Онтология и инжиниринг профессионального самоопределения школьников в проявлении синергии естественнонаучных и математико-информационных методов

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АННОТАЦИЯ

Введение. В современном мире очень важны вопросы проектирования методик обучения предметным областям (естественные науки, математические и информационнные методы) с эффектом профессионального самоопределения старшеклассников. В основе инноваций лежит проблема актуализации постнеклассической рациональности естественнонаучного познания и деятельности в открытой цифровой образовательной среде профессионального самоопределения, в основе которой лежит модус самоорганизации обучающихся в освоении содержания прикладного естествознания.

Цель исследования: выявить модели, технологии и механизмы перехода от учебной деятельности субъекта к профессиональному самоопределению и выбору профессии в процессе исследования сложных естественнонаучных процессов и знаний прикладной направленности средствами математического и компьютерного моделирования.

Материалы и методы. Онтологические приемы готовности школьников к профессиональной деятельности и инжиниринг освоения сложных процессов и знаний в области прикладного естествознания; математическое и компьютерное моделирование в цифровой образовательной среде поисковой и исследовательской деятельности школьников; метод голографичности профессионального самоопределения школьников в освоении прикладного естествознания.

Результаты. Выявлены критерии отбора и депозитарий образцов прикладного естествознания на основе математико-цифровых трансформаций; построена структурно-функциональная модель онтологий базисных конструктов методики обучения предметной области с эффектом профессионального самоопределения индивидуума; реализованы принципы и технология исследования многоэтапных математико-информационных заданий в прикладном естествознании с эффектом проявления синергии естественнонаучного образования.

Заключение. Изменчивость и наукоемкость современных профессий прикладного естествознания создают возможности для освоения их технологических компонентов и формирования профессионального самоопределения обучающихся средствами симбиоза математического и компьютерного моделирования.

КЛЮЧЕВЫЕ СЛОВА

профессиональное самоопределение, естественнонаучное образование, математическое и компьютерное моделирование, синергия образования

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The ontology and engineering of professional self-determination of school students in synergy manifestation of natural science with mathematical and digital methods

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ABSTRACT

Introduction. One In modern world the questions of teaching methods designing in subject areas (natural sciences, mathematical and digital methods) with the effect of professional self-determination of secondary school students are very important. The innovation is based on the problem of the actualization of post-non-classical rationality of natural science cognition and activity in an open digital educational environment of professional self-determination. It is based on the modus of student's self-organization in content mastering of natural sciences application.

The purpose of the study is to identify the transition of models, technologies and mechanisms from subject's educational activity to professional self-determination and career choice in the process of complex natural science and applied knowledge researching by using of mathematical and computer modeling.

Materials and methods. Ontological techniques of student's readiness for professional activity and engineering of complex processes and knowledge mastering in the field of applied natural sciences; mathematical and computer modeling in the digital educational environment of student's search and research activities; method of student's holographic professional self-determination in the development of applied natural sciences.

Results. Selection criteria and a repository of an applied natural science samples based on mathematical and digital transformations are identified; structural and functional models of basic constructs ontologies on methodology of subject area teaching with student's professional self-determination effects are constructed; research principles and technology of multi-stage mathematical and informational tasks in applied natural science with synergy effects of natural science education are implemented.

Conclusion. Variability and scientific intensity of modern professions of applied natural sciences create the opportunities for their technological component's development and student's professional self-determination formation by means of mathematical and computer modeling symbiosis.

KEYWORDS

professional self-determination, natural science education, mathematical and computer modeling, synergy of education

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INTRODUCTION

In recent decades, the educational space for school students has been rapidly changing, including due to the demand for modern technologies and knowledge-intensive industries in creative and motivated workers. The UNESCO International Centre for Professional Education (UNESCO-UNEVOC) defines social, technological and economic imperatives as leading priorities in vocational education in all regions of the world. The UNESCO Science Report "Towards 2030" [33] notes the trends that characterize a new stage in the development of modern society – transition to a post-industrial, information society. Simultaneously with the society formation of new type, there is a transition to an innovative economy – a "knowledge economy". The backbone element of new economy based on knowledge-intensive knowledge is human capital, the importance of which is increasing every year. The dynamism of labor market, the availability of huge amounts of an information, reduction of time intervals from an innovative idea to its implementation in technical solution, growth of self-awareness and self-actualization of student's personal preferences determine the narrative of professional tests fundamentalization in the means of mathematical and digital transformation of educational space (school and university). So, it defines the effects of professional self-determination growth for both the student and the teacher. According to a study conducted in 2015 in Irkutsk region (Russia), only 15.5% of families adhere to the post-industrial model of self-determination, while the industrial model is typical for almost 52% of families (K.A. Smirnov [20]). The content of social and labor roles of an individual in post-industrial era is changing, new opportunities are emerging: volunteer, freelancer, entrepreneur, investor, etc. This process can be implemented through the actualization of professional samples of school students in the process of "problem zones" resolving applied natural science in search and research activities. First of all, this is the search for "problem zones" of educational and professional motivation, digitalization of training based on the dialogue of mathematical, humanitarian and natural science cultures in examples of professional implementation, professional self-determination and opportunities for the growth of creative potential of each student based on self-organization, founding of personal preferences, pedagogical support and personalized support. In the studies of S.N. Dvoryatkina [1] – software package to support school students' research activities, V.S. Sekovanov [2] – an element of discrete dynamical systems theory, Yohei Sato [37] – tumor microenvironment (TME) as a unique ecosystem that surrounds tumor tissues, R. Luo [14] – model identification based optimal control and its applications to multi-agent learning and control, E. Egaña-Marcos [4] – post-nonclassic paradigm in education, E. Morin [5] – complexity paradigm, K. Mainzer [6] – synergy of education and others, it is convincingly shown that the implementation of "problem zones" development in the context of post-nonclassical rationality in the complexity paradigm of natural science school education is based on the symbiosis of mathematical and computer modeling. One of the most important means of student's professional self-determination updating is the adaptation of specific manifestations and synergy of modern achievements in science, high technology and production to the content of school subjects. This could be, for example: computer methods of fractal geometry elements in nanotechnology (V.S. Sekovanov [21]): structural analysis using electron microscopy of cyanobacterial citrate synthase showed that different subunits of the protein enter into unique interactions, creating the asymmetry necessary for formation of fractal geometry of Sierpinski triangles ([F.L. Sendker [22]); foundations of natural science applications of fuzzy sets and fuzzy logic (E.A. Klimov [23]); information coding and encryption, genetic engineering, Benard cells and Verhulst scenario, self-organization in living and inanimate nature, robotics and 3D modeling, chemical evolution at the molecular level (molecular fractals), broadband and multi-range fractal antennas (A.V. Smirnov [24]), topological indices of dendrimers and polynomials (M. Arockiaraj [25]), artificial intelligence and high technology, etc.

An important factor is the fact that positive personal changes in school students' mentality are manifested in rich digital educational environment using innovative forms and means of mastering complex systems and knowledge: means of dynamic geometry and computer algebra (Tongxin Li [7] – embedding uncertain temporal knowledge graphs, Maaliw R.R. III [13] – adaptive virtual learning environment based on learning styles for personalizing e-learning system); the introduction of multi-stage mathematical-informational and natural science tasks (M. Klyaklya, V.S. Sekovanov, E.I. Smirnov, H. Hyunsuk [9] – utility of receiver operating characteristic curve and complex knowledge in educational assessment); Wei Pan [34] – an evaluation of elevators based on fuzzy theory and machine learning algorithms; search and research activities of schoolchildren (S.V.

Shcherbatykh [10] – using an artifitial intellect in education, V.A. Testov [11] – education in gidital society, I.V. Kuznetsova [12] – school student's functional literacy), using of intelligent systems in mathematics and natural sciences education (Z. Shabani Isenaj [8] – effectiveness of a school-based environmental education program on improving knowledge, attitudes, perceptions; Sait San [36] - an analytical and dynamical study of solitary waves in a fractional magneto-electro-elastic system; E.I. Smirnov [3] – synergetic approach in introduction to project activities). The leading idea of the study: to develop an ontology and engineering of professional self-determination of high school students based on modern methodology for teaching applications of natural science using examples of updating professional samples. The methodology for organizing of such complex pedagogical activity in the development of student's professional self-determination in the post-nonclassical paradigm requires for teacher to conduct a thorough ontological analysis of complex systems and knowledge subject area based on deep essential connections between the genesis of personal preferences and development, subject areas fundamentalization and coherent analysis of modern achievements in science, technology and production.

METHODOLOGY AND METHODS

The methodology of professional self-determination of an individual are considered by scientists in formation context of psychological and pedagogical categories of student's self-determination and self-realization (K.A. Abulkhanova-Slavskaya – psychological foundation of life strategies formation, L.S. Vygotsky – technology of "zones" of nearest development, A.N. Leontiev – an aproaches of complex activity, E.A. Klimov [15] – typology of professional moduses, D.I. Feldshtein [16] – methods of individual's social development in ontogenesis, L.I. Bozhovich [17] – principles of self-assessment in activity as the basis of personality self-determination, etc.). Let us single out the category of professional self-determination as a personal feature of adolescence in an independent determination of semantic and value modus of expression of professional orientation and professionally important qualities of an individual. For a teacher, issues of pedagogical support for the formation of student's professional modus are aimed at forming the result of high school student's readiness for conscious and independent understanding of his or her professional future. Student's professional self-determination in the process of professional modus mastering at natural science, mathematics and computer science subject areas is accompanied by a number of stages: preparatory (familiarization with the depository of subject area positive implementations in applications; selection of applied aspect of subject area and readiness to master the instrumental and fundamental base (including professional diagnostics), possibility of realizing personal preferences), content-technological (expression of professional tests in the implementation of subject areas by means of mathematical and computer modeling; completion of multi-stage natural science and mathematical-information tasks in small groups; mastering a set of technological techniques and instrumental procedures for practice-oriented problems studying), reflexive-activity (professional tests, acceptance of pedagogical support and consulting, professional adaptation of the individual, self-realization in work) (Yu.P. Povarenkov [18] – methods of psychological content creation of person's professional development, T.V. Khutoryanskaya [19] – foundation of psychological features of student's professional self-determination).

The methodology for managing and organizing the process of student's professional self-determination in subject area of "natural science" is based on the development of three types of activities:

- studying the techniques for natural science, informational and mathematical concepts and procedures mastering, practice-oriented skills developing, assessing them and ways of updating them in the components of professional self-determination of an individual by means of "professional samples" studying of modern technologies and industries (S.N. Dvoryatkina [35]);

- teaching technologies, substantiation, interpretation and generalization of natural science, informational and mathematical statements for application in professional activities, their analysis and synthesis, selection of personal preferences;

• teaching how to solve and research complexes of multi-stage natural science and mathematical-digital tasks of different types and levels complexity in the context of professional focus in natural sciences field [21].

The design of didactic systems for professional self-determination of school students should be based on a deep psychological and pedagogical basis, based on the structure and characteristics of each individual and methodology for pedagogical systems managing. At the same time, the object and subject of teaching methods in subject areas should be consistent with the educational, upbringing and developmental goals of training. The design of a depository of multi-stage natural science and mathematical-digital tasks is based (as well as an originals and samples of subject areas applications in professional activities) on the identification of driving forces, structure and content of mathematics and computer science subject areas, "natural science" as a fundamental basis and language of natural science applications in types of professional activity. The following figure 1 shows a model of mathematics as a science with a possible interpretation of interaction with subject areas of physics, chemistry, biology and computer science.

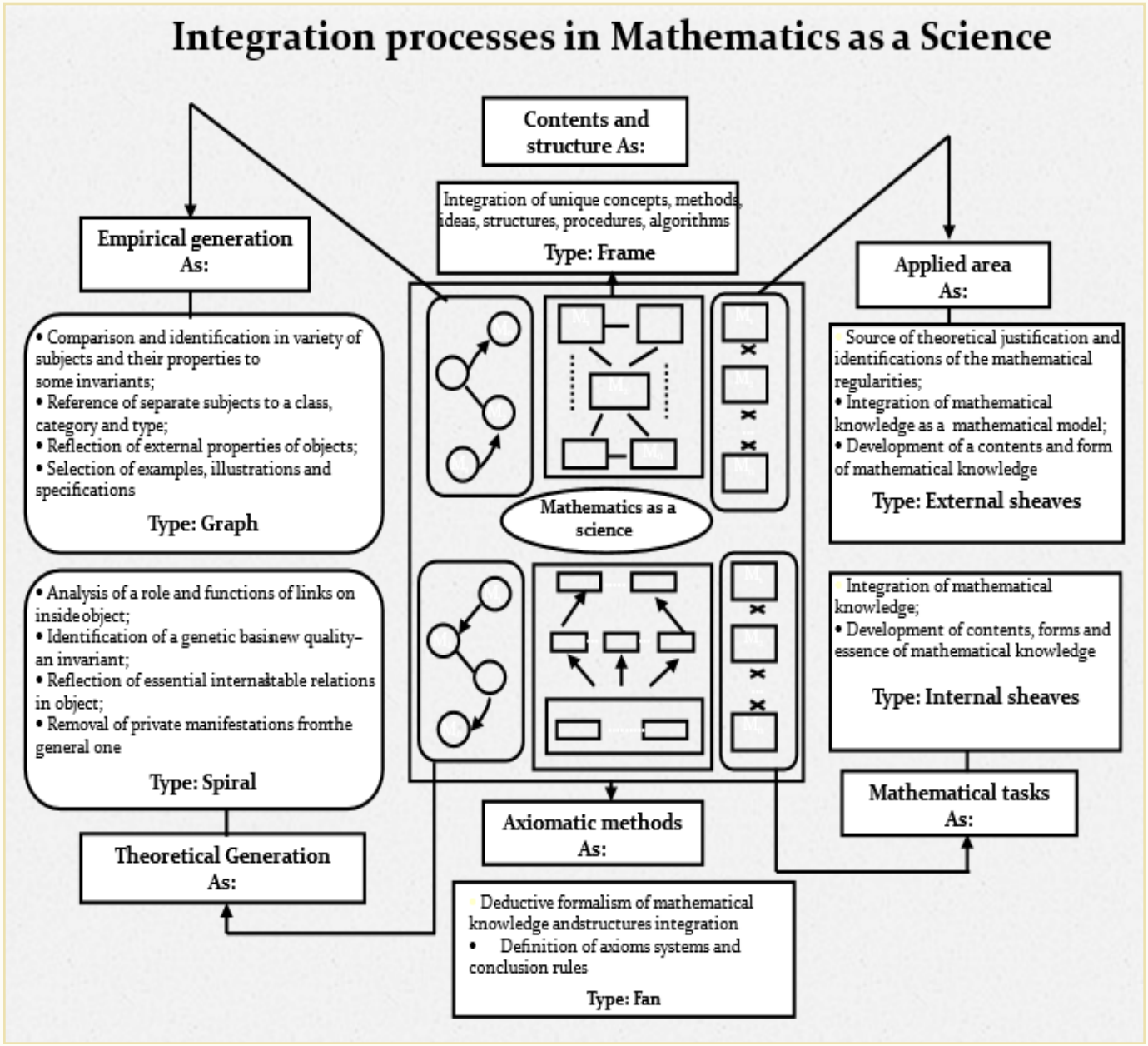

Figure 1 Structural-functional model of mathematics as a science in the context of natural science interactions

The possibilities of organizing search and research activities, game interactions (quests, quizzes, business and simulation, organizational and activity games, etc.) of extracurricular activities with a professional context immerse school students in complex cognitive activity in the form of solving multi-stage natural science and mathematical-information tasks for small groups of schoolchildren (M. Klyaklya, V.S. Sekovanov, E.I. Smirnov [21]), etc.). At the same time, the design of creative independence in the awareness of fundamental principles and synergy of complex natural science practice-oriented processes and tasks makes it possible to manage the processes of student's professional self-determination the basis of pedagogical support.

RESULTS

The modernity of teaching methodology of natural science subject area with the effect of manifestation and expression of student's professional self-determination is determined by the integration of science and education, comprehension of fundamental principles of modern technologies and production based on mathematical and computer modeling of depository elements of professional manifestations of mathematical, natural science and computer modeling symbiosis, awareness of the criteria for professional samples, choice and implementation selecting of personal interests, preferences and values.

Table 1

Professional samples depository of mathematical, natural science and computer modeling on symbiosis manifestations

Patterns depository of applied natural sciences	Contents and methods	Visualization and technologies (scientists)	Forms, resources and stages of learning adaptation	Potential of professional samples
Biology				
Molecular fractals	A new paradigm of fractal organization in biomimetics and nanotechnology: structural analysis using electron microscopy of cyanobacterial citrate synthase; mathematical methods and computer modeling of fractal geometry of Sierpinski triangles	F.L. Sendker, Y.K. Lo, T. Heimerl (Institute M. Plank, 2024) Self-organization of proteins and evolution of complex structures; randomness and neutral mutations; biomimetics and nanotechnology	Extracurricular, search and research activities; work in small groups; multi-stage applied mathematical and information tasks; mathematical and computer modeling; experimental methods *Approximate project topics:* ● Fractality and random construction of "Sierpinski napkin". Molecular bioanalogues ● Mathematical and information models of microorganism growth. P. Verhulst scenario ● Fractal dimension of cell and neuron ensembles *Stages:* - referential; - empirical; - content-technological; - generalizing-transformative	● Nanotechnology ● Biomemetics ● Microbiology ● Biophysics ● Nanomedicine ●Industrial microbiology ●Medical microbiology ●Environmental microbiology
Chemistry				
Mathematical (computer) chemistry	Modeling of various properties of complex molecules, molecular graphs and operations, group theory and algorithmization of chemical problems. Combinatorics and discrete mathematics, computer programming, mathematical logic, computational experiment	H. Wiener, Schultz index (H.P. Schultz) Wiener index, Schulz molecular topological index, adjacency and distance matrices. Richard F. W. Bader, R.B. King A molecular graph is a connected undirected graph and the structure of chemical compound; vertices of graph correspond to the atoms of molecule, and the edges of graph correspond to chemical bonds between these atoms	Extracurricular, search and research activities; work in small groups; multi-stage applied mathematical and information tasks; mathematical and computer modeling; experimental methods *Approximate project topics:* ● Verhulst's scenario in the Jabotinsky-Belousov effect ● Ethylene glycol acetic acid ester ● Topological indices in the classification of organic compounds and databases *Stages:* - referential; - empirical; - content-technological; - generalizing-transformative	●Chemical cybernetics ● Thermodynamics ● Pharmacology ●Chemoinformatics ● Bioinformatician in chemistry ● Infochemist ●Software developer for chemical research ●Specialist in visualization of chemical structures and processes

Physics				
Methods and means of microelectronics	Using of computer design systems and mathematical modeling of technology in microelectronics allows us to improve the technology of manufacturing integrated circuits (IC) and to develop the technological modes in order to optimize them to achieve required physical and topological parameters of devices	Kinetics of the process – Deal-Grove and Massoud model; L.A. Koledov, E.A. Pecherskaya Pyrolytic method of film formation (method of chemical vapor deposition). Based on the use of pyrolysis or chemical reactions phenomenon in the formation of polycrystalline silicon films (E. Grove, A.G. Alekseenko, Yu.A. Gatchin, A.N. Ignatov). The basis of digital microcircuits is a field-effect planar (flat) transistor with an induced channel. Using of schematic cross-sectional view of an n-channel transistor	Extracurricular, search and research activities; work in small groups; multi-stage applied mathematical and information tasks; mathematical and computer modeling; experimental methods. *Approximate project topics:* ● Physical models. Methods and algorithms for calculating silicon oxide deposition from the gas phase ● Structures of digital and analog integrated microelectronics ● Electron beam and X-ray lithography in the production of microcircuits *Stages:* - referential; - empirical; - content-technological; - generalizing-transformative	● Electronics and nanoelectronics ●Electronic engineer ●Vacuum deposition process operator ● Diffusion process operator (microelectronic production) ●Electronic equipment assembler
Informatics				
Computer modeling of applied and mathematical problems	Symbiosis of mathematical and computer modeling in the study and solution of applied problems of modern production, high technologies and the use of artificial intelligence	P. Bezier, P. de Casteljo, S.N. Bernstein Programming codes and algorithms for constructing Bezier curves and surfaces based on two-dimensional Bernstein polynomials, with practical use in various industries related to modeling and computer graphics Generation of images based on fractals and attractors (Ultra Fractal 5.04; ChaosPro 4.0.228; XenoDream 2.3; Fractracer 1.1, etc.). F. Slijkerman, M. Pfingstl, P. Sdobnov, P. Borys, R. Hordijk	Extracurricular, search and research activities; work in small groups; multi-stage applied mathematical and information tasks; mathematical and computer modeling; experimental methods. Approximate project topics: ● Models. methods and algorithms for calculating the construction of curves and Bezier surfaces in applications ● Structures of digital and analog integrated microelectronics ● Digital environments of computer graphics and fractal geometry in economics and production	● Design engineer ● Car designer ●Software engineer ● Advertising and computer graphics ●Radio engineering ● Macroeconomics ● Architect ● Petrochemist

The following criteria serve as the basis for conscious selection of professional patterns and samples reflecting the content of "problem zones" and personal preferences of school students:

1. Beauty and harmony of mathematical and digital formulas and procedures for updating the professional sample with manifestation of synergistic effects and the essence of generalized constructs.

2. Efficiency and accessibility of an adapting processes for mathematical and digital manifestation of professional sample to the content of school natural science subjects and mathematics.

3. The possibility and necessity of studying the "problem zones" of applied natural science and mathematics by using digital educational environments.

4. Significant and accessible manifestation of studying applied effects for complex problem by means of mathematical and computer modeling.

5. The possibility of student's cultures dialogue and an interactions coherence in cognitive activity process studying of an applied natural science issue.

6. Variability and actualization of perception modalities (symbolic, verbal, figurative-geometric, concrete-activity and digital) and mutual transitions of symbolic systems in the process of complex systems and knowledge mastering.

Technological map of an adaptation stages deployment for complex natural scientific and mathematical knowledge

Professional tests of senior pupils are designed by means of mastering the foundation of applied natural science in the context of mathematical and computer modeling symbiosis manifestation. The main such means is the study and solution of multi-stage mathematical and information tasks of applied natural science in extracurricular and research activities of school students. The implementation of criteria for selecting tasks and their multiple goal-setting in an open digital educational environment of professional orientation create the basis for updating the basic components of professional self-determination of an individual (value-motivational, content-technological, emotional-volitional, reflexive, effective (Lei Qin [31]).

Below is a technological map of an adaptation stages deployment for complex natural science and mathematical knowledge in the context of components and technologies mastering of applied natural science:

● reflection of the significance and adequacy of selection criteria, volume of samples and patterns of professional tests, structure and content of "problem zones" in determining the natural science potential of mathematical knowledge that have applied capabilities with synergy manifestation in training and future professional orientation;

● diagnostics of synergetic effects of an adapting applied natural science knowledge mastering and current state of personal meanings and preferences in mastering methods of natural science and mathematical-digital content;

● study of research samples depository of scientific and applied problems (at the standard and situational levels) with the possibility of professional self-determination and synergy manifestation of complex natural science knowledge by means of mathematics based on the implementation of ICT tools to support the digital educational environment;

● updating the attributes and parameters of research and adaptation of specific scientific and applied natural science problems of professional activity ("problem area") by means of mathematical and computer modeling with detailing, analysis, features and stages of professional samples research with multi-stage natural science tasks;

● updating, generalization and assessment of mathematical, information, humanitarian and natural science knowledge and methods in procedural period of «problem area" research of an applied natural science in the context of updating and diagnostics of student’s professional self-determination components manifestation.

The solution of such tasks allows to actualize and concretize in student’s educational cognitive activity on natural scientific foundations of modern production and technologies: ecological thinking, artificial intelligence and robotics, architect of virtual and augmented reality, landscape designer, bioinformatics, microbiologist, nanotechnologist, etc. Below in Figure 2 is presented the structural and functional model of an ontology of basic concepts of teaching methodology on applied natural science with the effect of student’s professional self-determination.

In this case, the teacher can expand the depository of applied natural science tasks taking into account the pedagogical and personal capabilities and the range of preferences of senior pupils based on the identified methodology. School students organize research in small groups with the possibility of receiving information support and consultation, including with the help of artificial intelligence. The complexity of professionally oriented tasks of applied natural science and the need for overcoming efforts using mathematical and computer modeling tools create the basis for self-organization of school students in light of G. Mintzberg’s strategic principles of synergy manifestation [32];

● plan – (stochastic planning, multiple goal setting);

● ploy – (research behavior based on cultures dialogue and threshold bifurcation and fluctuation transitions);

• perspective – (the final effect and result does not coincide with (exceeds) the volume of information flows used);

• pattern behavior – patterns of behavior and cognitive activity (availability of an up-to-date database of technological solution constructs and patterns of research behavior);

• position in respect to others – position in relation to others (the emergence of effects of self-organization, self-actualization and self-development in conditions of openness to external influences).

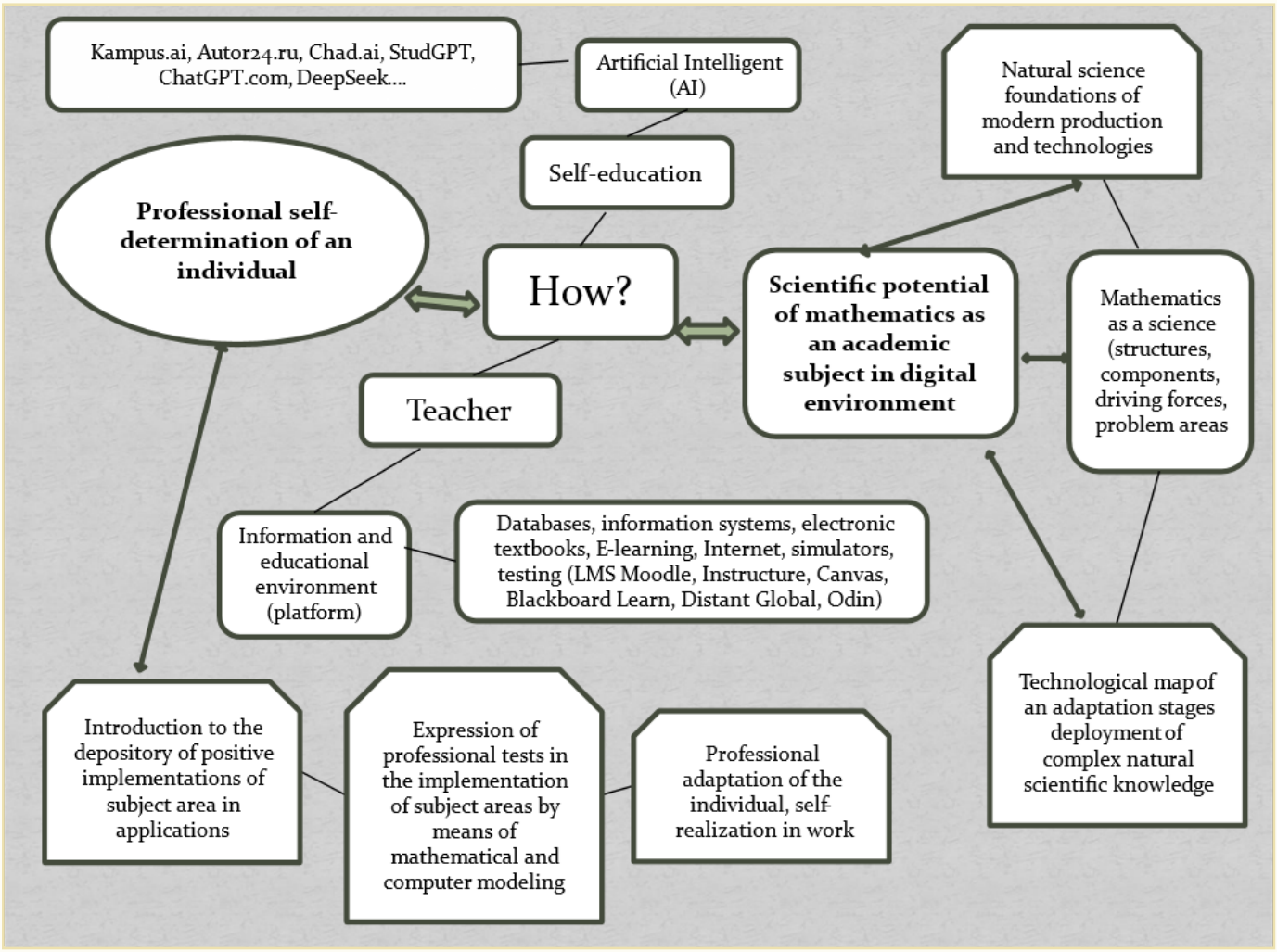

Figure 2 Structural and functional model of basic concepts ontology on methodology of natural science teaching with the effect of student's professional self-determination

We have identified the following principles for designing school students' professional self-determination:

• *principle of perspective* – it is necessary to have an image of future profession, understand the holographic nature of professional manifestations and tests, be able to self-organize and be ready for constant changes;

• *principle of variability* – choice by secondary school students of various forms of self-organization in the field of professional tests, determining the paths of mastering complex systems and knowledge in the context of mathematical and computer modeling symbiosis;

• *network principle* is the ability to adequately and quickly respond to changes in personal preferences, requirements for professions, dynamism of an open digital educational environment,

build communications and offer relevant solutions to problems, form an innovative practice focused on the changing needs of society, update moral values and the need to access network information;

● *principle of pedagogical support* creates the basis for a conscious and confident forecast of student's professional self-determination.

DISCUSSION

In the interpretation of an individual's professional self-determination by E.A. Klimov [23], three accents are clearly present: "I want" – the need for interest in choosing profession, "I can" – the ability to work productively in profession, "I must" – the need to take into account the needs of labor market. All these positions are implemented in the author's approach to fundamentalizing professional trials of applied natural science in rich digital educational environment by means of multi-stage mathematical and information tasks studying. At the same time, professional self-determination interpreting as a conscious and free choice of life path (N.S. Pryazhnikov [26] – components of professional self-determination; M. Heidegger [27] – freedom is a fundamental ontological given of a choice; Yu.P. Povarenkov [28] – features of professional self-determination), the article implements the technologies of a "fan" of professional trials and opportunities for choice based on the fundamentalization of applied natural science by means of mathematical and computer design symbiosis. At the same time, the effect of overcoming in the interpretation and adaptation of complex systems and knowledge to the content of school subjects (K. Mainzer [29] – components of complex system thinking; Egaña-Marcos [4] - examines how social support influence mental well-being in Spain; J. Santos [30] – innovative pedagogical practices in education; R.R. Maaliw III [13] – learning styles for personalizing e-learning system) creates and demonstrates the synergy of natural science education based on the self-organization of student's adaptation processes to modern achievements in science and technology.

CONCLUSION

Professional self-determination of secondary school students is a complex transition of adolescence subject to a necessary stage of life. This choice is the result of the influence of many factors: personal preferences, interests and assessment of work, abilities to perform professional operations, conditions and prospects of work, awareness and dynamics of the professional market, etc. The possibilities of one's own choice and interpretation of abilities, interests and values, probability of trial and errors, self-organization of activities create the situations of need to search for and interpret the fundamental principles of future profession related to mathematical, digital and subject competencies. This is especially relevant during the period of intensive development of the economy, the information environment and social interactions in digital environment. At the same time, for the subject area of natural science and mastering of complex mathematical-information context in the applied aspects of science, situations of conscious professional self-determination of senior school student are created based on the expression of professional tests of applied natural science by means of mathematical and computer modeling. It will be suitable in the conditions of emotional and applied saturation of mastering processes of complex activities. At the same time, technological nature of an ontology basic concepts constructing of applied natural science in the conditions of post-nonclassical paradigm deployment of complex systems and knowledge mastering create the significant guidelines for student's professional self-determination development.

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