Измерители готовности педагога к управлению математическим и компьютерным моделированием обучающихся в освоении сложных систем и знаний

Введение. Развитие креативности и самоорганизации обучающихся является в последние годы базовым трендом математического образования в школе и вузе в связи с необходимостью обработки больших объемов информации, изменчивостью и неопределенностью воздействия внешних факторов, возрастанием роли значимости компетенций в решении практико-ориентированных заданий. Педагогический опыт, теория и практика, запросы и вызовы реальной жизни показывают, что центральную роль в определении различных уровней успешности интеллектуального и личностного развития (в том числе, формирования математической грамотности) обучающихся играет готовность педагога к управлению процессом освоения сложных систем и знаний в математическом образовании.

Цель исследования – выявить личностные, предметные и методические дефициты педагогов и их измерители в готовности к управлению и интерпретации обучающимися сложных систем и знаний как фактора развития личности, используя оригинальные измерители компетенций в форме кейс-тестов.

Материалы и методы. Реализуется личностно-деятельностный, компетентностный, интегративный и синергетический подходы, диагностические материалы кейс-тестов измерения профессиональных дефицитов педагогов, методы контент-анализа, фундирования опыта личности и наглядного моделирования определения критериев, особенностей, содержания и структуры готовности управления процессами освоения обучающимися сложных систем на основе интерпретации методов математического и компьютерного моделирования.

Результаты исследования. Выявлены критерии, особенности, содержание и структура готовности педагога к управлению освоением обучающимися сложных систем и знаний; определены профессиональные дефициты педагогов и измерители готовности управления освоением сложных систем и знаний; разработаны подходы, направления и методы создания насыщенной информационно-образовательной среды освоения сложных систем и знаний (в том числе, робототехнических систем, технологий виртуальной и дополненной реальности, элементов фрактальной геометрии, нечетких множеств и fuzzy logic и т.п.) на основе симбиоза математического и компьютерного моделирования.

Заключение. Состояние выраженности личностных, предметных и методических компетенций должно определять ценностно-мотивационную, личностно-адаптационную, когнитивную, процессуальную и обобщающую-преобразующую готовность педагога к управлению процессами освоения и способами адаптации сложных систем и знаний (современных достижений в науке) к наличному состоянию опыта обучающихся, вариативность форм и средств представления обобщенных конструктов, владение методами математического и компьютерного моделирования, знание образцов и эталонов востребованных приложений сложного знания к реальной жизни, технологиям и производствам.

Ключевые слова: математическое образование, сложные системы и знания, профессиональные дефициты педагогов, измерители готовности педагога

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Introduction. In recent years the development of student's creativity and self-organization has been the basic trend of mathematical education in schools and universities due to the need of large amounts of information process, the variability and uncertainty of external factors impact, the increasing role of competencies importance in practice-oriented tasks solving. The works of philosophers, psychologists, and teachers show that the main means of these problems solving in modern world can be overcoming difficulties in complex systems and knowledge study by students based on a symbiosis of mathematical and computer modeling (including modern achievements in mathematics, robotics, information and intelligent systems). Pedagogical experience, theory and practice, requests and challenges of real life show that the teacher’s readiness to manage the process of mastering complex systems and knowledge in mathematical education plays a central role in determining the various levels of intellectual and personal development success (including the formation of mathematical literacy) of students.

The purpose of the study is to identify of teacher’s personal, subject and professional deficits and their meters in readiness for the management and interpretation of student’s complex systems and knowledge as a factor of personality development, using original competence meters in the form of case tests.

Materials and methods. Personality-activity, competence-based, integrative and synergetic approaches are implemented, diagnostic materials of case tests for measuring teachers' professional deficits, methods of content analysis, founding of personal experience and visual modeling of determining criteria, features, content and structure of teacher’s readiness to manage the processes of student’s complex systems mastering based on the interpretation of mathematical and computer modeling methods.

The results of the study. Revealed that the criteria, content and structure of teacher’s readiness to manage of student’s complex systems and knowledge development are identified; teacher’s professional deficits in the readiness to manage of student’s complex systems and knowledge development are identified; approaches, directions and methods for creating a rich information and educational environment for complex systems and knowledge development (including robotic systems, virtual and augmented reality technologies, elements of fractal geometry, fuzzy sets and fuzzy logic, etc.) are developed based on a symbiosis of mathematical and computer modeling methods.

Conclusions. The state of personal, subject and professional competencies expression should determine the teacher’s value-motivational, personal-adaptive, cognitive, procedural and generalizing-transforming readiness to manage the mastering processes and ways of complex systems and knowledge adapting (modern achievements in science) to student’s current state of experience, the presenting variability of generalized constructs forms and means, the possession of methods mathematical and computer modeling, samples and standards of popular applications of complex knowledge to real life, technologies and productions. The experiment was conducted on representative sample of mathematics teachers of Perm Region in Russia with the identification of teacher’s patterns and professional deficits in the context of complex systems and knowledge teaching possibility.

Keywords: mathematical education, complex knowledge, professional deficits of teachers, teacher’s readiness

For Reference:
Introduction

In the modern period, the quality of mathematical education significantly depends on the transfer of educational technologies from university to school and on teacher’s professional competencies. Especially scientists pay attention on their ability to innovate the self-organization both in the implementation of personal preferences and in the content and methodology of mathematics teaching in context of education digitalization. The effectiveness of high technologies implementation in production requires the student’s developed creative thinking and the ability to self-organize and self-develop their scientific potential. The new global initiative of UNESCO educational concepts until 2050 "The Future of Education" aims to ensure the training and retraining of teachers, constantly improving their level and quality in the face of growing demands for complex educational process. Scientists in Russia have long proved that the development of intellectual thinking operations is possible during the complex systems and knowledge development, especially in the development of school and university mathematics. Complex knowledge is a variety of essential connections of information essence actualization in the unity of mastering and cognitive activity processes. At the same time, complex mathematical knowledge in the process of its cognition generates of mathematical and computer modeling symbiosis, which is inherent in the manifestations of generalized constructs of complex knowledge essence, causes an emotional response to applied effects and integrates a knowledge and activities from various fields of science (robotics, artificial intelligence, fractal geometry, fuzzy sets and fuzzy logic, coding theory and information encryption, virtual and augmented reality, etc.) and dictate the need to integrate of science and education as a fundamental paradigm for the development of school mathematics education. An essential fact is synergetic paradigm actualization in mathematical education: self-organization tasks of complex system (G. Haken [1]), post-non-classical paradigm of self-organization (V.G. Budanov [2]), self-organization of complex systems in the real world (G.G. Malinetsky [3]). A students should already get acquainted with the symbiosis effect of mathematical and computer modeling based on nonlinear thinking actualization (V.S. Sekovanov [4]), know and find the associations in real life of modern synergetic phenomena in nature, life and technology, such as Benard cells ("the road of giants" in Ireland), Lotka – Volterra equations in the predator-prey system (S.N. Dvoryatkina [5]), Koch snowflake and Mandelbrot set [6], Ferhulst scenario and "butterfly effect" of strange Lorentz attractor (V.N. Ostashkov [7]). It is these and similar directions that provide a unique opportunity for student’s motivated involvement in the process of coordinated development of subject content in an open and rich information and educational environment and visual modeling both in formal and informal mathematical education processes (T.N. Karpova [8]).

A teacher of modern mathematics should be ready for updating and organizing possibility the student’s project and research activities level based on mathematical and computer modeling symbiosis during of complex knowledge development. This leads to identify the need of teacher’s readiness degree to manage the development of student’s complex systems and knowledge based on the identified criteria and their measures of professional deficits. It creates the conditions for goal-setting multiplicity and content
selection of complex knowledge mathematics teaching, the presence of rich information and educational environment in the context of mathematical and computer modeling symbiosis, the deployment of hierarchical bases and complexes of multi-stage mathematical-informational research tasks, the availability of effective feedback and monitoring of scientific potential of each student growth. Therefore, the research problem is what are the criteria and measures for determining of teacher’s readiness to manage the development of student’s complex systems and knowledge, the severity of teacher’s professional deficits in educational processes managing of complex mathematics mastering based on value-motivational, cognitive, professional-technological and generalizing-transforming modes actualization of teacher’s professional activity. The solution of this problem can give a powerful motivational charge to mathematical disciplines and their applications study based on modern scientific achievements adaptation; as a result, interest in real mathematics development of theoretical and empirical thinking (comparison, analogy, analysis, synthesis, etc.) will increase, mathematical literacy and scientific potential and self-organization of each student will be effectively formed. Thus, pedagogical support processes of student’s complex systems and knowledge mastering should be carried out by a teacher who has his own experience of complex mathematical knowledge mastering, aimed at student’s personal qualities developing, demonstrating the non-standard meta subject of techniques and methods using for "problem areas" research of mathematical activity mastering in saturated information and educational environment.

Methodology and methods

The post-non-classical thinking of modern person based on the nonlinearity of the surrounding reality, situationality and uncertainty in decision-making, multiple goal-setting and ambiguity of strongly choice dictates the need and possibility of complex systems and knowledge mastering as an imperative for the effective development of intellectual thinking operations and science and education integration. Complex knowledge arises in complex systems and generates multiple hierarchies and problems available in mastering the manifestations of mathematical knowledge generalized constructs both at school and at university.

So, object of the study is teacher’s readiness to manage of complex knowledge as the knowledge result about semiotic and informational connections content of nonlinear systems and phenomena of real and virtual world. It is represented in the unity of descriptive and computational diversity and hierarchies of subject content representation in agreement with (S.N. Dvoryatkin [9]). At the same time, founding of perception levels and personal-activity approach are necessarily realized by teacher’s readiness to manage together with (L.S. Vygotsky, S.L. Rubinstein, A.N. Leontiev), based on individual personification methods, training activity of student in innovation research of complex knowledge and taking into account the preferences and features of personal development, emotional response actualization to the applied effect of knowledge and competencies being formed (A. Maslow, A.G. Asmolov, N.A. Leontiev).

One of the fundamental methodological ideas that form the teacher’s readiness to manage the processes of student’s complex systems and complex mathematical knowledge
mastering is the synergetic approach as the basic mechanism of individual self-organization. The synergy of mathematical education in this case will be considered by us as a symbiosis and a qualitative change in nonlinear effects of self-organization and self-development of the individual during the development of mathematical activity in complex stochastic processes management based on the coordination of different factors and principles in three contexts: substantive (semiotic), procedural (imitation) and social adaptation, following (A.D. Uvarov [10]). Positive changes associated with the manifestation of mathematical education synergy generate the founding method of internal mechanisms deployment of student’s self-organization during the mathematical construct’s development at ever new levels of complexity, while actualizing the ways of forming their mathematical literacy. It is necessary to build the hierarchies of complex multi-level knowledge based on mathematical and computer modeling by visual modeling method, self-organization and reliance on didactic rules and patterns of mathematical activity mastering based on synergetic approach and student’s personal experience founding. There is a need to develop an environment for distance learning in mathematical disciplines within the framework of developer’s methodological initiatives deployment – mathematics teachers, as well as for complexes of on-line courses and remote environments; it is necessary to be able to develop the provision of ICT support tools (including the mathematical package of computer algebra Mathematica, GeoGebra, Lego Mindstorms, Arduino, etc.) in complex systems and tasks development in teaching mathematics (N.M. Galaseeva [11]); to use the "tetrad" technology in student’s research activities: so peculiarity here is that students will have to perform the four types of creative activity: a) creative mathematical activity; b) construction of fractal sets with the algorithms and high-level programming languages development; c) performing laboratory work in mathematics with computer experiments; d) studying a scientist’s creative biographies and creating artistic compositions using fractals and ICT. The mathematical education synergy will be considered by us as a symbiosis and a mechanism of qualitative change in nonlinear effects of individual’s self-organization and self-development during the mathematical activity development in complex stochastic processes management based on the coordination of different factors and principles in three contexts: substantive (semiotic), procedural (imitation) and social adaptation (E.I. Smirnov [12]). All teacher’s professional competencies characterize the manifestation of complex knowledge synergy in mathematical education at school based on modern achievements in science adaptation, mainly in the forms of integrative and elective courses implementation, project activities and web quests, laboratory calculation and resource classes, including in gaming activities.

In the process of students’ research of complex knowledge generalized constructs, the influence peculiarities of external factor’s actualization are manifested in founding methods and forms of mathematical objects and procedures essence. It based on goal-setting multiplicity, stages and hierarchies construction of sign-symbolic and figurative-geometric activity (E.I. Smirnov [13]), including a creative search and analysis of side solutions to the problem by using an information technologies and network interactions, variability and parametrization of identification of bifurcation transitions and attraction basins in multi-stage mathematical and informational tasks based on information’s ensuring coherence flows during cultures dialogue. The basic tool of personality-activity approach is visual modeling and individualization of students’ personal preferences processes in the form of spirals and
clusters founding deployment of personality experience – as integral integrating mechanisms for essential connections manifestation of complex knowledge generalized constructs and personality qualities formation. The integrity and orientation of this generalized construct is determined by blocks of meaningful, motivational and applied components deployment based on generic theoretical generalization and technological understanding construction of its specific manifestations. At the same time, it is important to note that the increase in complexity in open and non-equilibrium systems (such is mathematical education) it is not a destructive mechanism, but on the contrary creates the necessary paths and transitions to new level of self-development development. It is noted that the difficulty in achieving of certain critical levels is a synthetic characteristic of self-organizing ability, the ability to develop and self-develop the student’s thinking and personal qualities.

Such mechanism and important factor of teacher's readiness to manage a cognitive processes can be the launching of individual’s self-organization "factor-impulse" during complex knowledge adaptation development:

- by means of updating the content of complex knowledge generalized constructs, including fractal structures as meaningful zones of bifurcation and integrity at increasingly complex levels of mathematical and computer modeling integration. At the same time, the agreed empirical stages (individual manifestations observation and patterns of self-organization activity; identification of facts and their quantitative certainty; identification of structural, statistical, phenomenological laws; theory as an organized set of empirical laws) are deployed (G.V. Kalinina [14]);
- by means of generalized rules and values actualization in visual-digital models of complex knowledge mastering as founding attractors and abilities and processes development of understanding personality (V.M. Monakhov [15]);
- cultures dialogue and interdisciplinary integration as a means of integrative processes deploying, ways of goal-setting and coherence multiplicity to search for truth, emotional response to applied effects and awareness of information and pedagogical support availability (S.A. Rosanova [16]).

An effective construct may be following stages of synergy manifestation deployment of complex knowledge in mathematical education at school as a mechanism for student's mathematical literacy formation: motivational (self-actualization ("I'm interested in this"); approximate information saturation (self-determination ("what can I do"); procedural-activity (self-organization ("I'm capable manage the process"); control and correction (evaluation of results empirical verification); generalizing and transformative (self-development of the personality ("I can do something new"); at the same time, it is necessary to develop the methods for the selection, justification and development of psychological diagnostic methods and evaluation procedures for teacher’s professional deficits identifying and technologies for identifying synergetic effects in teaching mathematics.

We note the following features of teacher's readiness to manage of complex problems solution and an implementation of which can actually lead to increase in student’s mathematical literacy and creativity in the study of mathematics mastering (A.N. Poddiakov [17]):

- it requires the teacher’s ability to design the different descriptions and solutions variety, both in education content and in cognitive processes that differ from each other and complement each other; built, among other things, on the basis of
empirical rather than theoretical generalizations, studying of which allows the using of computer and mathematical modeling;

• it requires the ability to characterize changes not only at the level of specific manifestations, but also at the level of essence (generalized constructs), most significant for the actualization of understanding processes and developmental effects of self-organization presence. In complex educational systems, effective rules (founding modes of phased deployment) can be distinguished by self-organization types based on visual modeling of content implementation;

• requires the ability to explore and adapt the complex dynamic systems (modern achievements in science) to the subject and build of search samples variety (experimental cross–sections, comparative analysis of specific manifestations, computer modeling, analogies, analysis through synthesis, etc.) - real interactions with the system, but not just theoretical activity with its abstract models;

• competencies are required in setting diverse, diverse and multi-level goals (multiple goal setting) that can compete with each other. One of the main person’s emotional states in complex systems studying in mathematical education is uncertainty, doubt, willingness to accept the twofold (based on prediction and random) results of actions, etc.;

• it requires the understanding that results of human activity with complex system of mathematical education content and methods, interaction results with it cannot be predicted completely, exhaustively. Only probabilistically guaranteed educational outcomes are possible, therefore, along with direct, predictable educational outcomes, a variety of side, unpredictable products of personal development and mathematical activity are formed, both at school and at university.

The features, criteria, components and characteristics of teacher’s readiness to manage of student’s innovative activities are covered in sufficient details in pedagogical literature. So, I.B. Beljavskaja [18], N.I. Raitina [19], L.T. Chernova [20], etc., distinguish the following criteria: motivational (cognitive interest in innovation, the need for projects application and implementation, goals formation, self-education and creative self-realization in innovation, receptivity to innovation; the desire for active participation in pedagogical innovations dissemination); cognitive (knowledge of the essence and specifics of innovations, their types and signs; knowledge of the essence of pedagogical design and constructing logic of its stages, the ability to formulate a design problem), operational (the ability to carry out the design and prognostic activities in pedagogical innovation field; possession of situational and supra situated ways of pedagogical situations solving; creating a model of probabilistic professional behavior in conditions of innovative activity; experience in the application of pedagogical innovations in educational practice). A number of scientists N. Plahotniuc, N.N. Savina, E.E. Voropaeva [21] note the importance of such additional criteria as emotional-volitional, personal (the ability to assess adequately oneself as a person, professional, subject of educational process in innovation field, creative abilities), creative (the ability to find the non-standard solutions to pedagogical tasks, the ability to develop the creative imagination and alternative thinking (combine, find analogies, associations) and others. As already noted, the readiness to manage the processes of student’s complex systems and knowledge mastering is based and determined on teacher’s creative and innovative activity
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(V.A. Slastenin, L.S. Podymova, etc.) with its own indicators and diagnostic tools. However, the projection of teacher’s innovative activity on processes development of student’s complex systems and knowledge managing determines its special features of teacher’s readiness as in criteria, and in diagnostic tools.

Results

In the course of research and pedagogical analysis of best practices in teacher's determining the readiness for innovation, as well as the problems of student’s project and research activities managing, the following criteria and characteristics of teacher's readiness to manage the processes of student’s complex systems and knowledge mastering were identified: value-motivational; personality-adaptive; cognitive; procedural; generalizing-transformative (Table 2). The teacher’s readiness degree of each criterion severity is determined by teacher’s professional deficits volume (personal, methodological, subject and methodological) in the implementation of the processes in development managing by mathematical and informational content of student’s complex systems and knowledge. Let's define the diagnostic tools of teacher’s professional deficits in accordance with the typology listed above.

Personal professional deficits

- Johnson's creativity questionnaire, adapted by E.E. Tunick

The questionnaire is based on two approaches to the problem: (E.P. Torrens) creativity manifests itself with a lack of knowledge in the process of: incorporating information into new structures and connections, missing information identifying, in the process of new solutions finding and verifying them, results communicating; (Johnson D.L.) creativity manifests itself as an unexpected productive act, performed by the performer spontaneously in certain environment of social interaction based on their own knowledge and abilities. The overall creativity score is the sum of eight points (the minimum score is 8, the maximum score is 40 points). Table 1 shows the points correspondence to creativity levels sum.

Table 1

<table>
<thead>
<tr>
<th>Creativity levels</th>
<th>Sum of points</th>
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<tbody>
<tr>
<td>Very high</td>
<td>40–34</td>
</tr>
<tr>
<td>High</td>
<td>33–27</td>
</tr>
<tr>
<td>Normal, average</td>
<td>26–20</td>
</tr>
<tr>
<td>Low</td>
<td>19–15</td>
</tr>
<tr>
<td>Very low</td>
<td>14–8</td>
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</table>

- The map of pedagogical assessment and self-assessment of teacher’s abilities to innovate (V.A. Slastenin, L.S. Podymova)

This technique shows the level of teacher’s readiness for innovation. Based on criteria and indicators, three levels of teacher’s readiness are distinguished: low, sufficient and high (up to 60 points – low, from 60 to 120 – sufficient, from 120 to 150 – high).
Questionnaire "Motivational readiness of teaching staff to master innovations" (according to T.V. Chirkova)

The results are processed by analyzing the responses. More stronger teacher’s motives associated with prevail possibility of personal self–realization (paragraphs 2, 6, 8, 13 – a total of 15 points with a choice of 6 options), lead to higher level of innovative potential of teaching staff.

Table 2

Teacher’s readiness to manage in processes of complex systems and knowledge mastering

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Indicators</th>
<th>Diagnostic tools</th>
</tr>
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<tbody>
<tr>
<td>Value - motivational</td>
<td>• presence of external incentives and interests for pedagogical innovations and value acceptance of advanced pedagogical technologies, ideas; • interest in science and education integration, using of Data Mining tools, tasks, methods and algorithms in effective solution of complex mathematical and information problems; • personal experience of mathematical and informational creativity and need to develop an individual style of pedagogical activity in student’s project management; • independent ability to tasks and research problems setting, to search for creative methods of problem solving it both for students and for self-realization of teacher; creative level of thinking, striving to overcome stereotypes, harmonization of reflexive outputs, a new creative product, evaluation and prediction of further actions, motivation for self-actualization; • experience and culture of psychological diagnostics of student’s personal qualities and teacher’s self-diagnosis, determination of speed and intensity of cognitive operations, regulation of student’s emotional state</td>
<td>• Map of pedagogical assessment and self-assessment of teacher’s abilities to innovate (V.A. Slastenin, L.S. Podymova); • Questionnaire &quot;Motivational readiness of teaching staff to innovations mastering &quot; (according to T.V. Chirkova); • Johnson’s creativity questionnaire, adapted by E.E. Tunick</td>
</tr>
<tr>
<td>Personal-adaptational</td>
<td>• wide development of self-diagnosis and development means of teacher’s personality motives for self-actualization on the basis of new values acquiring and their own determining the most effective and successful manifestations of pedagogical experience; • development of convergent and critical thinking; selection of multi-stage mathematical and informational practice-oriented tasks, systematized in the form of founding complexes with necessary stages fixation: problem setting, data collection and analysis, hypotheses, mathematical modeling and analysis of ICT support tools possibilities and their implementation in subject area, reflection and generalization of results; • ability to pedagogical reflection and development of its types (intellectual, personal, cooperative and communicative), search and analysis of innovative pedagogical problems; • multiple experiences of micro-problems solving in “warming up” mode and the development of supra-situational activity (emotional experience, reflection, visual modeling, insight, solution verification, transfer); • competencies in the development of student’s divergent thinking against the mastering background of complex knowledge integrative constructs, taking into account the probable and improbable circumstances, constructing the content, stages, basic and variable characteristics of object design; • ability to adapt and develop in social communications based on self-management principles, role distribution, awareness of personal meanings and preferences, creation of creative groups; formation of a positive &quot;I-position&quot; in the context of cultures dialogue and creative independence; • pedagogical analysis and ability to transfer of results theoretical and empirical generalizations, reflexive control formation of an individual style characteristics of pedagogical activity; • intensity of awareness processes of professional motivations, determination of their composition and self-realization; results verification by dissemination and approbation of pedagogical experience</td>
<td>• Map of pedagogical assessment and self-assessment of teacher’s abilities to innovate (V.A. Slastenin, L.S. Podymova); • Questionnaire &quot;Motivational readiness of teaching staff to innovations mastering &quot; (according to T.V. Chirkova); • Johnson’s creativity questionnaire, adapted by E.E. Tunick</td>
</tr>
</tbody>
</table>
### Creative

| • the presence of samples variability of solving pedagogical problems with analysis and features of complex systems and knowledge creative research (at the reference and situational levels);  
| • innovative techniques design, for example, "warming up": problem – reflection – visual modeling – insight analysis – verification of solutions – transfer to multifunctional project activities;  
| • modern technologies mastering for students’ research activities managing: founding of personal experience, visual modeling, expansion of metacognitive experience, etc.;  
| • availability of samples and experience (at the reference and situational levels) of educational and scientific problems solving in mathematical content with detailed information of technology support, analysis and features, presentation of research stages, methods and procedures;  
| • competence in requirements and types of hypotheses nomination and formulation, analysis of their adequacy, verifiability, reliability; verification of hypotheses, their modification, evaluation of methods and procedures for finding results, varying conditions and data for complex systems and tasks studying;  
| • management skills in the assessing of hypotheses truth, forecasts and strategies; effectiveness self-analysis of strategies and methods solution, choosing the optimal way to problem solving;  
| • skills in founding of spirals and clusters designing by type: theoretical and empirical generalization of knowledge and methods, integration of knowledge and methods against the background of obtaining a new quality of interaction, actualization and formation of personal experience in “zones of immediate development”;  
| • system integration skills of subject, information, mathematical and professional knowledge based on visual modeling in setting and solving tasks of professional activity and development managing of student’s research tasks mastering  

### Procedural

| • technological readiness and culture design: knowledge of methods and means of pedagogical innovation;  
| • introduction and management of techniques and methods development of scientific cognition, creating situations of intellectual tension, student’s self-determination and self-actualization in problematic situations;  
| • creating of information-rich educational environment (stimulating of success situation; working in small groups; tolerance to uncertainty; readiness for discussions and multiple solutions to problem solving; identification and popularization of creative behavior samples and its results);  
| • formulation and search managing for research problem solving, information updating and mastering "zones of near and distant associations", forms and methods collecting and a variety of information presenting, probabilistic-statistical, content, graphical, cluster, mathematical analysis of data, identifying patterns, analogies, associations, dynamics of processes, phenomena and facts under studying;  
| • development management of statistical packages and office editors, small informatization tools, computer algebra systems and Web support; ICT tools capabilities analysis to verify the solution adequacy;  
| • processes management of designing and building a plan for problem solving, conceptual, subject, information and mathematical models, analysis of ICT support tools capabilities  

### Notes

- Competence-oriented test of methodological readiness to master of complex systems and knowledge (E.I. Smirnov);
- Evaluation materials of levels measurement in teachers’ proficiency in subject competencies in the field of functional (mathematical) literacy in complex systems and knowledge management (E.I. Smirnov)

- Questionnaire of mathematical modeling competencies in intelligent and robotic systems (N.M. Galaseeva);
- Questionnaire for study of teacher’s methodological competence deficits in providing of functional (mathematical) literacy formation in complex systems and knowledge management (E.I. Smirnov)
| Generalizing-transforming | ● situations management of probable and improbable circumstances manifestation, assessment of their effectiveness, ability to set and solve tasks in uncertainty conditions;  
● competencies in theoretical and empirical generalization of knowledge and methods, integration of knowledge and methods against new quality background of interaction obtaining, actualization and formation in “zones of immediate development” of student’s personal experience;  
● processes management of research culture improving in situational activity experiences and students’ participation in ongoing scientific seminars and workshops, active methods testing of innovative profile teaching, experimental and creative sites using, research groups temporary, etc. in introducing process of new interactive techniques and information technologies;  
● experience in monitoring and evaluating the effectiveness of pedagogical strategies and their modifications in process managing of student’s complex systems and knowledge development;  
● experience in professional culture improving based on new approaches to managing these processes in the form of permanent seminars and workshops using active teaching methods, experimental and creative platforms, temporary research groups, etc., in introducing process of new interactive techniques and information technologies;  
● competence in management of independent task settings and search for methods of solving it, situational level of student’s thinking, desire to stereotypes overcome, harmonization of reflexive outputs, tolerance to the emergence of new creative products, assessment and prediction of further actions, severity of self-actualization motivation |
| Johnson’s creativity questionnaire, adapted by E.E. Tunick;  
● Methodology of “Teacher’s ability to creative self-development” (I.V. Nikishina) |

Diverse diagnostics in 5 regions on representative samples of teachers (Yaroslavl, Lipetsk, Perm Krai, Nizhny Novgorod, Republic of CO-Alania) of Russia showed that in their innovative activities for management of complex systems and knowledge development (modern achievements in science) the teachers are guided by social motives associated with interaction and creative colleagues, with desire to be in contact with scientists and teachers and an adequately assessed level of pedagogical competencies by scientists. The motives of self-actualization, self-determination and achievements in innovation with the management of student’s complex systems and knowledge development do not play a significant role for teachers. This creates an additional problem area for the teacher’s readiness processes due to the above-mentioned importance for improving of mathematical education quality and vocational training at the university concerned with actualization of science and education integration during complex systems and knowledge development.

**Methodological professional deficits**

- *Competence-oriented test of methodological readiness to master of complex systems and knowledge (E.I. Smirnov [22])*

Cognitive field: psychological theories of teaching, standard of pedagogical activity, competence, universal educational actions, structure of personal qualities and teacher’s experience, visibility in teaching, modeling, visual modeling, founding, spirals of founding, basic educational elements and coding, generalized essence of concepts, methods, theorems. The questionnaire consists of 30 questions with answers choice (sometimes several). Correct answers are marked with “•”.

Diagnostics of teacher’s methodological readiness to manage of student’s complex systems and knowledge development has shown that teacher’s professional deficits manifest themselves the most prominently in this niche. Teachers are poorly guided by methodological approaches sound (personal-activity, synergetic, interdisciplinary, etc.) to improve the management quality of students' of complex systems and knowledge development (less than
30% of respondents), insufficiently use the modern methods of forming project and research activities among students (about 45% of respondents), founding of personal experience, visual modeling of mathematical objects and processes (less than 15% of respondents), information technologies and tools are not yet used in mathematics teaching as a necessary tool for mathematical essence mastering of complex knowledge (38% of respondents), teacher’s diagnostic culture is at a low level (only 20% of respondents possess methods of mathematical statistics and are able to identify the "problem areas" in student’s personal development with valid psychological and pedagogical meters available to the teacher).

**Subject professional deficits**

- **Questionnaire of mathematical modeling competencies in intelligent and robotic systems (N.M. Galaseeva) [11]**

  The questionnaire presents 4 blocks of 15 questions in the form of closed-type tests: connection of mathematical modeling and robotic systems; mathematics – basic mathematical models; mathematical modeling of complex knowledge; mathematical models of machine learning.

  The availability of subject competencies is the most important problem of teacher’s readiness to manage of student’s complex systems and knowledge development. The historical experience of world mathematics problems solving shows that, for example, the result of following problems cognition is a complex mathematical knowledge: the problem of 4 colors for coloring maps (V. Haken, K. Appel); Riemann’s hypothesis about zeros of zeta function; Goldbach’s binary problem; transcendence of numbers π+e; rationality of Euler-Mascheroni number; problem P=NP – difficulties for computational efficiency of iterative problems (P. Cook, L. Levin, A. Wigderson); Fermat’s Great Theorem (A. Wiles); fractal characteristics of Schwartz cylinder and Smirnov’s "cup" (T. Schwartz, B. Mandelbrot, E.I. Smirnov [23], etc.). A generalized construct of complex systems studying (robotic and intelligent systems, cellular automata, machine learning, etc.) and complex mathematical knowledge can represent the applied or practice-oriented knowledge, essence studying and manifestation of which is based on mathematical and computer modeling symbiosis. These can be of fractal geometry elements: variations of Julia and Mandelbrot sets, games of "chaos" in randomized design and studying of fractal characteristics of "Serpinsky napkin" and its generalizations, strange attractors of Henon, Roesler and Lorentz studying; graph theory (transport networks, queuing theory, etc., L. Euler, F. Harari, R. Diesel); fuzzy sets and fuzzy logic (L.Zadeh, Ye Mamdani); information encoding and encryption (K.Shannon, D. Haffman); stochastic methods of optimization problems (J. Holland, J. Koza), etc.

  Therefore, teacher’s knowledge of modern mathematics, interest in the introduction of complex systems into mathematical training with the actualization of mathematical and computer modeling symbiosis creates a precedent for teacher’s readiness to motivated manage of mathematical constructs development, increases of student’s mathematical literacy and actualizes the interdisciplinary interaction of academic subjects. However, the results of teacher’s diagnostics show a significant professional deficits, extremely insignificant teacher’s opportunities and interest in mastering and managing of modern complex systems and knowledge generalized constructs in mathematics teaching (less than 10% of respondents).
An important aspect of teacher’s readiness is also processing management and researching of practice-oriented tasks solving based on mathematical modeling.

- Evaluation materials measurement of teachers’ proficiency in subject competencies in the field of functional (mathematical) literacy formation (E.I. Smirnov [24])

The above components and characteristics of teacher’s readiness to accompany students in the development of complex systems and knowledge determine the direction and composition of content and meters of teacher’s professional deficits. One of modern means of personal qualities diagnosing are case tests (or test cases), namely, a high-level test case will be used – a test scenario with abstract preconditions, input data, expected results, postconditions and actions.

**Testing methodology**

*Entrance control:* A study of teachers' competence deficits.

*The purpose of the study:* to study the level of proficiency in subject and methodological competencies of teaching staff, ensuring the formation of student’s mathematical and digital literacy in the process of complex systems and knowledge mastering.

*Research objectives:*
- research organization and conduct of teacher’s subject and methodological competencies on the basis of developed evaluation materials (Examples 1, 2);
- analysis of studying results of teacher’s subject and methodological competencies;
- recommendations development of teacher’s subject and methodological competencies in the process of scientific and methodological support of educational organizations teaching staff.

The studying participants are teachers of municipal educational organizations that carry out the educational activities according to educational programs of basic general education. Evaluation materials are developed in accordance with following principles:
- compliance with methodology and conceptual framework of PISA international comparative studies;
- focus of teacher’s labor functions and labor actions specified in the draft updated professional standard.

*The main characteristics of measuring materials.* Diagnostics is carried out in the form of subject tests and methodological competencies online. The execution time is no more than 60 minutes (3 standards and 9 tasks are presented (distance; functionality; revolving door).

This indicates that the majority of teachers (80%) adequately assess their scientific and methodological potential, are tolerant of innovations in didactics, have their own experience in identifying "problem areas" of complex mathematical knowledge mastering (including modern achievements in science). Comparison of time intervals of test execution and low average results of teachers indicates the presence of subject deficits among mathematics teachers in the field of mathematical knowledge applying in practice-oriented tasks solving, as well as in issues of adequate interpretation of task conditions and results. Therefore, the professional mathematical training of future teacher should not only fund the content of school mathematics at a generalized theoretical level (which is not always observed in curricula and curriculum), but also reflect the content of modern achievements in science adaptation (fractal geometry, fuzzy sets and fuzzy logic,
theory of information encoding and encryption, cellular automata, etc.). The approach to school mathematics will create an additional motivational and applied aspect based on mathematical and computer modeling integration.

**Methodological competencies** of teachers were determined in 6 tasks distributed in 2 blocks: block 1 – factors and problems of complex mathematical knowledge mastering; block 2 – methodological possibilities of categories studying (space and form, change and dependencies, quantity, uncertainty and data) and play activities in mathematical education. The test results are presented in Table 3:

<table>
<thead>
<tr>
<th>Block/Results</th>
<th>Average (score / max)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>86/134</td>
<td>64,2</td>
</tr>
<tr>
<td>2</td>
<td>81/134</td>
<td>60,4</td>
</tr>
<tr>
<td>Σ</td>
<td>83,5/134</td>
<td>62,3</td>
</tr>
</tbody>
</table>

The latest results should be regarded as positive – they indicate the teacher's readiness for professional self-development, the ability to adapt and knowledge using of science modern problems in practice-oriented tasks solving with student’s motivation and self-organization effects, as well as the ability to form a rich information, educational and gaming environment by means of mathematical and computer modeling in practice-oriented tasks solving and of gaming activities organization. At the same time, subject deficits of teachers and factors hindering the processes of complex knowledge adapting to school mathematics were identified: difficulties in conceptual modeling of practice-oriented tasks, understanding of plot situation and its translation into mathematics language; mutual transitions of sign systems in mathematical modeling; difficulties in working with real data, quantities and units of measurement. At the same time, diagnostics showed teacher’s difficulties and professional deficiencies in knowledge generalizing and student’s activities. It seems as a consequence predicts of teacher’s insufficient ability to bring the student on the level of private knowledge generalization, actualize the meta-subject competencies and universal educational actions: without such an analysis and proper emphasis, student’s knowledge and actions will be limited and will have a weak potential for expansion. One of the ways to solve this problem is to study and adapt a modern achievement in science to school mathematics (robotic and intelligent systems, fractal geometry, the theory of encoding and encryption of information, fuzzy sets and fuzzy logic, etc.).

**Discussions**

We agree with the authors (W. Daher [25], J. Wang [26], R. L. Long II [27]) about the need to solve complex problems in mathematics teaching by integrating mathematical and computer modeling (GeoGebra, Maple, Deep Learning, STEM-education). In particular, with the effect of student’s mathematical literacy formation: cultivation of functional literacy by holistic education (N. Meseșan [28]), issues of functional literacy (K.H. Perry [29]) on the basis of practice-oriented tasks comprehensive solution in various directions (nature, society, infrastructure, science, production). However, scientists have proved that the teacher's
readiness to manage of complex systems and knowledge development requires not only efforts in the operationality of innovative activities with complex systems, but also an internal organization of student’s symbolic activity with high level of educational motivation and interdisciplinarity in modeling practice-oriented tasks actualization is necessary: motivational persistence and its implications (A. Toderic [30]), motivation of primary school teachers regarding non-formal activities (E. M. Coșarbă [31]), which is confirmed by our research. The data obtained by us are consistent with the opinion of next authors: automated enhanced learning system using IOT (A. Saxena [32]), adaptive network based fuzzy inference system (D. Karaboga [33], intelligent soft computing-based security control (M. B. Kamal [34]) about weak readiness of teachers to innovate modern achievements in science using (fractal geometry, fuzzy sets and fuzzy logic, machine learning, etc.). Therefore, original direction of improving the mathematical education quality is technology’s introduction and transfer for complex knowledge studying based on the determining of teacher’s readiness to manage of student’s cognitive activity on the development of complex knowledge generalized constructs.

Conclusion

It is revealed that the central role in success of various levels determining of teachers' readiness to manage of student’s complex systems and knowledge development is played the teacher’s tolerance for self-education, development of their fundamental mathematical competencies, understanding the significance of overcoming difficulties in student’s abilities and intelligence development. An essential factor in complex systems and knowledge development is problem solving in creating of rich information and educational environment for mathematics teaching by changing the content of educational programs and practices in direction of complex knowledge mastering. This should be realized in the course of step-by-step studying of complex knowledge generalized constructs and complexes of practice-oriented subtasks solving. It leads to ability in effectively interpreting tasks from real life: that is, to solve a wide range of tasks in various spheres of human activity, communication and social relations. The priority for teacher’s readiness is situations when student’s ability to use the existing knowledge and skills, to obtain a new information is manifested. The creative students who think independently and able to function in difficult conditions and master of complex knowledge are required. This creates a precedent for teacher's readiness to innovate with complex systems and knowledge, to expand and deepen the student's experience based on his current status (it is necessary to take into account the individual differences of students, i.e., practice-oriented tasks should be multi-level). Formation and development of motivational sphere of teaching (due to samples and adaptation of modern scientific knowledge and technologies actualization that are in demand in life and accessible to perception), development of intellectual operations and abilities are based on founding mechanisms, mathematical and visual modeling of manifestation possibilities and correction of student’s functional, operational and instrumental competencies in mathematics complex constructs and procedures mastering. The conducted research revealed an integral block of teacher’s personal, methodological, subject and methodological deficits in complex systems and knowledge mastering and adapting to school mathematics and processes managing of student’s self-organization in research activities.
REFERENCES


