile studying, universality of stochastic education, representativeness, capacity, minimization, time, prospects.

The administrative-procedural component regulates the order of organizing the educational process at the university, it is realized through a complex of forms, methods and means of teaching that affect the motivational sphere of the students and stimulate in them an active cognitive activity. The forms of teaching stochastics at university are: traditional forms of classroom activities, forms of organizing independent work, forms of organizing research work, forms of using information technology. Teaching stochastics methods in the university are: lectures, discussions; visual: illustrations, schematization, symbolization, demonstration; work with the book; practical: observation, statistical research, experiments (including statistical), laboratory work, practical work, modeling; interactive: discussion, project methods (Hutchinson, 1991; Phillips, Burwood & Dunford, 1999), case studies (Ellet, 2007; Yin, 2009); methods of control. The means of teaching stochastics at the university are: printed; means of information technologies, including electronic educational resources; audiovisual; teaching instruments and others.

Table 1. Distribution of Langerhans islets in the pancreas of the chimpanzee

Number of islets in squares, x_i	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Number of squares, f_i	327	340	160	53	16	3	1
$p_i = f_i/n$	$\frac{327}{900}$	$\frac{340}{900}$	$\frac{160}{900}$	$\frac{53}{900}$	$\frac{16}{900}$	$\frac{3}{900}$	$\frac{1}{900}$

The control and evaluation component reflects the requirements to the quality of stochastic preparing students, defined by the Federal State Educational Standard of higher education for the Biology specialization and normative documents. It assumes the interaction of lecturers and students, the lecturer's supervision, on the part of students – independent working and self-controlling, which include oral control (individual and frontal interview); written control: testing (Gorev, Zelenina & Shilova, 2013), taking control works and tests; self-controlling (analysis of the results of one's own work and identification of the mistakes made, self-controlling the level of learning educational material). The resultative component involves analyzing the effectiveness of teaching stochastics in the light of the ideas of a professionally-applied orientation in accordance with the target component, identifying the level of mastering knowledge, forming students' skills based on the results of the control-evaluation component. The effectiveness criteria of the projected methodological system for teaching stochastics at university are: increasing the level of professional knowledge and skills of students; increasing their cognitive interest; developing critical thinking (Buntod, Singseevo & Suksringam, 2010) as some super subject quality. One of the main indicators of the methodology effectiveness for teaching stochastics to university students is the ability to adequately apply statistical methods both in research activities (at research student seminars) and in performing the experimental part of the final qualifying work (Ashikhmina, Bushmeleva & Shilova, 2014).

We will point out the qualities that can be formed in students when implementing the methodological system for teaching stochastics: 1) some ideas about modern problems and ideas of stochastics; 2) the ability to apply stochastic knowledge to solve practical problems; 3) the ability to build mathematical models of real phenomena and processes in the field of Biology; 4) dealing with a stochastic apparatus to study certain types of mathematical and statistical models; 5) understanding the essence of elementary methods used in stochastic studies, and the primary skills of mastering these methods; 6) sufficient skills to use stochastic knowledge in the study of other educational disciplines and for self-education.

Peculiarities of the implementation of the methodological system for teaching stochastics to university students of the Biology specialization

Here we will dwell in more detail on the aspects of realizing the practical constituent of the content-related component of the methodological system for teaching stochastics, which we realize through the implementation of various practical tasks, through the use of a specially selected system of tasks that take into account the students' specialization, their future profession. It is impossible to underestimate the possibilities of applied tasks, including computing ones (Richard & Sriraam, 2005). The professionally applied tasks at the level of higher education require planning of solutions as a special form of activity (Suthar & Tarmizi, 2010), their solution consists of several stages using the method of mathematical modeling. Professional-applied tasks were compiled taking into account three levels of application of stochastics in Biology: 1) data processing by statistical methods; 2) simulating stochastics of different objects of study; 3) "merging" of biometrics with stochastics.

The system of professionally-applied tasks in probability theory and stochastics for the Biology specialization is presented more widely and fully in a number of works (Shilova, 2015, 2016; Shilova & Shilov, 2007, 2015); some of them are presented below as an example.

Task. The distribution of the islets of Langerhans in the pancreas of the chimpanzee is studied. In total, 900 squares were viewed. The distribution of the islets of Langerhans in the pancreas of the chimpanzee is presented in the **Table 1**. Determine the distribution law.

Table 2. Baseline data

No	Tree species	Number of trees	Scores
1	downy birch	4	2, 2, 3, 4
2	spruce	4	2, 2, 3, 3
3	aspen	5	2, 2, 2, 3, 4

Decision. The probability of finding the islet of Langerhans (for this the histological sections are projected onto the screen, Langerhans islets are found on them, taking into account the number of squares) on any square is the same and small, but the distribution of the islets in individual squares is uneven. We can assume that it corresponds to the Poisson distribution. We will find the mathematical expectation and variance, respectively:

$$M(x) = \mu = 0 \cdot \frac{327}{900} + 1 \cdot \frac{340}{900} + 2 \cdot \frac{160}{900} + 3 \cdot \frac{53}{900} + 4 \cdot \frac{16}{900} + 5 \cdot \frac{3}{900} + 6 \cdot \frac{1}{900} = 1.$$

$$D(x) = (0-1)^2 \cdot \frac{327}{900} + (1-1)^2 \cdot \frac{340}{900} + (2-1)^2 \cdot \frac{160}{900} + (3-1)^2 \cdot \frac{53}{900} + (4-1)^2 \cdot \frac{16}{900} + (5-1)^2 \cdot \frac{3}{900} + (6-1)^2 \cdot \frac{1}{900} = \frac{916}{900} \approx 1.$$

The proximity of the values of the mathematical expectation and variance, as well as the very small probability of the emergence of the Langerhans islets $p = \frac{\mu}{n} = \frac{1}{900} \approx 0{,}001$ serves as a proof that the distribution of the Langerhans islets is Poisson.

Thus, the development of certain characteristics in time are often studied in biological, environmental, medical studies, for example, studying changes in stem height, average growth rate, leaf surface in different periods of plant life, water pollution levels, population growth, population rates of organisms, increase in linear dimensions, weight gain, titration of vaccines, etc. In these cases, the most accurate characteristic of average changes is a geometric mean (Shilova & Shilov, 2015).

Task. (Shilova & Shilov, 2007, 2015). To determine a harmful impact of anthropogenic factors and forecast the state of forest ecosystem under study, an assessment of the state of the mixed forest tree stand is made. An area of 100 m² is randomly selected, types of trees growing on it are determined. Using the scale of visual assessment of trees by external characteristics, we set scores of the state to the tree of each species (x_i) and define the coefficient of the state for each species (j) of trees according to the following formula: $\overline{K_j} = \frac{\sum_{i=1}^{m} m_i \cdot n_i}{n}$, where n_i – is the total number of trees of each state score, m_i – number of different scores, n – is the total number of considered trees of the same species, then the state of the trees on the whole (K) can be determined by the formula: $K = \frac{\overline{K}_1 + \overline{K}_2 + \ldots + \overline{K}_N}{N}$, where N – is the number of different tree species. An assessment of the state of the forest stand is carried out according to the generally accepted classification in Biology: 1) $K \le 1{,}5$ – a healthy timber stand (state: level I); 2) $1{,}6 \le K \le 2{,}5$ – weakened timber stand (state: level II); 3) $2{,}6 \le K \le 3{,}5$ – strongly weakened timber stand (state: level III); 4) $3{,}6 \le K \le 4{,}5$ – shrinking forest (state: level IV); 5) $K \ge 4{,}6$ – dead forest (state: level V).

Decision. During the examination of trees on the test site, the data shown in **Table 2** were obtained.

We shall find the coefficient of state of individual tree species, based on the above formulas:

$$\overline{K}_{\text{birch}} = \frac{2 \cdot 2 + 3 \cdot 1 + 4 \cdot 1}{4} = \frac{11}{4} = 2{,}7. \quad \overline{K}_{\text{spruce}} = \frac{2 \cdot 2 + 3 \cdot 2}{4} = \frac{10}{4} = 2{,}5. \quad \overline{K}_{\text{aspen}} = \frac{2 \cdot 3 + 3 \cdot 1 + 4 \cdot 1}{5} = \frac{13}{5} = 2{,}6.$$

The state of the forest stand on the whole is equal to

$$K = \frac{\overline{K}_{\text{birch}} + \overline{K}_{\text{spruce}} + \overline{K}_{\text{aspen}}}{3} = \frac{2,7 + 2,5 + 2,6}{3} = \frac{7,8}{3} = 2,6.$$

As $2,6 \le K \le 3,5$, the state of the forest is estimated as greatly weakened, therefore, it is necessary to find out the reasons and take measures to eliminate them. Thus, the system of professionally-applied tasks plays the role of the main tool in the process of assimilation of stochastic concepts, axioms and theorems, thus establishing the connection of stochastics with the real world, with the future professional activity of students, similar tasks in probability theory and mathematical statistics are presented in the works of Z. V. Shilova & O. I. Shilov (2007, 2015), Z. V. Shilova (2015, 2016).

Thus, the methodological system was designed and implemented in the light of ideas of a professionally-applied orientation, the latter is included in all the components of the system: target, motivational, content-related, administrative-procedural, control-evaluation and resultative, all the components interconnected. When selecting the content of the discipline material, forms, methods and means of teaching stochastics, we took into account the specificity of future professional activity of university students. The theoretical and methodological basis of our research was: the theory of systemic understanding of pedagogical processes (Krayevsky & Khutorskoy, 2007; and others); the positions of the competence approach in professional education (Zimnyaya, 2003; and others); basic principles and principles of the activity approach in the organization of cognitive independence (Pidkasisty, 2003; and others); the principles of the theory of technological development of the pedagogical process (Bespalko, 1989; and others), including the ideas of using pedagogical, information and telecommunication technologies in the educational process (Grigoriev & Grinshkun, 2005; Zheldakov, 2003; Levchenko, 2009; Zaslavskaya & Sergeeva, 2006; Polat et al., 2009; Robert, 2010; Zakaria & Lee, 2012; and others). To solve the stated tasks, the following research methods were used: specifically theoretical: analysis of mathematical, psycho-pedagogical and scientific-methodical literature, dissertations on the methodology of teaching mathematics and on the implementation of the methodological system of teaching mathematics; practical: analysis and generalization of the experience of teachers and their own experience in conducting studies in the system of higher education, analysis, systematization of concepts and methodological systems of mathematical education (Vanyurin, 2003; Episheva, 1999; Korolev, 2012; Mayer, 2001; Samsonova, 2004; Shcherbatykh, 2011; and others), diagnostic techniques, pedagogical experiment.

RESULTS

The implementation of the methodology components for teaching stochastics to university students of the Biology specialization was carried out during 2015-2017 at Vyatka State Humanities University and at Vyatka State University.

Ascertaining stage of the experiment

We used the following research methods at the ascertaining stage of the work: designing the methodological system for teaching stochastics to the university students of the Biology specialization (group B11, 20 people of the Vyatka State Humanities University), selecting content, forms, methods and means of teaching, working out the methodology of conducting seminars, questioning and testing. Questionnaire survey and testing of students showed that the traditional course of probability theory and mathematical statistics is not very productive from the point of view of students mastering stochastics and the skills of solving professional tasks in the field of Biology. Practically the traditional course does not give anything and in the methodological sense as well: students remain unaware of the role probability theory plays in understanding the structure of the world, their awareness of the statistical nature of probabilistic concepts is insufficient as well as in the field of statistics, little is known about its role and possible application in their professional field of activity, students do not form an integral system of natural science knowledge. The result of the search phase of the experimental work was the scientific and methodological justification of the feasibility of implementing a professionally-applied orientation in the design of the methodological system for teaching stochastics to university students of the Biology specialization, and the development of methods for teaching stochastics within the framework of the proposed concept.

Table 3. Results of a survey of university students

First survey (before the experiment)	Pond survey (after the experiment)
Negative answer	**Positive answer**
a=10 (number of pairs that X=0,Y=0)	b=29 (number of pairs that X=0, Y =1)
c=5 (number of pairs that X=1, Y=0)	d=12 (number of pairs that X=1, Y =1)

Table 4. Results of a questionnaire survey of university students

Opinion	Shift sign	Shifts number
Level increased	+	20
Level not changed	0	14
Level decreased	-	4

Forming stage of the experiment

At the forming stage in the groups Bb1101, Bb1102 (specialization 060301 Biology, Vyatka State University), teaching probability theory and mathematical statistics was carried out by implementing the authors' technique of teaching the stochastics system, and the effectiveness of its application was determined. Here, an extensive examination of the influence of the projected methodological system of teaching stochastics at university on the formation of the students' ability to independently systematize and generalize the acquired knowledge was made. In the same groups, a survey was carried out before and after studying the probability theory and mathematical statistics (groups Bb1101, Bb1102 of the specialization 060301 Biology, 20 and 21 students respectively, Vyatka State University), the answers of students at the beginning of the semester constitute the sample X_i, and at the end – Y_i, taking into account that the influence that the sample members have on each other was excluded, the parameters (X_i; Y_i) can be considered mutually independent. The name scale has two categories – "1" (positive answer) and "0" (negative answer). All of the above allows us to apply the McNamara criterion to assess the impact of the teaching methodology on creating favorable conditions (Shilova, 2015, p. 131). The null hypothesis H_0: $P(X_i=0, Y_i=1)=P(X_i=1, Y_i=0)$ was tested. The implementation of the author's method of teaching stochastics has no advantage in comparison with traditional teaching. As an alternative, the hypothesis H_1: $P(X_i=0, Y_i=1)\neq P(X_i=1, Y_i=0)$ was accepted, that is, the realization of the methodical training system promotes more comfortable and better teaching of stochastics. The results of the survey are listed in the **Table 3**.

We have $b+c=34 > 0$, then the observed (experimental) value of the criterion is equal to $= \frac{(b-c)^2}{b+c} = \frac{(29-5)^2}{29+5} =$ 16,9. $T_{critic} = \chi^2(0{,}01; 1) < 10{,}8. \chi^2(0, 01; 1) < T$, then the null hypothesis is rejected and we accept the alternative hypothesis H_1. Therefore, teaching stochastics, taking into account the implementation of the professionally-applied orientation, helps students acquire more solid knowledge and skills.

The evaluation of forming the cognitive interest of students to stochastics was conducted through a questionnaire and the criterion of signs in groups B1101 and B1102 (38 people from 41 took part). The results of the questionnaire survey are listed in the **Table 4**.

Null hypothesis H_0: during the study of stochastics according to the developed method, the level of cognitive interest will not change. Alternative hypothesis H_1: the level will change.

The empirical significance of the statistics of the sign criterion G is equal to the number of answers that have been least distributed, since positive answers predominate, then the hypothesis H_1 will take the form: the level of development of cognitive interest will increase. $G = 4$. $G(0{,}05; 20) = 5$. $G < G(0{,}05; 20)$, then in our case an alternative hypothesis is accepted. Therefore, we can state that the level of cognitive interest of the students in the groups studied has increased significantly.

Further observation of the students of the groups under study and conversations with teachers of specialized disciplines made it possible to ascertain the fact that in comparison with previous years, the number of students of the junior courses of the Biology specialization who want to engage in research activity and possess the ability to integrate their knowledge has increased.

Thus, taking into consideration the results of the carried out experimental work, we can conclude that the developed methodology of teaching university students of the Biology specialization in stochastics is effective, and during the educational process the students' integrative links with other subjects are formed and the coherent-integrative connection with the subject "Mathematics" is strengthened.

DISCUSSIONS

In accordance with the requirements of higher education standards in Russia, one of the priority in the educational process is the formation of professional competence among students. At the same time, many researchers pay attention to the shortcomings of the traditional methods of teaching mathematics, in particular stochastics, to students of higher educational institutions, which do not provide high quality assimilation of mathematical material and the formation of professional competence among students. The methodology for teaching students stochastics in the Biology specialization allows us to eliminate the shortcomings of the traditional methods of teaching. Here we consider it necessary to take into account the professional orientation of the students, which is possible, for example, using a system of professionally-applied tasks based on the modeling method. In turn, the use of professionally-applied tasks increases the motivational and educational components of the development of the students' personalities. The method of teaching stochastics suggested in this paper allows us to implement integrative interdisciplinary ties with other disciplines and coherent-integrative – interdisciplinary links with various fields of mathematics: differential calculus, integral calculus, and others.

CONCLUSION

In the course of the research, a methodical system for teaching stochastics has been designed, some of its aspects have been separately revealed, namely the formation of a meaningful, administrative-procedural, control-evaluation and resultative components. The leading idea of implementing the system is the realization of a professionally-applied orientation, one of the ways of implementing a professionally-applied orientation is the use of specially selected functionally-applied and professionally-applied tasks in the teaching process, the main method of solving which is the method of mathematical modeling. We have chosen a system of professionally-applied tasks for university students of the Biology specialization. The effectiveness of the methodology of teaching stochastics to university students in the conditions of implementing a professionally-applied orientation is proved. The specificity of the developed methodology lies in the fact that the theoretical component of the content-related component of the methodological system of teaching stochastics is logically and methodologically interrelated with the practical component, which, in turn, contains the authors' system of professional and applied tasks, built on the integration of natural science knowledge, within the framework of the professionally-applied orientation (real tasks in the field of Biology), based on the modeling method. The proposed methodology helps increase the level of stochastic knowledge and skills among students, cognitive interest in Mathematics, develops critical thinking on the subject matter. As a whole, this allows to actualize the personal experience of students, helps them increase the level of their professional and general competencies, allows organizing the educational process and mastering knowledge more efficiently and methodically. Here is the key to the successful implementation of the methodological system of teaching stochastics – it is the constant correlation and interconnection of all components of the methodological system of teaching stochastics, the nature of the educational process, pedagogical actions, studying activity and its results with educational goals and objectives, taking into account the professional and applied orientation of education.

The materials of this article can be useful for lecturers of higher education institutions and teachers of schools with in-depth study of Biology. The proposed methodology can be used in the process of organizing teaching probability theory and mathematical statistics. The presented work will allow university students and

teachers to apply the received knowledge purposefully and methodically in the process of teaching stochastics in the conditions of realization of the professional and applied orientation of education.

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