Фасетная технология как основа разработки комплекса исследовательских задач по стохастике для гибридной интеллектуальной системы обучения

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АННОТАЦИЯ

Введение. Современное образование предполагает интеграцию инновационных методов обучения и цифровых технологий. В контексте новой цифровой парадигмы актуальными становятся вопросы обеспечения управления качеством образовательных систем, которые в полной мере удовлетворяют потребности каждого учащегося в самореализации, актуализации его когнитивных и мотивационных процессов. В этом аспекте проблема организации и сопровождения исследовательской деятельности школьников в области математики посредством интеллектуального управления приобретает особое значение. Интеллектуальные образовательные системы способны обеспечить процессы саморегуляции личности и индивидуализации обучения при освоении сложных математических знаний.

Материалы и методы. Для наполнения базы данных исследовательских заданий по стохастике гибридной интеллектуальной системы обучения использован фасетный метод классификации, предложенный Ш.Р. Ранганатаном и предполагающий параллельное разделение множества объектов по одному признаку на отдельные, независимые друг от друга подмножества. В качестве независимых классификационных параметров при наполнении базы данных исследовательских заданий определены два фасетных признака – уровень развития исследовательской деятельности и профиль мышления.

Результаты исследования. Раскрыты дидактические возможности фасетной классификации, обеспечивающей генерацию широкого спектра проблемно-ориентированных заданий, построение индивидуальной образовательной траектории, управление глубиной внутрипредметных, междисциплинарных и межконцептуальных связей, а также интегративными мыслительными процессами в целом. База данных исследовательских заданий представлена в виде классификационной матрицы, учитывающей градацию уровней исследовательской активности школьников и профилей мышления.

Выводы. Включение школьников в деятельность по овладению математическими понятиями и процедурами в гибридной интеллектуальной среде обучения является важным фактором повышения уровня учебной мотивации и исследовательской культуры, обеспечения гармоничного развития личности за счет повышения интеллектуального и творческого потенциала.

КЛЮЧЕВЫЕ СЛОВА

обучение математике, исследовательская деятельность, фасетная классификация, интеллектуальная обучающая система

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Faceted technology as the basis for the development of a set of stochastic research tasks for a hybrid intelligent learning system

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ABSTRACT

Introduction. Modern education involves the integration of innovative teaching methods and digital technologies. In the context of the new digital paradigm, the issues of ensuring quality management of educational systems that fully meet the needs of each student in self-actualization, activation of his cognitive and motivational processes become relevant. In this aspect, the problem of organizing and accompanying the research activities of schoolchildren in the field of mathematics through intellectual management acquires particular importance. Intellectual educational systems can provide the processes of self-regulation of personality and individualization of learning during the development of complex mathematical knowledge.

Materials and methods. A facet classification method proposed by Sh.R. Ranganathan assuming a parallel partitioning of a set of objects on a single feature into distinct, mutually independent subsets. Two facet features are defined as independent classification parameters when filling the database of research tasks – the level of development of research activity and the profile of thinking.

The results of the study. The didactic possibilities of facet classification are revealed, which provides the construction of a wide range of problem-oriented tasks, the construction of an individual educational trajectory, the management of the depth of intra-subject, interdisciplinary and inter-conceptual connections, as well as integrative thought processes in general. The database is presented in the form of a classification matrix that considers the gradation of the levels of research activity of schoolchildren and thinking profiles.

Conclusion. The inclusion of schoolchildren in the activities of mastering mathematical concepts and procedures in a hybrid intellectual learning environment is an important factor in increasing the level of educational motivation and research culture, ensuring harmonious personal development through increasing intellectual and creative potential.

KEYWORDS

teaching mathematics, research activity, facet classification, intelligent learning system

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INTRODUCTION

Modern trends in the development of the socio-economic and cultural spheres of Russian society contribute to the acceleration of the process of becoming a new education system based on the fourth generation of educational technologies and aimed at entering the world educational space. EdTech-4.0 represents an evolution that uses the latest advances in artificial intelligence, machine learning, big data, and other innovative technologies to create more personalized, adaptive, and effective learning. Implementing AI-based solutions in education is a priority governmental task of any country. In 2021, the UN General Conference on Education, Science and Culture (UNESCO) adopted a Recommendation on the ethical aspects of artificial intelligence. The Recommendation articulates the value settings on which the author's hybrid intellectual learning system is built, inter alia: ensuring diversity and inclusion; fairness and non-discrimination; sustainability development.

The most important condition for building an educational process in a school that determines positions in the world ranking of educational systems is the formation and development of 21st century competencies in modern schoolchildren: cognitive (critical thinking, ability to search, analyze and synthesize information); interpersonal (communication skills, ability to work in a team); intrapersonal (ability to manage their own educational activities, choose learning strategies, use digital tools for self-education).

The data of the latest psychological and pedagogical research indicate that these competencies are most effectively formed in the process of independent search and problem-setting, generating non-standard ideas and solutions, transferring knowledge to new situations [19]. In this regard, one of the key tasks of a modern school is the formation of a holistic system of research activities among graduates.

It is important to emphasize the dominant role of mathematical disciplines in the development of students' research skills, which is due to the specifics of the mathematical method. Using this method requires mastering the most important intellectual operations: modeling, design skills, as well as universal skills of planning and verification. Didactics has accumulated a wealth of experience in solving the problem of intellectual development in the process of teaching mathematics, in educational practice, technologies of problem-based, programmed, multi-level, adaptive, modular learning are widely used. At the same time, it should be noted a number of factors that do not fully realize the developing potential of these technologies: insufficient elaboration of methodological aspects, insufficient attention of teachers to the development of educational motivation among schoolchildren and weak practical orientation and applied orientation. Thus, organizational and methodological support of the process of developing students' research activities during the development of mathematical content is an urgent problem of teaching at school at the present stage.

In the last decade, the idea of integrating the process of educational cognition and modern digital technologies has been widely spread, methods of managing educational and research activities are being developed through the use of automated training systems. The distinctive features of these software products based on artificial intelligence methods are the presence of a flexible interface close to the natural language level; a high degree of adaptability, expressed in the ability to group the contingent of students into clusters of individual characteristics, to build parametric models of students reflecting the features of their cognitive development, to carry out differentiation of educational material. Among the most popular foreign intelligent learning systems, we can note MATHia by Carnegie Learning, Yixue Education, Wayang Outpost, Century Tech, Math-u-See, Education Perfect, Wayang Outpost. At the same time, Russian learning systems based on artificial intelligence technologies are rarely used in the educational process of the school. Most of them are developed and implemented within individual universities, within the framework of specific academic disciplines [3]. In this regard, the relevance of the development of didactic mechanisms for the design and implementation of intelligent learning systems for the effective support of research activities of schoolchildren in teaching mathematics is increasing.

The aim of this article is to develop a set of stochastic research problems for a hybrid intelligent learning system based on facet technology considering the gradation of schoolchildren's research activity levels and thinking profiles.

RESEARCH OVERVIEW

In the theory and practice of education, the research activity of students is understood as a special type of intellectual and creative activity, initiated as a result of the functioning of search activity mechanisms and based on research behavior. To the most essential components of A.I.'s research behavior. Savenkov relates convergent thinking (logical algorithms, analysis and synthesis, judgments and conclusions) and divergent thinking (the ability to detect and formulate a problem, generate a large number of ideas for its solution, a non-trivial approach to assessing the situation) [25]. Management of research activities is assessed by researchers as a difficult task, since the teacher cannot always control the process of obtaining educational results and adjust the teaching methodology depending on the individual characteristics of the student, the pace of mastering the material, learning ability and other factors [20].

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This opportunity has appeared thanks to the creation of automated learning systems of a new generation – intelligent learning systems, the concept of which is based on the use of a wide range of intelligent technologies: expert systems, fuzzy logic, neural networks, associative memory. The most important characteristics of intelligent learning systems include the ability to accumulate knowledge and use it for self-learning, adapt to the individual capabilities and needs of the student, design an individual educational route depending on the level of subject training.

Currently, numerous studies are being conducted in the field of creating and implementing intelligent learning systems in the educational environment of schools and universities. In the works of E.A. Lavrov and N.L. Barchenko, a neural network model of a student is constructed, which allows solving the problem of choosing the optimal educational impact in an adaptive learning environment [16]. As the parameters that formed the core of the model, not only the initial knowledge and procedural components of mastering the course materials were identified, but also psychophysiological characteristics (type of thinking, learning ability, receptivity to knowledge), which ensures the updating of the model during training.

In the research of P.D. Basalkin, A.E. Timofeev, the implementation of the shell of a hybrid intellectual learning environment based on production-type knowledge and neural network decision-making technologies is presented. As a formalism for describing the knowledge of an expert (teacher) at the infological level, a graph of solutions is proposed that allows to compactly describe the logic of reasoning when planning a working learning scenario. The knowledge acquisition subsystem provides algorithms for transforming the decision graph into a set of production rules and converting it into an equivalent direct distribution neural network according to the logic of "reasoning". The mechanism of step-by-step formation of a learning scenario under the control of a neural network is described, taking into account the possibilities of a two-level (compact and detailed) representation of the studied material and returning to any of the previous states if necessary, repetition of the studied concepts [5].

The works in the field of intellectualization of the educational research process deserve special attention. N. Nirmalakhandan's scientific article is devoted to the creation and application of computerized adaptive textbooks for assessing problem-solving skills [18]. D.H. Jonassen has developed educational materials that support the metatheory of problem solving based on the initiation of dialogue and research, rather than the formation of a final answer [12].

The scientific literature presents the results of empirical studies proving the advantage of learning in intelligent environments over the traditional format and the possibility of its mass use in educational organizations: an analysis of the effectiveness of an adaptive course in statistics at Carnegie Mellon University [6]; a comparative study of the effectiveness of adaptive courses for engineering areas under-Cooking at the University of New South Wales [21]; quasi-experimental research within the framework of the Adaptive Learning Market Acceleration Program [29]; Adaptive Learning in Statistics project at the Universities of Maryland [13]; research on the effectiveness of teaching mathematics on the Intellipath platform at the Colorado Technical University [9], as well as in the adaptive LearnSmart system at the University of Texas University [27].

An important task in the development of an intelligent learning environment is the construction of an integrated profile (model) of the learner, taking into account cognitive, affective and metacognitive factors and allowing to create personalized recommendations, to give timely and flexible feedback in terms of progress in educational modules. In a number of developed adaptive learning systems, personalization was achieved by identifying cognitive characteristics (working memory capacity, inductive reasoning ability, associative learning skills) [2, 7]; affective states [1, 8, 28]; personal characteristics [17]; consideration of emotional experience (interest in mathematics, expectation of success, self-efficacy) [22, 23]; learning dynamics [24]; styles of education [15]. In particular, paper [1] provides an overview of the theory of personalized learning, learning technologies that support personalization of higher education, current practices, and case studies of the implementation of technology models to support personalized learning. Paper [8] presents a learning path recommendation system using a variable-length genetic algorithm. The system takes into account the learning styles and knowledge levels of students. The aim of the paper [28] is to determine the effectiveness of the adaptive learning technology for the management course for undergraduate students in comparison with traditional teaching methods. In this case, the effectiveness assessment was based on Bloom's taxonomy of learning competencies.

It should be noted that the design based on learning style models is recognized by the international community as the dominant direction in the field of e-learning. Most scientific studies show that adaptive systems that take into account the learning style, contribute to increasing the productivity and level of student achievement, reduce learning time [11].

Thus, the analysis of the scientific and methodological literature allowed to formulate requirements for the selection of content and structuring of knowledge databases and procedures taking into account the individual and psychological peculiarities of students in the digital intellectual environment of mathematics learning, in particular:

1. Accounting for the dominant channel of perception and analysis of information by learners;

2. Taking into account the dynamics and levels of formation of age and personal needs, interests and qualities, as well as the characteristics of learners;

3. Taking into account the age characteristics of learners, as the information and educational environment is increasingly used by different age groups, therefore, it should be developed with the needs of learners in mind;

4. Taking into account the thinking styles of schoolchildren (synthetic, pragmatic, nonlinear, probabilistic, etc.), as they determine how students approach research tasks, what is the content and volume of intellectual support of the information and educational environment;

5. Accounting for the executive functions of managing behavior change.

RESEARCH METHODS

A team of scientists from I.A. Bunin Yelets State University has developed a hybrid intelligent learning system (HIOS) that provides management of students' research activities based on the deployment of individual educational trajectories during the development of complex mathematical knowledge.

The key aspect of the student's personality development when teaching mathematics in this system is the activity of performing ordered, forming a single motivational and applied integrity of complexes of tasks belonging to the category of non-standard, research. Such tasks are characterized by the complete absence of an algorithmic prescription, the multiplicity of hypotheses, methods of solution and require the search for an explanation and proof of regular connections and relationships, experimentally observed or theoretically analyzed facts, phenomena. As a result, there is a "discovery" of new knowledge about the object of research, a method or medium of activity, the development of methods of scientific cognition, a deeper penetration into the essence of mathematical concepts, ideas. Such "zones of modern achievements in science" as fuzzy sets, elements of fractal geometry, complex numbers, optimization models and methods, random variables and processes act as generalized constructs of complex knowledge for managing the research activities of schoolchildren in the HIOS.

During the generation of a set of research tasks, the expert system of HIOS takes into account the peculiarities of the psychophysiological state of the student, the initial level of knowledge, selects such parameters of the educational process as the level of complexity and depth of study of the subject, the style of presentation, the speed of providing the material, thereby building an individual educational trajectory. Pedagogical support of research task complexes is represented by instructions and rules, detailed by the levels of development of research activities; information support (references, bibliographic sources, presentations, videos, formulas and tabular data, graphic materials) taking into account the factors of modality of perception and the profile of thinking.

In order to fill the database of research tasks for a hybrid intelligent learning system, the faceted classification method of S.R. Ranganathan was used, which assumes parallel division of a set of objects by one attribute into separate, independent from each other subsets. The advantages of facet classification are its multidimensional nature, the ability to simultaneously take into account several independent parameters [26].

The didactic possibilities of facet classification include: multilevel (the possibility of using it at different stages of research – from hypothesizing to constructing and transforming a mathematical model, then to setting a new research task), simplicity of automatization (the possibility of integrating algorithms for constructing facets into a hybrid learning system), the construction of an individual educational system. trajectories (the possibility of forming a variable set of problem-oriented tasks of varying complexity and content).

Two facet features are defined as independent classification parameters when filling the database of research tasks – the level of development of research activity and the profile of the student's thinking.

The gradation of the levels of research activity is based on the time of deployment of research procedures by a student in accordance with such criteria as the degree of independence at certain stages of the study, the measure of completeness of the operations performed, their rational consistency. The characteristics of the levels of research activity are presented in Table 1.

Table 1

Characteristics of the levels of research activity of schoolchildren in the field of mathematics

Level	Research activity procedures in the process of mastering complex mathematical knowledge
Approximate-motivational	-actualization of the basic contradictions leading to the emergence of the problem field of the mathematical object under study; -analysis of the variability of definitions, methods of representation and conditions of existence of the object; -historical and genetic substantiation of the content of mathematical knowledge;
Reproductive	-updating of previously acquired mathematical knowledge; -actualization of forms and methods of scientific cognition based on the analysis of standards of problem solving; -the choice of methods of activity for the disclosure of individual qualities of the object under study;

Empirical	-implementation of empirical tests, search for particular manifestations of the essence of the object under study; -formulation of hypotheses, analysis of their adequacy, reliability;
Theoretical	-setting a research task and building a plan for its solution; -construction of a conceptual and then mathematical model of the object under study; -mastering the methods of scientific thinking (induction, deduction, analogy, etc.)
Creative	-varying the conditions and data of the task, independently setting new tasks; -transfer of research methods to a new situation;-generation of conclusions, theoretical and empirical generalizations; -search for the area of real applications of the studied mathematical models

Organizational and methodological support for the development of research activities of schoolchildren in the HIOS requires taking into account the individual characteristics of each student in choosing approaches to the problems of modeling the phenomena under study and to finding solutions to problems. These features are largely due to the dominant type of thinking, which is a set of individual methods of analytical and synthetic transformation of information, manifested in the dynamics and orientation of mental activity, methods of decision-making and their implementation.

American psychologist J. Bruner identified four basic types of thinking (objective, figurative, symbolic, symbolic), each of which has specific characteristics. Regardless of the type of thinking, each individual is also characterized by a certain level of creativity – the ability to think creatively and find non-standard solutions to problems, the presence of which ensures success in any field of activity. The combination of the dominant type of thinking and the level of creativity is the most important personal characteristic that determines a person's style of activity, his inclinations, interests, and professional orientation. This characteristic in classical psychology is designated by the term thinking profile.

Let's give a brief description of the thinking profiles diagnosed in high school students at the initial stage of work in the HIOS. The authors have identified the following profiles of thinking: sign-symbolic, figurative-geometric, concrete-activity, information-computing and historical-genetic.

STUDY RESULTS

Let's consider the facade technology of constructing a chain of research tasks in mathematics on the example of stochastics. In our opinion, the priority role of stochastics in the improvement and development of mathematical thinking of schoolchildren is due to the possibility of indirectly forming a unified scientific picture of the world, stochastic worldview, modern (probabilistic) style of thinking, as well as mathematical culture as one of the main components of the general culture of the individual.

The base of research tasks in stochastics is presented in the form of a classification matrix, in which vertically we distinguish the levels of development of research activity of schoolchildren, and horizontally – the profiles of thinking. A partial filling of the bank of stochastic research problems is presented in Table 2.

Table 2

A partial filling of the bank of stochastic research problems

Vertical levels	Horizontal levels
	Symbolic
	In a round target, which can be considered a set of points *(x, y)* such that $x^2+y^2 \leq 1$, *one shot is fired. Specify all possible events that can be determined based on a set of* Ω *elementary events*

Approximate-motivational	**Figurative-geometric**
	There is a regular triangular pyramid, one of the faces of which is gray, and the other three are white. The pyramid is thrown on the table and the edge with which it comes into contact with the table is observed. Are the events "tetrahedron fell on the gray face" and "tetrahedron fell on the white face" equally possible?
	Concrete-activity
	Do the following experiment: tossing a coin before the coat of arms appears. What are the possible elementary outcomes?
	Information and computing
	In the binary number system, a machine word is written in a memory cell containing 32 numbered binary digits. What is the total number of equally possible outcomes for writing in such a cell?
	Historical and genetic
	There are 3 pairs of identical gloves in the box. Two gloves are pulled out of it without looking. Suggest possible sets of elementary events and determine how many elementary outcomes make up the selected sets.
Reproductive	**Symbolic**
	Let Ω={«1», «2», «3», «4», «5», «6»}, and the relative frequencies are known P*n({«5», «6»})=0,70; P*n({«1», «2», «3», «4»})=0,30. Will there be a three (Ω, S, P*n) a probability space if: а) S= {θ,{«1», «2», «3», «4»}, {«5», «6»}, Ω}? б) S= {θ, Ω}? в) S= {θ,{«5», «6»}, Ω}? г) S= {θ,{«1», «2»}, {«3», «4», «5», «6»}, Ω}?
	Figurative-geometric
	Some faces of a regular icosahedron are colored black, and the rest are white. When throwing the icosahedron, it was found that the probability of a black face falling out is 3 times greater than the probability of a white face falling out. How many faces are painted white?
	Concrete-activity
	Conduct a thought experiment consisting of 100 coin tossing tests. What do you think, what numbers are approaching with the increase in the number of experiments conducted: a) the relative frequency of loss of "eagles"; b) the relative frequency of the loss of "tails"; c) the difference in the relative frequencies of "eagles" and "tails";d) the difference in the absolute frequencies of "heads" and "tails"?If you find it difficult to answer these questions, conduct a real experiment.
	Information and computing
	The information system encodes the signal using m-dimensional vectors whose coordinates are the numbers 0 and 1. Considering such a vector as a random event, construct in particular cases a) m=1; б) m=2; c) m=3 the space of elementary events and, in general, determine its dimension.
	Historical and genetic
	When determining an infection using a medical test, the following absolute values are found: a positive test is observed in 298 out of 300 cases when there is an infection and in 340 out of 4000 cases when there is no infection. a) Determine the probability of an incorrectly positive test when the test shows the presence of an infection, but there is actually no infection. b) Determine the probability of an incorrectly negative test when the test shows the absence of infection, but it actually exists.
Empirical	**Symbolic**
	The number x is randomly selected from the segment [0; 1]. Find the probability that: а) $x^2 < 0,25$; б) $x^2 < 0,09$; в) $x^2 - 1 \geq -0,36$; г) $x^3 > 0,027$
	Figurative-geometric
	A point is randomly selected on the chessboard. What is the probability that it will fall: a) on a white cell; b) on a black cell; c) on the border of black and white cells?
	Concrete-activity
	Come up with an example of such an infinite series of tests with Monet-the one in which the difference in the absolute frequencies of the loss of "heads" and "tails" increases indefinitely, and the difference in relative frequencies decreases and approaches zero. What do you think will happen to these differences in a real test series?

	Information and computing
	Randomly selected an integer from the interval (100; 200). Find the probability that: a) it does not end with zero; b) among its digits there is at least one digit greater than 2; c) it is not the square of an integer;d) the sum of its digits is less than 17.
	Historical and genetic
	The Earth's satellite moves in an orbit that is enclosed between 60o north and 60o south latitude. Considering the fall of the satellite to any point on the Earth's surface between these parallels is equally possible, find the probability that the satellite will fall above 30o north latitude.
Theoretical	**Symbolic**
	Let ξ_k — the number of occurrences of outcomes k in n trials of the polynomial scheme. To find: 1) $P(\xi_1=m_1)$; 2) $P(\xi_2 = m_r, ..., \xi_k=m_k/\xi1=m_1)$, if p_k 1,..., N, – the probability of occurrence of outcome k in one trial.
	Figurative-geometric
	The segment is divided into four equal parts. Eight points are thrown at random on the segment. Find the probability that two points will fall on each of the four parts of the segment. It is assumed that the probability of a point hitting a segment is proportional to the length of the segment and does not depend on its location.
	Concrete-activity
	The insurance company has 10 thousand customers. The insurance premium of each client is 500 rubles. Upon the occurrence of an insured event, the probability of which, according to available data and expert estimates, can be considered equal to p = 0.005, the insurance company is obliged to pay the client an insurance amount of 50 thousand rubles. What profit can an insurance company expect with a reliability of 0.95?
	Information and computing
	An 8-bit binary number is written to the memory cell. The values 0 and 1 in each digit appear with equal probability. Find the probability that a binary number contains four units.
	Historical and genetic
	In a sociological survey, in order to determine the share of the electorate supporting a certain party, an independent survey of a random sample of voters is conducted. Is it appropriate to describe this experiment with a Bernoulli test scheme?
Creative	**Symbolic**
	One telephone line can receive two types of calls: urgent and simple. When an urgent call is received, the conversation on a simple call stops. Probabilities of receipt over time (t; t+h) urgent and regular calls are equal respectively $\lambda_1 h+o(h)$, $\lambda_2 h+o(h)$, $h \to 0$; the probability of termination of any conversation during (t; t+h) equal to $\beta h+o(h)$. Let P1(t), P2(t), P3(t) – the probability that at time t the line is free, busy with an urgent call, busy with a simple call. Write for Pk(t) differential equations and find $\lim_{(t\to\infty)} P_k(t)=\pi_k$
	Figurative-geometric
	On the segment AB of length a, five points are thrown at random. Find the probability that two points will be located from point A at a distance less than x, and three at a distance greater than x. It is assumed that the probability of a point hitting a segment is proportional to the length of the segment and does not depend on its location.
	Concrete-activity
	Suppose two people are playing a game with each other consisting of a sequence of separate games. In each game, the opponents have the same chances of winning, there can be no draw in the game according to the rules. For winning a game, the winner gets one point, the loser gets zero points. The results of different parties have no influence on each other and are independent in a probabilistic sense. According to the terms of the game, the first one to score three points will receive the entire prize fund of 10,000 rubles. With the score 2:1 in favor of the first player, the game was interrupted due to circumstances beyond their control and cannot be continued later. In this situation, how to divide the prize fund fairly?
	Information and computing
	Numbers divisible by 4 are selected from the table of random numbers until 588 is typed. Find an approximate value of the probability that a table containing at least 2100 numbers will be required.
	Historical and genetic
	The three brothers sowed wheat, but "... in a long time, grief soon happened to them: someone began to walk in the field and stir the wheat. Finally they figured out to stand guard, to save bread at night, to waylay an evil thief." In their village, everyone knows that the older brother falls asleep on patrol with a probability of 0.8, the average is 0.4, and the younger one has insomnia. Find the probability that all the brothers will be able to catch the thief on the first night.

DISCUSSION AND CONCLUSION

The study proposed a new solution to the problem of organizational and methodological provision of a hybrid intelligent school learning system in the form of hierarchical and multistage complexes of mathematics research problems. In order to populate the database of research tasks, the authors used a facet classification method. This method has already been applied by researchers in high school [10] and its effectiveness has been established by the authors for basic school. The technology of meaningful filling of the bank of research tasks based on facet classification is generally presented in a sequence of steps: 1) selection of a section (topic) of the training course; 2) selection of tasks of a similar structure related to a certain facet; 3) selection of facet signs (changeable elements, on the basis of which subgroups are allocated and facets are constructed) and basic words (common im-mutable elements); 4) formation of a facet formula of the problem (a structure writ-ten using facet features and base words); 5) determination of the possible values of the facet features, the combination of which with the facet formula will generate new task conditions.

Following the technology of facet classification, at each level it is possible to obtain a variety of tasks constructed according to one facet formula. Their number depends on the set of possible values of each facet feature and can be increased by adding new facet values to those already indicated.

In the course of the study, the expediency of using facet technology for constructing a complex of research tasks with variable structural elements covering the entire space of thinking profiles and levels of development of research activity in school-children is substantiated. The didactic possibilities of facet classification are revealed, which allow automating the construction of an individual educational trajectory, developing students' skills of independent research activity. The corresponding facet formulas have been developed and the completion of a facet complex of multilevel stochastic research tasks has been proposed, which has the properties of dynamism and extensibility, which allows generating tasks of intermediate and final control, tools for evaluating results.

The obtained results are consistent with previously conducted studies reflecting the idea of technical support for scientific developments and educational technologies using automated systems [14; 26]. The materials presented in this article make a joint contribution with the authors to the development of the problem of using faceted classifications as an effective tool for constructing knowledge organization systems accessible for machine processing.

Thus, a significant contribution has been made to solving the problems of organizational and methodological support of students' research activities in the process of mastering complex mathematical knowledge using the functionality of a hybrid intellectual learning environment.

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