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TECHNOLOGY OF DEVELOPMENT OF A HYBRID INTELLIGENT SYSTEM OF TEACHING MATHEMATICS

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Abstract

Hybrid neural networks are an effective tool for solving complex, multicomponent, multifunctional tasks, which include the system for assessing knowledge and competencies. At the same time, expert systems with fuzzy logic, staged data analysis with elements of stochastic analysis should be updated. The objectivity and efficiency of assessing the educational results of students belong to the class of tasks with the peculiarity of the development and parameterization of structural-logical, hierarchical, functional and fractal schemes for structuring data of the integral didactic field of educational elements. In this regard, it is relevant to build a hybrid intelligent system with dynamic random sampling on layers of an artificial neural network with the function of evaluating educational results. The article defines the functional of the hybrid intellectual system of research activity of schoolchildren on the basis of the identified key parameters and structure of an artificial neural network using expert systems and fuzzy modeling. A technology has been developed for constructing structural-logical, hierarchical, functional and fractal schemes for structuring databases of generalized constructs of modern knowledge. The principles, content and structure of parameters and components of databases, selection criteria and the content of complexes of educational standards of research activity of schoolchildren have been determined.

Keywords: Intelligent systems, principles and technology for designing training systems, artificial intelligence

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1. Introduction

The problem of self-organization and self-development of a pupil's personality in the process of teaching mathematics dictates the need to include in a single integrity research and cognitive, social and personal strategies of behavior in the course of mastering mathematical content. This creates a precedent for the symbiosis of mathematical and computer modeling in an enriched information and educational environment with the implementation of the functionality of intelligent systems in the process of mastering complex knowledge. At the same time, the possibility of adapting modern achievements in science to school mathematics and computer interactive interaction with a school subject enhances the developmental effect and increases educational motivation, reveals connections with real life and practice, creates the phenomenon of manifestation of synergistic effects in the development of complex mathematical knowledge.

Design and development of intelligent learning environments – systems with elements of artificial intelligence, today is not only the trend of modern education in the era of the network society, but an urgent need. The study of the methods and technologies of artificial intelligence (AI) in education enables educators at the international level to make a breakthrough to personalized learning, explore the various effects of the impact of AI on learning, and explore the possibilities of more productive use of these technologies in education. It is necessary to manage and apply it correctly in the direction of modernizing training models focused on new competencies and forms of training, provoked with the dynamics of economic development in conditions of uncertainty, a rapid change in technology, namely, on the formation of skills and competencies of the 21st century.

In the modern period, it is necessary to revise the basic principles and technologies, scientific and methodological approaches to improving the information and educational space in the context of the design and development of hybrid intelligent systems based on AI methods both in teaching mathematics and in determining technologies for assessing knowledge and competencies. *How and in what educational situations is it possible to effectively use intelligent systems, including hybrid artificial neural networks?* This is especially true for assessing the knowledge and competencies of pupils, which are characterized with the complexity and non-formalization of tasks, the variety of individual differences among students and the multiplicity of primary factors that determine the essence and objectivity of assessing the results of personal achievements (subject, meta-subject and personal). The second direction of the possible use of intelligent systems in education can be associated with improving the quality of research activities of schoolchildren. These can be quality parameters such as the level of scientific training, motivation, organization, perseverance and responsibility, creative self-development and self-realization, critical thinking, independence. In addition, it is teamwork, intercultural interaction, actions in conditions of uncertainty, self-improvement, the need for intellectual activity, collection, study and processing of information, analysis of the problem, the practical significance of the project, self-assessment (objectivity), etc. (Carnoy et al., 2016; Golubev & Testov, 2015; Larina & Kapuza, 2020; Paniagua & Istance, 2018).

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2. Problem Statement

We will proceed from the fact that the system of parameters of the elements of scientific knowledge and the quality of research activity of schoolchildren consists of three clusters of parameters: scientific thinking, scientific activity and scientific communication. The ultimate attractor of the research activity of schoolchildren should be a database of modern achievements in science (elements of fractal geometry, the theory of information coding and encryption, fuzzy sets and fuzzy logic, generalized functions, cellular automata, etc.). Researchers conclude that complexity is an integrating characteristic of the ability to self-organize when reaching certain critical levels, the ability to effectively develop and self-develop thinking and personal qualities of the learner. Bruner (1962), Haken, (1996), Ostashkov et al. (2016), Sekovanov (2016), De Corte (2019) have convincingly shown that effective personality development occurs when mastering complex knowledge (different levels of its complexity depending on the personal development of learners, including inclusive education). Moreover, if there is creating situations of overcoming difficulties in the process mastering knowledge and a single picture of the world on the basis of a high degree of deployment of educational and professional motivation of learners in a single network of interactions, independence and coherence.

The resolution of contradictions related to the quality and success of the research activities of schoolchildren and an objective assessment of the results of teaching mathematics is possible with the strengthening of the *individualization* of the research and evaluation process and the development of the subjectivity of schoolchildren on the basis of recognizing the processes and results of adaptation of complex knowledge and procedures. If there is creation of conditions for the disclosure of internal processes and mechanisms of the adequacy of the development of cognitive processes and external acts on the basis of personality identification in the process of mastering complex knowledge and procedures. They are *personalization*– the representation of the subject in other people; *isolation*– the selection of an individual in interaction with other people; *appropriation* by the individual of the all-round human essence.

The use of intelligent systems in education (neural networks, fuzzy logic, cellular automata, hybrid expert systems with fuzzy logic, etc.) is actively implemented in the development of instrumental environments and software systems for assessing learners' knowledge and competence (Chaira, 2019; Dvoryatkina, Menlikov et al., 2017; Dvoryatkina, Smirnov et al., 2017; Hadzhikolev et al., 2019; Kozlov et al., 2017; Ostroukh & Surkova, 2015; Pyatkovsky & Guner, 2012 etc.). Pedagogy is full of fractal constructions: from a multilevel educational system of knowledge engineering (an expert system learning interface) to a subsystem for learning knowledge and procedures by students (based on the organization of the user interface). Revealing the fractality of the structure of pedagogical phenomena and objects (scientific and mathematical knowledge, educational content, educational element, knowledge base) makes it possible to apply fractal methodology and its principles in the phase of analysis, selection and structuring of educational material as a knowledge base based on the identification of hierarchies and characteristics of fuzzy modeling, in the choice of methods for its primary representation by fuzzy and linguistic variables, as well as in the diagnosis of the quality of assimilation of educational material by learners based on artificial neural networks. It has been established that the use of fractal methods increases the compactness, accuracy and depth of assessing the level of training of learners, complexes of

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intellectual operations and integrative qualities that allow mastering and applying interdisciplinary knowledge and skills in professional activities (Dvoryatkina, Melnikov et al., 2017; Smirnov et al., 2016, etc.). The emergence and formation of self-similar structures in pedagogy is not accidental, since this is one of the natural ways to increase the efficiency, reliability and sustainability of the development of modern intelligent learning systems. This determines the importance of the fractal approach in pedagogy when using intelligent systems to support and accompany the mathematical education of schoolchildren.

3. Research Questions

Intelligent management of the research activities of schoolchildren is characterized with the solution of the following questions:

3.1. determination of the parameters of the functioning of stochastic, threshold, bifurcation and fluctuation transitions of search and creative procedures for the content of the cognitive activity of schoolchildren;

3.2. assessment of education results based on the implementation of expert systems with fuzzy logic and hybrid neural networks;

3.3. the multiplicity of goal-setting of the functional and content of computer modeling of processing and accounting processes of personalized databases of images, texts, signals, tabular data based on effective feedback;

3.4. organizing a dialogue of mathematical, informational, natural science and humanitarian cultures and the resulting effects of synergy and self-organization of schoolchildren in research activities and assessing the quality of knowledge and competencies;

3.5. optimization of the results of the functioning of intelligent systems in the direction of their classification, clustering, segmentation, regression in accordance with the standards and patterns of intellectual management of cognitive activity and the assessment of the results of mathematical education.

4. Purpose of the Study

The purpose of the study is to develop a technology and model for a hybrid intelligent system of support and accompaniment of research activities of schoolchildren in the course of adaptation of generalized constructs of modern scientific knowledge.

5. Research Methods

In the course of the research, a theoretical analysis of scientific literature and the design of a hybrid intellectual system capable of accompanying and supporting the research activities of schoolchildren were applied.

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The basic principles, methods and guidelines for the design and development of intelligent learning systems (ILS) are considered in the context of the unity and mutual influence of the three components of the structure of methods for designing information and educational space:

- integration and functionality of adequate digital educational platforms and technologies based on the deployment of neural networks, expert systems and fuzzy modeling;
- the unity and integrity of the generation of the digital interaction infrastructure in the context of the interactive triad "teacher – computer – learner" of the educational process;
- the hybridity and effectiveness of the implementation of feedback in the digital information and educational content of support for the research activities of schoolchildren.

The fundamental principles and guidelines for designing ILS as a set of digital platforms and technologies are:

- hybridity;
- intelligence of management;
- prismatic;
- the unity of educational and technological logic;
- the openness of the system;
- coherence;
- consistency of technologies and instrumental environments.

6. Findings

The basic requirements and technological components of the digital interaction infrastructure of an artificial neural network have been developed in the context of the implementation of the interactive triad "pedagogue – computer – learner" of the educational process of organizing research activities of schoolchildren:

- *flexibility and adaptability of the organizational structure*, which is responsible for the implementation of various options for building an individual educational strategy, depending on the personal characteristics and capabilities of the learner. The principle permeates all aspects of the educational process: content, forms of organization, methods, technologies and teaching aids. ILS is aimed at qualitative changes in the individual characteristics and abilities of students; it favors an increase in the speed of thought processes, an increase in the level of knowledge and skills, efficiency, the level of cognitive and practical activity in educational activities. The principle of flexibility is designed to respond quickly to changes in the content of education, taking into account the needs and interests of learners, the constantly changing requirements of the educational paradigm. An adaptive digital educational process, including a system for diagnosing individual characteristics, automatically adjusts to the needs of each

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specific student. It implements the possibility of creating unique educational programs that adapt to psychological and pedagogical characteristics (determining the order, method and pace of presentation of educational material, the level of complexity of tasks, identification of the level of knowledge and skills, diagnosis of deficiencies in understanding, pedagogical assistance and advice, etc.);

- *resonant-wave effect*– this principle implies the frequency, intensity and contextual emphasis of the impact of information on the student, regulated with the system, in order to intensify the perception of educational material;
- *signs of the expertness of the system in the mode of support of research activities* are manifested in the activation of algorithms for the transition to a highly specialized subject area and the intensification of the use of heuristic databases;
- *motivational-synergetic effect* is the absence of dead-end educational routes, the creation of a situation of success and sustainable motivation for the process of cognition, leading to the self-organization of the student's creative activity and immersive perception of the studied material as a unified system of knowledge;
- *fuzzification of the information flow is carried out* during its transition to the tasks of the middle and upper levels of the gradation of the educational material with the subsequent dispatching of the input data from the student. Thus, the mode of operation of the ILS is emulated by analogy with the functioning of the human brain at the conscious and subconscious levels;
- *visibility of personal assessment* is providing and stating the assessment of the student's performance in the form of a simplified interface;
- *systemacity, variability and integrity of ILS*– content, methodological, technological integrity of the educational process in the continuity of all levels of education.

Below is a model of a hybrid intellectual system of support and accompaniment of research activities of schoolchildren in the course of adaptation of generalized constructs of modern scientific knowledge (Figure 01).

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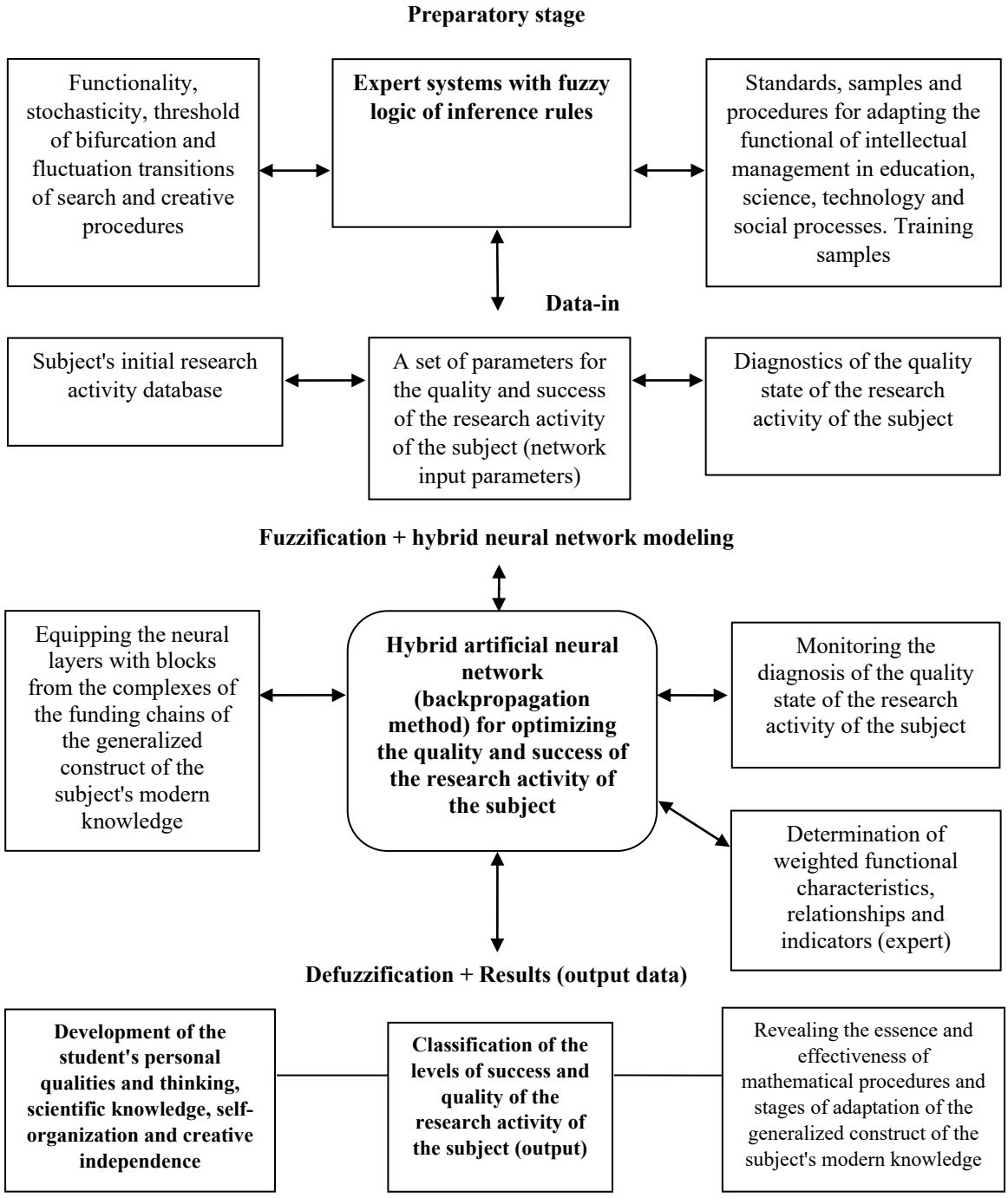

Figure 1. Model of a hybrid intelligent system of support and accompaniment of research activities of schoolchildren

Thus, the basic principles and guidelines for the design of ILS have been developed as a combination of digital information and educational content:

- *informational richness of the educational environment* – the principle is focused on the redundancy of didactic, resource opportunities when choosing elements of the content of educational material and the level of its development for a high-quality solution of educational problems;

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- *individualization and personalization of educational routes*– it is based on the establishment and maintenance by the system of fast dynamic feedback and correction of the ILS actions according to the individual characteristics and needs of the student;
- *fractality* – it allows you to present the educational elements of the subject area in the form of fractal models and to ensure, on this basis, the identification of the essence of objects and procedures for the study of "problem areas" or the integrity of the reflection of local attractors of a complex system (knowledge and procedures) in the process of assessing the quality of the educational process depending on from the depth of interpenetration and intersection of growing and multiplying fractal structures;
- *transdisciplinarity*– it provides a solution to complex problems of interaction between natural science and humanitarian cultures, as a constructive dialogue between various scientific fields, as a form of interaction between disciplines to understand the phenomenon of systems complexity.

7. Conclusion

Requirements have been developed for the organization and construction of an artificial neural network for organizing and designing research activities of schoolchildren based on fuzzy modeling: an artificial neural network is a multi-layer network (consisting of input, output and hidden layers) of direct action with back propagation of errors based on fuzzy modeling.

In the direction of using the elements of fractal geometry, technological designs of clusters have been developed, which constitute the basis for the design and individualization of research activities, the development of generalized constructs of modern scientific knowledge by schoolchildren with the use and support of a hybrid intellectual system. In particular, it is revealed that the didactic field of research activity is equipped with a system of multi-level hierarchical databases of exercises, motivational-applied, research, practice-oriented tasks using expert systems and the integration of mathematical, informational, natural science and humanitarian knowledge and procedures.

The novelty is determined by the peculiarity of interactive interaction (subject – intellectual system – expert (teacher)) in the course of the research activities of schoolchildren and the correspondence of the quality of the studied educational elements to the parameters of the individual formation of personal qualities. The resulting system of principles for designing ILS allows you to modernize and improve existing interactive training systems.

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