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Технология самоорганизации математической деятельности на основе интеллектуального управления

Авторы исследуют проблему самоорганизации личности в процессе адаптации современных достижений в науке в обучении математике методами компьютерного и математического моделирования на основе интеллектуального управления. Исследование касается задачи освоения современного раздела математики доступными как для школы, так и для вуза средствами построения обобщенных конструкций сложного знания, касающихся анализа и существования нечетких множеств на основе нейросетевого моделирования. Разработана технология самоорганизации математической деятельности в ходе исследования и адаптации современных достижений в науке на основе математического моделирования и компьютерного дизайна с проявлением эффектов самоорганизации личности. В ходе освоения сложного понятия на основе историогенеза и приложений выстроены технологические конструкты кластеров фундирования компонентов обобщенного конструкта в направлении построения индивидуальных образовательных траекторий обучающихся с использованием гибридных искусственных нейронных сетей. Выявлено содержание мотивационного поля математической деятельности обучающихся в соответствии с личностными предпочтениями, реализовано множественное целеполагание процессов освоения нечетких множеств и fuzzy logic, разработаны средства коммуникации на основе интеграции математических, информационных, естественнонаучных и гуманитарных знаний и процедур. Интеллектуальное управление когнитивной деятельностью обучающихся в ходе освоения сложного знания создает зоны ближайшего развития и саморазвития обучающихся на основе развертывания индивидуальных образовательных маршрутов и интеграции математических и информационных знаний, проявления синергетических эффектов в освоении математики.

Ключевые слова: обучение математике в школе и вузе, самоорганизация личности в математической деятельности, интеллектуальное управление

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Self-organization technology of student's mathematical activities based on intelligent management

The problem of a personal self-organization in the adaptation of modern achievements in science process in teaching mathematics by means of computer and mathematical modeling based on intelligent control are considered. The research for both schools and universities concerns the problem of modern areas of mathematics mastering and adaptation based on neural network modeling and using an artificial intelligence methods and synergistic approach by means of complex knowledge generalized constructions related to the analysis and essence of fuzzy sets. The technology of mathematical activities self-organizing of students in learning and adaptation of modern scientific achievements on the basis of mathematical modeling and computer-aided design with the manifestation of synergistic effects are developed, technological constructs of founding clusters of generalized construct components are built during the complex knowledge development based on historiogenesis and applications. The directions of student's individual educational trajectories building using the hybrid artificial neural networks are considered. The content of the motivational field of student's mathematical activity in accordance with personal preferences is revealed, multiple goal-setting processes for the development of fuzzy sets and fuzzy logic are implemented, communication tools based on the integration of mathematical, information, natural science and humanities knowledge and procedures are developed. Intelligent management of student's cognitive activity during the complex knowledge development creates the zones of immediate development and self-development of students. It will be based on the deployment of individual educational routes and integration of mathematical and information knowledge, the manifestation of synergetic effects in mathematics understanding.

Key words: teaching mathematics at school and university, personal self-organization in mathematical activity, intelligent management

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Introduction

The problem of self-organization and self-development of student's mathematical activities in teaching mathematics process is most important in modern period. It necessitates the inclusion in the unified integrity of motivational value and research, meta-cognitive and emotional-volitional components, social and personal strategies of student's activity during the cognitive development and learning of subject contents. This creates a unique opportunity for the formation and expansion of student's personal experience based on current conditions, the formation and development of critical thinking based on visual modeling of the adaptation processes of modern achievements in science and correction of basic and instrumental competencies in mathematics development. At the same time, the ability to adapt the modern achievements in science to school or university mathematics on the basis of mathematical and computer modeling creates a developing effect of integrative interaction of mathematics with information technologies. It strengthens and increases the educational motivation, reveals connections with real life and practice, creates a phenomenon of synergistic effects in complex mathematical knowledge development in terms of identifying of its essence. First of all, there is an increasing need to update the essence and technology of generalized constructions of modern knowledge adaptation to teaching mathematics both at school and university. At the same time, the key aspect of synergetic effects phenomenon in teaching mathematics can be the ability to adapt the modern achievements in science. It can be realized on the basis of intelligent management and updating the stages and characteristics of the manifestation of complex mathematical knowledge essence, phenomena and procedures in the context of individual educational trajectories of student's deployment. Thus, this research is an attempt to develop a technology for self-organization of mathematical activities based on the adaptation of modern achievements in science by means of intellectual management during the individual educational trajectories deployment in complex knowledge development.

Materials and methods

The implementation of the declared concept is associated with the development of student's complex knowledge by means of mathematical and computer modeling in rich information and educational environment [4; 5; 10; 11]. An effective tool for mastering of complex knowledge can be the study and adaptation of modern achievements in science to school or university mathematics, clearly and significantly represented in applications to real life, the development of other sciences, high technologies and industries. The development of philosophical concept of complexity is mediated by extensive experimental material, practice, and the interdependence of integrative processes in science, technology, economics, social transformations and educational paradigms [6; 7]. Polyvalence, multiplicity, multipolarity, unpredictability, emergence and disequilibrium of modern world cannot be linked to the categories of the essence objects development, phenomena and processes through the manifestation of regularities of higher levels of complexity transitions as the development components of concretely universal theory. *Such procedures are especially evident in the study and adaptation to school or university mathematics of complex mathematical knowledge by gradual and multifunctional manifestation of its generalized essence and*

its integration with educational elements – such in our work are modern achievements in science (for example, [8; 9; 12-16]).

The development of intelligent learning systems based on artificial intelligence methods is a promising direction in solving complex problems of managing students' cognitive activity, aimed on increasing their self-organization and self-learning levels with a continuous decrease of teacher participation degree. Intelligent management of learning process in "teacher – computer – student" triad requires a hybrid approach in mathematical and computer modeling symbiosis of the content and hierarchies of knowledge and procedures, interactive intellectual training and evaluation activities in information environments. It integrates the functions of expert systems, fuzzy logic, artificial neural networks and genetic algorithms. The main question is defined by developing of:

- methods, algorithms, techniques, characteristics of pedagogical and ergonomic quality, technical and software that implements innovative engineering procedures;
- building hierarchies, methods of recognition by fragment;
- evaluating the level of subject knowledge and procedures mastering (image recognition in expert systems) in a computer-simulation environment at all stages of student's training.

It is one of the main components of intelligent educational management systems which remains open in this direction. A distinctive feature of this subject area is characterized by high degree of uncertainty, randomness, instability and the influence of various factors. So that the construction and using of learning models accuracy based on phenomenology, classical mathematics and computer modeling are often ineffective. As a result, more and more works by Russian and foreign authors use a wide range of artificial intelligence methods to solve complex problems of developing intelligent training systems: expert systems, artificial neural networks, fuzzy logic, genetic algorithms, as well as a hybrid approaches with other mathematical directions. The using of intelligent systems in education (neural networks, fuzzy logic, cellular automata, hybrid expert systems with fuzzy logic, etc.) is actively implemented in tools environments development and software systems for evaluating student's knowledge and competence.

Objective: to develop methodological, theoretical and technological bases and the Concept of creating and functioning of an instrumental hybrid intellectual environment for student's research activities in the secondary school education on the basis of modern achievements in science adaptation to school mathematics and evaluation of mathematical knowledge and competencies based on synergetic and fractal approaches:

- to develop and implement a software system using neural networks, expert systems and fuzzy modelling, rules structure the data field of didactic training elements in the course of subject interaction, intelligent systems and expert (teacher) with the manifestation of synergistic effects and the development of personal qualities and thinking of students;
- to develop and justify the methodology of student's research activities and manifestations of mathematical education synergy based on modern achievements in science adaptation to school mathematics and the methodology for evaluating student's knowledge and competencies using intelligent systems in rich information and educational environment;
- to scientifically substantiate and determine the content and structure of intellectual training system in the interactive triad "teacher-computer-student" based on synergetic and fractal approaches, computer modeling and hybrid interface. Conduct

computational experiments and check the effectiveness and validity of the obtained results.

The leading idea is as follows: the basic aspect of development and manifestation of synergetic effects phenomenon and student's personal development in teaching mathematics is complex knowledge reclamation based on modern achievements in science adaptation in rich information and educational environment using hybrid intelligent systems that represent the ability to:

- actualization of the stages and mastering of research characteristics of complex mathematical knowledge essence, phenomena and procedures based on digitalization of educational environment, fractal and synergetic approaches, understanding of research processes of complex knowledge mastering, self-organization of personal activities;
- creating conditions for communication, individual choice of preferences and effective of mathematical, information, natural science and humanitarian cultures dialogue;
- visual modeling of founding modes of student's experience development and personal qualities in the context of creating, mastering and implementing hierarchical complexes and research tasks banks of modern scientific knowledge in the direction of generalized constructs essence identifying;
- identification of self-organization attributes of content, processes and interactions (parameterization and generalization, attractors, bifurcation points, pools of attraction, iterative procedures, etc.) in the course of mathematics "problem areas" research development and knowledge and competencies assessment based on the actualization and adaptation of modern achievements in science (generalized constructs of modern knowledge) and using of hybrid intelligent systems in the context of synergetic and fractal approaches.

Innovative organization technology of research activities based on using of hybrid intelligent systems

Tasks of modern achievements research in science:

- to master the stages of generalized scientific knowledge adaptation to the processes of mathematical activity with student's self-organization effects by means of mathematical and computer modeling techniques;
- to identify and substantiate the mathematical results during the development and research of essence manifestation stages of generalized construct (build a founding spiral of the essence); build graphs of educational elements coordination with elements of generalized structures; provide visibility of modeling and high level of student's educational motivation and self-organization in the context of applications updating and the essence specifying of generalized construct;
- to reflect and update the thesaurus of mathematical education synergy in the course of student's research activities: fluctuations, bifurcation points, attractors, pools of attraction, etc.;
- to develop the divergent thinking and creative independence of students against the background of mastering integrative constructs of mathematical knowledge and procedures, taking into account probable and improbable circumstances, constructing the content, stages, basic and variable characteristics of the object design;

- to develop the ability to adapt and develop in social communication and cognitive activity based on mathematical, information, natural science and humanitarian cultures dialogue.

Conceptual modeling. In the last decade, the interest in artificial neural networks in quantitative and qualitative context increase in the practice of its application in the education field has significantly increased. In English-speaking countries, the issues of personalization and automation training with using of technical and software tools based on neural network algorithms have long been successfully solved. These software products include: GeekieLab, CTI-Content Technologies Inc, Mika, Microsoft Presentation Translator, Thinkster Math, Brainly, Cram101, and others. Many Russian researchers have studied the use of intelligent computer systems in education based on neural network technologies. These studies are: E. I. Goryushkin (adaptive testing in computer science), S. P. Grushevskii (neuro network computer training system), N. Yu. Dobrovolskaya (computer neural network technology as a means of individualized learning), L. R. Tuktarov (intelligent control of educational- upbringing process organization), Zar Ni Hlaing (intelligent support system of learning microelectronics management) and others. Intelligent computer learning systems are developed within individual universities for clearly defined disciplines and groups of students. There is no wider integration into educational activities, particularly in secondary education. In modern psychological and pedagogical research, training is considered as an intellectual process that allows you to design and implement the individual educational routes depending on subject training level and individual psychological characteristics of students in hybrid learning environment. Promising are new interdisciplinary research areas in the study of complex self-organizing systems. The leading role in the analyzed aspect is played by the synergetic approach in education, which determines the design of individual educational environments that consist of educational elements of different levels based on the processes of its self-organization. The synergetic approach is based on mechanisms of interdisciplinary interaction in order to create a new, more complex structure with new quality.

Intelligent management in the mathematical education of students is use of intelligent systems functionality (including a hybrid artificial neural networks) in conditions of openness (to external influences and factors) and the synthesis of mathematical and computer modeling in order to identify the essence and effectiveness of mathematical and evaluation procedures based on individualization of teaching mathematics and personalized and computerized feedback actualization of cognitive and evaluation processes. It is characterized by:

- functioning of stochastic, threshold, bifurcation and fluctuation transitions of search and creative procedures for the content of student's cognitive activity;
- evaluation of educational results based on implementation of expert systems with fuzzy logic and hybrid neural networks;
- multiplicity of goal setting functionality and of computer modeling content of processing and accounting of personalized databases images, texts, signals, table data based on effective feedback;
- mathematical, informational, natural science and humanitarian cultures dialogue and final student's synergy and self-organization effects in research activities and assessment of knowledge and competencies quality;
- optimization of the of intelligent systems functioning results in the direction of their classification, clustering, segmentation, regression in accordance with the standards and models of intellectual management of cognitive activity and evaluation of mathematical education results.

Below is a model of hybrid intellectual system for supporting and accompany of student's research activities by means of founding clusters mastering [6] and generalized constructs adapting of modern scientific knowledge (Fig. 1).

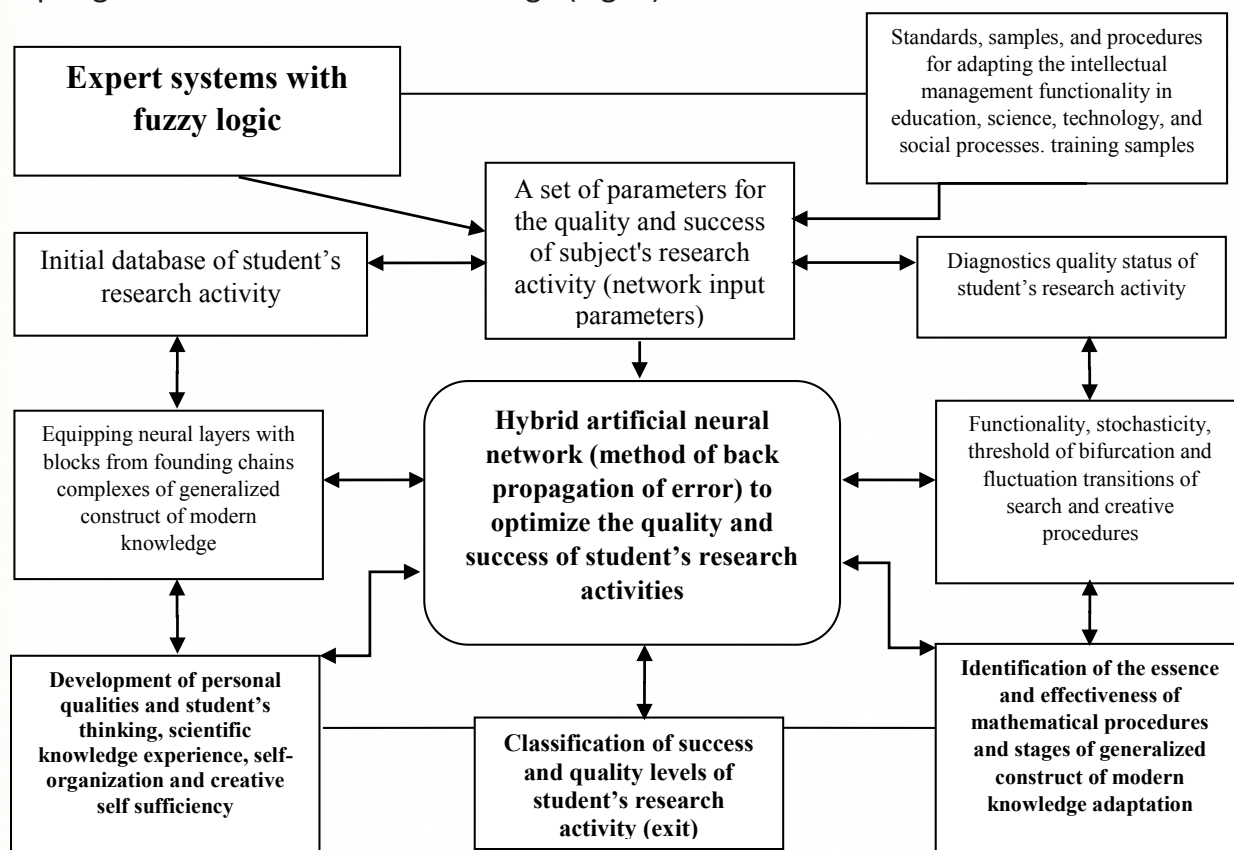


Figure 1 Model of hybrid intelligent system for supporting and supporting student's research activities

Possible using direction of intelligent systems in secondary education can be associated with improving the quality of student's research activities and teacher's innovative activities. These can be such quality parameters as:

- levels of scientific training, motivation, organization, perseverance and responsibility, creative self-development and self-realization, critical thinking, independence, teamwork, intercultural interaction, actions in uncertainty conditions, self-improvement;
- need for intellectual activity, collection, study and processing of information, analysis of the problem, the practical significance of the project, self-assessment (objectivity) [2], technological readiness to search, self-assessment of personal growth, creative independence, etc.

We will proceed from the fact that the system of elements parameters of scientific knowledge and quality of student's research activity consists (among other things) of *three clusters of parameters: scientific thinking, scientific activity and scientific communication* [6]. The ultimate attractors and results of student's research activity should be a database of modern achievements in science (elements of fractal geometry, theory of encoding and encryption of information, fuzzy sets and fuzzy logic, generalized functions, cellular automata, etc.), differentiated by factors reflecting the content of cube coordinate parameters of E. I. Smirnov's mathematical object's essence [8]), based on the typology of perception modalities information [1; 3].

Thus, we will distinguish the following parameters clusters of scientific knowledge elements and quality of student's research activity:

- scientific thinking: creative acts, logical acts, principles and styles;
- scientific activities: research of experience (analysis, synthesis, associations, analogies, collection, study and processing of information, etc.); variability of data, limitation of experience; improvisation, reflection of common sense, trial and error, actions in conditions of uncertainty, problem statement and search for contradictions; obtaining a new or side result, setting an experiment, putting forward a hypothesis;
- scientific communication: accuracy of practical implementation, practical significance of the project, cross-cultural interaction, teamwork, social verification of new knowledge, etc.;
- typology of perception modalities: sign-symbolic, verbal, visual-geometric, concrete-activity;
- experience and personal qualities: technological readiness, need and interest in research activities, creative independence, self-actualization, self-organization, self-realization and self-assessment.

So the procedure for basic parameters diagnostic (no more than 10) at the initial, current (according to research activity levels) and final measurements is required. The research activities success is determined by classification qualimetry of parameter criteria (expert assessment). In addition, the complexity levels of generalized construct (3 levels) can become the factor of elements data base differentiation of modern achievements in science. Thus, if there are 10 generalized constructs, then each of them represents at least 8 modifications designed as a statement of the problem. The content of the database and its formal representation are implemented by experts, and the tool environment and software package are developed by programmers.

Example. A generalized description of the construct: *Fractal geometry of Mandelbrot's and Julia's sets*. Variations of generalized construct:

- historiogenesis and variability of iterative dynamics of Mandelbrot's and Julia's sets representations development;
- iterative processes and computer-based design of Julia's filling sets;
- iterative processes and computer design of Mandelbrot's sets;
- topological and fractal dimensions of Julia's sets and Mandelbrot's sets;
- smooth Julia's sets for Chebyshev polynomials: mathematical and computer modeling;
- method of visualization of Julia's and Mandelbrot's sets in information environments;
- calculation of Feigenbaum constant for the Mandelbrot's set;
- computer design and construction of Cantor and connected Julia's sets.

Results

So we have defined the innovative organization technology of research activities based on using of hybrid intelligent systems: tasks of modern achievements research in science: to master the stages of generalized scientific knowledge adaptation, to identify and substantiate the mathematical results, to reflect and update the thesaurus of mathematical education synergy, to develop the divergent thinking and creative independence of students, to develop the ability to adapt and develop in social

communication and cognitive activity; content and structure of conceptual modeling in artificial neural networks in quantitative and qualitative context in the practice of its application in the education field, content and structure of intelligent management in student's mathematical education using of intelligent systems functionality (including a hybrid artificial neural networks) in conditions of openness (to external influences and factors) and the synthesis of mathematical and computer modeling. Thus, we have distinguished the following parameters clusters of scientific knowledge elements and quality of student's research activity: scientific thinking, scientific activities, problem statement and search for contradictions, research of experience, scientific communication, typology of perception modalities, experience and personal qualities. The model of hybrid intellectual system for supporting and accompany of student's research activities by means of founding clusters mastering and generalized constructs adapting of modern scientific knowledge is constructed and characterized.

Discussion

The successful completion of research activities block chain (individual educational trajectory) on the basis of personal preferences and achievements in rich educational environment stimulates the manifestation of self-organization processes of students and mathematical education synergy in learning of complex knowledge in the identifying the essence context of generalized construct of modern scientific achievements. The student's research activities success will be determined by classification qualimetry of parameter criteria (expert assessment). In addition, the complexity levels of generalized construct (3 levels) can become the factor of elements data base differentiation of modern achievements in science. The content of the database and its formal representation will be implemented by experts, and the tool environment and software package will be developed by programmers.

Conclusion

Identification and research of modern achievements in science in teaching mathematics based on intelligent control allows you to master the generalized constructs of complex knowledge through the integration of various area of science. Thus creating the conditions of openness of educational environment, updating of complex mathematical structures, the plurality of goal setting and the possibility of obtaining by-products provide the basis for self-organization of personality and the effective development of intellectual operations, increase educational and professional motivation, creativity and critical thinking in learning mathematics both at school and university.

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