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MODEL OF FUTURE ECOLOGISTS' MATHEMATICAL COMPETENCE DEVELOPMENT PROCESS AT THE UNIVERSITY

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The relevance of the problem addressed in the article is determined by the ecologists' mathematical competence as one of the important conditions for successful specialists' adaptation in their profession, as well as high efficiency factor of their work. While teaching future ecologists at the university, it is necessary to form the framework for mathematical competence. The purpose of the article is to develop a model of the process for future ecologists' mathematical competence development at the university. The main research methods include simulation and expert assessment. The substantive framework for mathematical competence of ecologists combines experimental measurement, eco-modeling, ecological qualimetric, eco-monitoring, software-computer ones (characteristics of these competencies are given in the article). The theoretical analysis and employed complex diagnostic technologies enabled to identify levels of mathematical competence formedness (development) in university graduates majoring in "Ecology and Nature" (Bachelor). The article analyzes the data of long-term experiment, the results of which prove that university graduates, who have become young specialists-ecologists, apply mathematical methods for solving professional tasks in self-employment successfully. It greatly increases their competitiveness and professional mobility in the modern labor market. The results of this research can be applied in the practice (in the learning process) of universities that carry out professional training of future ecologists

Keywords: learning process in university; students of ecological specialties; mathematical competence, process model

INTRODUCTION

At the present stage of civilization development the lack of balance in the complex system "man - nature - society" is obvious: pollution of the human habitat and the biosphere degradation are increasing.

In most countries worldwide, the system of institutions engaged in training specialists in the field of ecology, social-ecological and environment protection management is expanding.

In recent years, active development has been observed in mathematical ecology which designs mathematical models serving to validate the theoretical concepts, provides methods for experimental data processing, experiment planning and observations (Zaripov, 2010). Consequently, mathematical competence is an essential component of the modern ecologist's professionalism.

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Currently in Russia the state educational standard of higher education in training direction "Ecology and Nature Management" (Bachelor) emphasizes that the graduate must be able to use mathematical and computer technologies for experimental data processing; to implement the project-analytical and expert-advisory activities; to build and use mathematical models for description and prediction of various environmental phenomena and processes. The abilities to apply mathematical apparatus for the needs of professional-ecological and environment protection activities formed in the future specialists during their learning at the university play an important role in solving these tasks.

The science has accumulated sufficient potential to solve theoretical-applied tasks connected with the issue of developing future ecologists' mathematical competence during university studies.

A number of research works are devoted to the problem of professionally-oriented mathematical training of future ecologists at high school (Averina, 2007; Marchuk, 1986; Martynov, 2014; Podzorova, 2013; Zhukovà, 2013). The investigations (Arora, & Rogerson, 1991; Bolker et al., 2009; Clark, 2007; Hamilton, 2005; Gorelov & Karelova, 2008) deal with the importance of mathematical training of future ecologists, substantial components of ecologists' mathematical education. Theoretical and methodological foundations of professional training in universities of the future ecologists are discussed in the works (Bauer, 1987; Grishagin, 2013; Kostova, 1989; Stapp & Polunin, 1991; Tarasova & Makarov, 2006). However, the specifics of the process of developing future ecologists' mathematical competence at the university is under-investigated in terms of modern features of using mathematical technologies in the environment protection activity.

METHODS AND DATA

The methodological basis of the study, findings of which are presented in this article, includes the methodology of phenomena integration and divergence; philosophical and methodological principles of the dialectical unity of man, society and nature (Vernadsky, 1991; Glazachev, 2002; Hësle, 1994), concepts of science greening (Danilov-Danilyan & Losev, 2000; Reimers, 1994); competence, personal-activity and contextual approaches to the professional training of future experts at high school (Bergsmann et al., 2015; Nicolaou & Constantinou, 2014; Nikitina *et al.,* 2014; Zimnyaya, 2003).

Research methods applied by the authors are analysis of philosophical, ecological, pedagogical, mathematical, sociological, psychological, methodological literature on the problem of ecologists' competence development, study and analysis of legal and regulatory documents in the sphere of environment protection, and also legislative and regulatory documents in the sphere of professional education of future ecologists; analysis of the content of academic disciplines, and curricula of universities training ecologists; modeling method; diagnostic methods (in particular, testing), analysis of the results of students' (future ecologists') educational and practical activities and analysis of the results of independent professional activities of university graduates (young specialists-ecologists), monitoring (including over monitoring), methods of expert assessment; and statistical processing of diagnostic data.

The study was conducted on the basis of faculties Health and Environment Protection of Russian State Social University (RSSU), Dmitry Mendeleev University of Chemical Technology of Russia (UCTR) and Kuban State University (KSU). At various stages of the experiment (2003-2016) the study covered more than 680 students, 48 university professors; 113 specialists-ecologists who worked at the universities' practical training facilities. All of these persons participated in experimental activity voluntarily; they were explained the significance, the meaning and the tasks of this working process on the future ecologists' mathematical competence development.

RESULTS

The essence of the concept of "ecologist's mathematical competence" and its structural components

To construct the authors' (original) definition of the concept of "ecologist's mathematical competence" the approaches to the disclosure of the nature and content-structural basis of a broader concept of "a specialist' professional competence" were studied.

Thus, literature analysis showed that while defining the concept of "professional competence", the scholars emphasize its different aspects: *1)* competence as the *ability* of the subject to relevant and high-quality implementation of professional activity (Everwijn *et al.,* 1993); *2)* competence as the *formedness of* specialist's skills appropriate to his/her professional functions (Nikitina & Rudko, 2012); *3)* competence as the *readiness* and the theoretical-methodological *preparedness* of the specialist to solve professional tasks qualitatively (Soare, 2013); *4)* competence as a *system-personal education*, cause-related with effective action criteria in professional situations (Mirabile, 1997); *5)* competence as a *qualitative characteristic* of the specialist's identity reflecting the ability to competently perform the tasks of work activity in accordance with functional requirements (Zimnyaya, 2003).

The conducted categorical analysis of the concepts of the "specialist's professional competence" (Evers *et al.,* 1998; Fleming, 1993) and "specialist's mathematical competence" (Boesen *et al.,* 2014; Friedrich *et al.,* 2013) and the summarized scientific position of the authors of this article, enabled to formulate the following definition: the ecologist's mathematical competence is system-personal professional education reflecting the unity of his/her theoretical and applied readiness and practical ability to apply mathematical tools for solving tasks of environment protection.

Structural components of this competence are 1) a *gnostic component* that includes system mindset and specialist's model thinking; complexity of mastering the system of the domain-specific knowledge; mastering of the mathematical apparatus used in ecology; possession of applied mathematical technologies of environment protection activity; 2) an *axiological component* that includes awareness of the importance and value of environmental activities in modern society; dominant ecocentric motivational attitudes with respect to nature; awareness and acceptance of the environmental activity mission in modern society; mastering of the ecologist's professional ethics; adoption of the egologist's special mathematical training at the individual level; 3) a *procedural-technological component* that includes skills in using mathematical methods and technologies for solving professional tasks; knowledge of mathematical tools and technologies used in different specializations of environment protection activity.

Substantial basis of the ecologists' mathematical competence is formed by the combination of the following competencies: experimental measurement, eco-modeling, ecological qualimetric, eco-monitoring, software-computer ones (these competencies are characterized in Table 1).

TABLE 1: RESULTS OF EXPERT ASSESSMENT OF ECOLOGISTS' (UNIVERSITY GRADUATES') MATHEMATICAL COMPETENCE FORMEDNESS, IN POINTS, MAXIMUM POINT – 6 (THE HIGHEST POINT OF SKILL FORMEDNESS)

Competences	*Relevant skills*	*2011 Graduates*		*2016 Graduates*		
		s		*s*		
		$\bar{x}_1$	σ_1	$\bar{x}_2$	σ_2	*p*
Experimental measurement	Skills: to determine the number of properties, parameters, displaying adequately the measured components of the ecosystem; define the basic values of the indicators; set a range (interval) of the measured parameters, define the boundaries of properties propagation; select the types of scaling and scales; apply the method of indicator averaging using the concepts of the probability theory.	3.52	1.75	4.13	1.64	<0.05
Eco-Modeling	Skills: to make and substantiate descriptive and qualitative models of ecological communities,					

contd. table 1

Competences	*Relevant skills*	*2011 Graduates* s		*2016 Graduates* s		
		$\bar{x}_1$	σ_1	$\bar{x}_2$	σ_2	p
	global ecological mathematical models, ecological-economic system models, graph (network) models, aquatic ecosystem models, forest cenosis models, agro-ecosystem models.	3.63	1.58	4.19	1.7	<0.05
Ecological Qualimetric	Skills: to integrate technologies of ecometrics, anthropometry, economic metrics, sociometry; reduce environmental quality indicators to the standard form; apply a comprehensive qualimetry method with the known functional dependence; choose the type of functional transformation of the environmental quality assessment; choose a mathematical model for environmental quality assessment; calculate the integral index of environmental quality; identify and substantiate the necessary and sufficient accuracy of the environmental quality assessment	3.41	1.71	4.27	1.58	<0.05
Eco-Monitoring	Ability to formulate goals of environmental monitoring; ability to apply of expert measurement method for environmental indicators; ability to apply sequential estimation technique for the measured eco-parameter rating	3.59	1.78	4.21	1.38	<0.05
Software-computer	Ability to use computer and mathematical technologies in the ecological-experimental data array processing; ability to create computer simulation eco-models on the basis of the mathematical-logistic apparatus	3.42	1.72	4.3	1.52	<0.05

*University professors supervising the internship bases, specialists-ecologists and administration representatives of the internship bases were the experts of this experiment.

Brief description of model development process of future ecologists' mathematical competence at the University

Model of future ecologists' mathematical competence development process at the university (Figure 1) includes the following interrelated modules: 1) a *functional-target* module which reflects the goals and objectives of professionally-applied mathematical training of the future ecologists; 2) a *content-problematic* module which reflects professional-applied and practice-oriented content of the training courses, elective and optional courses, different types of practices according to the curriculum of future ecologists' professional training; 3) an *organizational-technological* module which reflects certain professional and educational technologies that are effective for mathematical competence development (in particular, design, gaming, modular technologies); 4) a *criteria-assessment* module which reflects the essence and methods of monitoring to assess the effectiveness of future ecologists' mathematical competence formation.

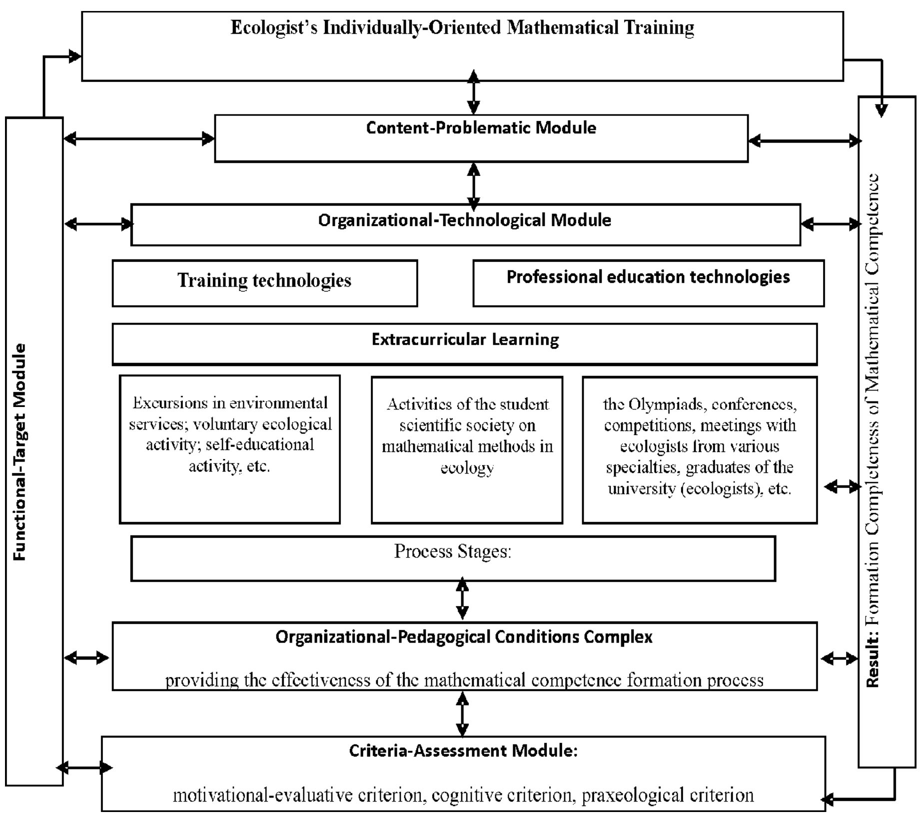

Figure 1: Model of future ecologists' mathematical competence development process

The main *functional-target* model references are development of teaching-learning and professional interests of future ecologists in the mathematical field; development of skills to analyze, generalize and systematize facts and phenomena, to infer cause-and-effect relationships; mastering of theoretical knowledge in the field of applied mathematics; development of the analytical-synthetic way of thinking, logically justifiable professional conduct; mastering a variety of forms, methods, technologies of using mathematical apparatus for solving specific tasks of the ecologist's professional work, including environmental monitoring and auditing; development of skills to make independent decisions in their professional activity; intensification of the creative approach to solving professional-environmental tasks that require mathematical apparatus; development of self-educational activity skills in the field of the ecologist's special mathematical training.

Content-problematic module reflects the complex of teaching units, problem-semantic aspects of professionally-oriented mathematical training of ecologists and also includes the following items: students' mastering the issues of universal significance of mathematical knowledge, evolution of relations between mankind and nature through the development of science based on mathematical language, studying theory of algorithms, studying the problems of modeling environmental phenomena and systems.

Applied basis for implementing the model of future ecologists' mathematical competence development process at the university includes: system of optional and elective courses dealing with the use of mathematical methods in ecologists' professional researches; excursions to environmental services aimed to analyze the use of mathematical methods in real work of specialists-ecologists; the Olympiads, competitions, scientific-practical conferences, meetings with experts in environmental monitoring (scientists, practitioners), university graduates working in the ecology sector; various kinds of students' self-educational activity in the mathematical field; use of computer technologies; application of mathematical technologies to solve specific tasks of ecologist's professional work during the internship; use of mathematical technologies in writing course projects and qualifying papers on ecological and environment protection problems; activity of student scientific society "Ecology and Mathematics".

In the course of forming pedagogical experiment (during the work with students majoring in "Ecology and Nature") the authors of this article tested numerous educational-informative, educational-professional and educational-research projects. These projects can be used at other universities and advanced training institutes in the process of future ecologists' mathematical competence formation: using the technique of optimal (linear) programming and objective function to calculate the diet of livestock, rare species in nature reserves; drawing up probability orgraphs to estimate impact of pasture fertilization on grazing; using the orgraph methods to carry out comparative ecological-economic analysis of construction and operation of thermal power plants (TPP) and hydroelectric power plants (HPP) in the same region; mathematical analysis of ecological-economic efficiency of the proposed atmosphere-protective and water-protection activities; calculation of relative hazard indexes within the territory of active pollution zone; mathematical modeling of organic matter dynamics in water reservoirs, in particular the phytoplankton abundance; development of different options of mathematical ecological "predator-prey" model taking into account the multi-dimensional factors affecting the growth of certain populations; using of mathematical theory of system description with limiting factors – L-systems (in particular, mathematical modeling of the plant biomass growth process), etc.

DISCUSSION

Assessing the aggregated mathematical competencies formedness in the university graduates (ecologists)

Solving of research tasks required special attention to the organization of various types of internship during which students performed the educational-professional tasks using mathematical apparatus. Following the results of pre-graduation internship the expert assessments of the undergraduate ecologists' mathematical competences development year were compared (see Table 1).

For identification the consistency of the assessments for each skill, the coefficient of concordance W was determined. It showed the consistency of experts' opinions from *average* (0.52) to *high* (0.78) with regard to the different groups of competencies, which enabled to consider a comprehensive assessment of the graduates' professional-mathematical skills to be sufficiently correct.

According to the results of the research experimental work, change in the levels of graduate students' logical thinking development was also recorded (Table 2) (the methodology by L.A. Gromova and A.V. Alekseev was used).

TABLE 2: RESULTS OF THE PROCEDURE FOR "DETERMINING LEVEL OF LOGICAL THINKING" (IN %)

Inspections	*Low level*		*Average level*		*High level*	
	2011 Graduates	*2016 Graduates*	*2011 Graduates*	*2016 Graduates*	*2011 Graduates*	*2016 Graduates*
Primary Inspection (1 year)	27.6	31.7	39.6	38.3	32.8	30
Control Inspection (4 year)	20.7	20	41.4	41.7	37.9	38.3

During the process of experimental work motivation of future ecologists studying mathematics at high school was also studied (Table 3).

While implementing the model of the process of future ecologists' mathematical competence development the following ***aspects*** have been identified in the content and technology of experimental work:

TABLE 3: QUESTIONNAIRE RESULTS "MOTIVATION OF FUTURE ECOLOGISTS DURING THE STUDYING MATHEMATICS" (IN %)

Types of motivation	*2011 Graduates*		*2016 Graduates*	
	full-time education	*part-time education*	*full-time education*	*part-time education*
Informative, intellectually–compelling, interest to the content of applied aspects of environmental mathematics, to computer programs of mathematical processing of experimentally-ecological data arrays, etc.	38.1	39.2	46.7	45.8
Perspective-professional motives, sense of responsibility and duty, awareness of the ecologists' mathematical competence necessity, etc.	40.3	41.4	42.6	43.3
Avoidance of educational failure situations, poor marks in mathematics, etc.	21.6	19.4	10.7	10.9

a value-oriented aspect (implying formation of students' attitudes to mathematical knowledge as to the value in the system of scientific culture of humanity which largely determines the prospects of modern high technology development designed to improve the standard of people living and population well-being);

a cognitive aspect (ecologists' mathematical competence should be formed relying on the knowledge of basic fundamentals of the various scientific disciplines: natural sciences, law, chemical-technological, social-ecological, economic, special-professional, etc.);

an activity aspect (expressed in activation of students' self-educational activity in studying applied aspects of mathematical technologies, in systematic lessons for the development of future ecologists' mathematical culture, since the high level of its formedness increases the graduates' competitiveness in the labor market among the professionals engaged in mathematical, statistical, computerized processing of experiment-environmental data arrays);

a moral-aesthetic aspect (a person understanding and perceiving the beauty of mathematical laws, theorems, axioms and formulae can realize the necessity of using mathematical apparatus in their professional activity);

a *personal aspect* (based on students' training-educational and educational-professional activities seeking to grasp the necessity of their knowledge of the mathematics fundamentals in various fields of employment. Due to personal experience a person assimilates a wise algorithm of activities after achieving these aims: analysis of the professional situation, highlighting the problem, reflection and pondering of the problem, action planning, rigorous peer reviewing, reasonable activity, results analyzing, critical assessment of own actions);

a *creative aspect* (formed mathematical competence implies a creative approach to the innovative use of various achievements of modern applied mathematics for efficiency improving in ecologist's professional activity; optimization of ways to solve different classes of standard environment protection and social-economic environmental tasks; creative development of new methods and techniques for quality improvement of experimental data array processing, creation of mathematical models of various ecosystems, etc.).

Assessing the levels of university graduates' (ecologists') mathematical competence development (formedness)

In compliance with the structure of the ecologist's professional-mathematical competence the criteria enabling to state the competence formedness levels have been determined: a *motivational-evaluative criterion* (including the following indicators: a positive attitude to professional-environmental activity, awareness of the need of mathematical knowledge, skills for solving environment protection activity tasks, sustainable pursuit of self-educational activity in the field of applied mathematical technologies); a *cognitive criterion* (including the following indicators: the possession of the professional mathematical knowledge system, algorithmic and heuristic applied mathematical technologies; formedness of critical, systematic, logical, integrative-inductive, analytical-prognostic style of thinking); a *praxeological criterion* (including the following indicators: willingness and ability to use mathematical technologies in environment protection activity, adequate insight into the essence of an ecological problem, ability to solve effectively professional tasks in rigidly defined rules and situational conditions, etc.).

The theoretical analysis of the problem and employed comprehensive diagnostic technologies that were approved in the course of the research allowed identifying the *levels* of mathematical competence formedness (development) in university graduates: *a basic level* (characterized by the interest to the problem of mathematical ecology, basic mathematical knowledge; ability to transfer an applied task of professional environment protection activity into the mathematical language, etc.); a *professional-responsive level* (characterized by the ability to construct an algorithm for applying mathematical apparatus to the solution of the simplest applied tasks of environment protection activity; available sustained motivation to improving own mathematical competence, desire to generalize own experience and the colleagues' experience, occasional achievement of success in solving complicated professional tasks using applied mathematical technologies); a *professional-technological level* (characterized by the ability to generalize applied mathematical knowledge, technologies into the holistic systems based on the operations of analogy, classification, analysis and synthesis; ability to develop mathematical models of different types, assess their adequacy, choose methods for mathematical processing of data arrays; high level of professional-personal responsibility; systematic success achievement in the solution of complicated tasks using the mathematical apparatus); a *professional-prolonged level* (characterized by the ability to predict the social significance of eco-monitoring and ecological qualimetric project, its consequences, the progress and the result of professional influence; automated use of applied mathematical technology complex for solving tasks of environment protection activity; desire to develop and substantiate the author's methods for solving non-standard tasks of social ecology); *a professional-research level* (adequate usage of systemic analysis to build complicated mathematical models; aspiration to systematic improvement of own professional competence in terms of mastering the technologies of ecometrics, sociometry, econometrics, anthropometry; optimal application of mathematical apparatus for the implementation of analytical-prognostic, expert-assessment functions of environment protection activity, etc.).

The level of professional-mathematical competence was identified on the basis of the completeness coefficient of the formed integrated professional-mathematical skills which is determined by the following formula:

$$K = \frac{\sum_{i=1}^{N} n_i}{n \cdot N}$$

where: n_i – the number of correct executed technological operations; n – number of operations to be executed; N – the number of calculated ecological-mathematical environment protection projects made by students; K – completeness coefficient of the professional-mathematical skills formedness.

According to this methodology, the levels of ecologists' professional-mathematical competence are located in following intervals:

$K<0.3$ – basic level,

$0.3 < K < 0.5$ – professional-responsive level;

$0.5 < K < 0.7$ – professional-technological level;

$0.7 < K < 0.9$ – professional-prolonged level;

$0.9 < K < 1$ – professional-research level.

Deferred monitoring for the graduates' professional growth was conducted using a combination of methods: interviews with colleagues, administrative authorities of the environmental services and environment protection organizations; analysis of the results of introducing the ecologists' recommendations in a particular institution, enterprise, environment protection area, etc.; implementation of comprehensive diagnostic methods. The deferred monitoring results confirmed the tendency to development of ecologists' professional-mathematical competence the foundations of which were formed during the university studies (Figure 2).

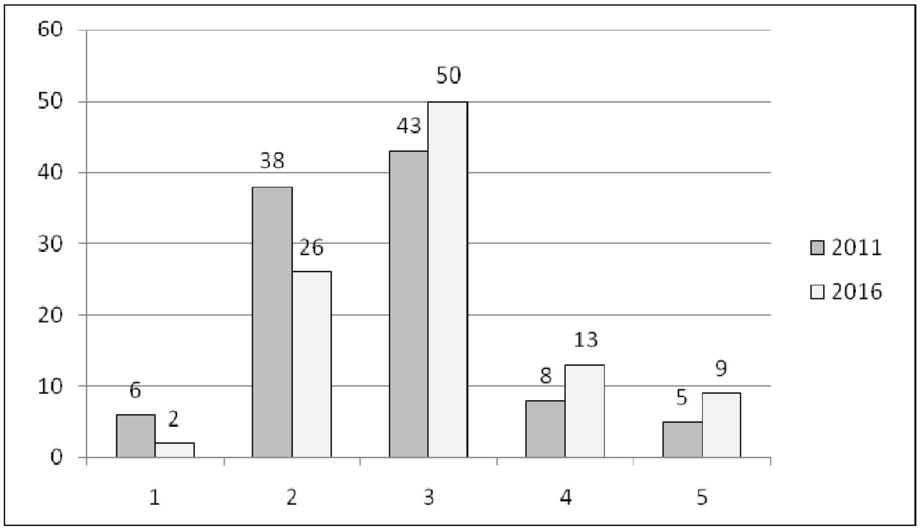

Figure 2: Levels of ecologists' (university graduates') mathematical competence formedness

Professional ecologists (former participants of the experiment) employed in different environmental services of federal, regional, municipal, local levels, perform their occupational activity skillfully, one of the components of this activity being the application of mathematical technologies for assessing the environmental quality of human being, social institutions, and society.

CONCLUSION AND FINAL CONSIDERATIONS

The ecologists' mathematical competence is one of the important conditions for successful adaptation in their occupation, as well as a factor of their high labor productivity.

The ecologists' mathematical competence includes individually developed strategies of applying mathematical apparatus in the labor sphere, computer and mathematical methods of solving professional tasks to transfer them from the experimental to the practice-targeted (applied) state.

The efficiency of forming future ecologists' mathematical competence at the university can be substantially improved if: *a)* substantial-technological support of future ecologists' mathematical competence reflects the requirements of qualifying characteristics and regional specifics of the ecologist work in various fields of environment protection activities; *b)* mechanisms for integration of students' natural science, mathematical, legal-regulatory, special ecological training aimed at the formation of various components of future ecologists' mathematical competence are implemented; *c)* the unity of professionally-applied mathematical theory and practice is provided and implemented in variative forms of students' educational and extra-curricular activities;) *d)* the required organizational-pedagogical conditions are created for the formation and development of future ecologists' mathematical competence at the university.

The complex of organizational-pedagogical conditions providing effectiveness of the process of future ecologists' mathematical competence formation at the university includes: *1)* implementation of structural-logical interdisciplinary connections that provide integrative environmental, mathematical, ecological qualimetric, legal, chemical-engineering, socio-economic and special ecological trainings; *2)* high level of professional-applied mathematical competence of the faculty members and their willingness to cooperate during the formation and development of future ecologists' competence; *3)* the priority of project-research, integrative-modular, task-activity-related, professional and educational technologies in the university educational process; *4)* intensification of students' self-educational activity in applied environmental mathematics; cumulative interaction of variative forms of extracurricular, learning, professional practical and research work relating to application of environmental mathematics technologies; *5)* active involvement of students in eco-monitoring and ecological qualimetric research, in projects during their internship and volunteer activities (students use mathematical methods during the project development); *6)* pedagogical monitoring of students' personal progress during the future ecologists' mathematical competence formation.

This research, findings of which are presented in this article, does not purport to be complete and comprehensive disclosure of the problem under study. The most relevant prospects for further development of the problem are: a) integration of theoretical-mathematical training and professional-applied activity of students during the internship; b) identification of qualitative differences in the content-technological basis of ecologists' mathematical competence depending on their specialty (ecologist-engineer, ecologist-auditor, etc.); c) development of students' self-educational culture in the process of mastering mathematical skills; d) improving the environmental experts' mathematical competence inside the advanced training system.

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References

Arora, M.S. & Rogerson, A. (1991). Future Trends in Mathematical Modelling and Applications, *In Teaching of Mathematical Modelling and Applications*, (Niss, M., Blum, W., Huntley, I, Eds.), Ellis Horwood, New York, pp. 111-116.

Averina, O.V. (2007). *The formation of professional-mathematical competence of ecologists at the University*: Candidate Thesis in Pedagogy. Moscow, Russian State Social University Press. 151 p.

Bauer, C. (1987). "Environment in Technology and Engineering Education". In Baez, A.V., Knamiller G.W., Smyth J.C., Eds, *The Environment and Science and Technologv Education. Science and Technology Education and Future Human Needs*, Vol. 8, Oxford, New York, Beijing: ICSU Press, Pergamon Press. 446 p.

Bergsmann, E., Schultes, M.-T., Winter, P., Schober, B., Spiel, C. (2015). Evaluation of competence-based teaching in higher education: From theory to practice. *Evaluation and Program Planning,* 52, 1-9. DOI: *10.1016/j.evalprogplan.2015.03.001*

Boesen, J., Helenius, O., Bergqvist, E., Bergqvist, T., Lithner, J., Palm, T., Palmberg, B. (2014). Developing mathematical competence: From the intended to the enacted curriculum. *The Journal of Mathematical Behavior, 33*, 72-87. DOI: 10.1016/j.jmathb.2013.10.001

Bolker, B., Brooks, M. E., Clark, J. S., *et al.* (2009). Generalized linear mixed models: a practical guide for ecology and evolution. *Trends Ecol. Evol*, 24: 127-135.

Clark, J. S. (2007). *Models for ecological data: an introduction*. Princeton, NJ: Princeton University Press. 152 p.

Danilov-Danilyan, V.I., & Losev, K.S. (2000). Environmental challenge and sustainable development. Moscow: "Progress-Tradition" Publishing House. 416 p. ISBN: 5-89826-045-5.

Evers, F. T., Rush, J. C., & Berdrow, I. (1998). *The Bases of Competence: Skills for Lifelong Learning and Employability*. San Francisco: Jossey-Bass Publishers. 273 p.

Everwijn, S. E. M., Bomers, G. B. J. & Knubben, J. A. (1993). Ability-or competence-based education: bridging the gap between knowledge acquisition and ability to apply. *Higher Education, 25*, 4, 425–438. DOÝ:10.1007/BF01383845.

Fleming, D. (1993). The concept of meta-competence. *Competence and Assessment*, 22, 6–9.

Friedrich, A., Jonkmann, K., Nagengast, B., Schmitz, B., Trautwein, U. (2013). Teachers' and students' perceptions of self-regulated learning and math competence: Differentiation and agreement. *Learning and Individual Differences,* 27, 26-34. DOI: 10.1016/ j.lindif.2013.06.005.

Glazachev, S. N. (2002). *Ecological culture and education: essays on social ecology*. Moscow: "Horizon"Publishing House. 244 p.

Gorelov, V. I. & Karelova, O. L. (2008). *Mathematical modeling in ecology*. Moscow: Russian Peoples' Friendship University Press. 139 p.

Grishagin, V. M. (2013). Professional environmental training (at the university) in the conditions of integrated education. *Vector of science of Tomsk State University*, 2(24), 405-409.

Hamilton, A. J. (2005). SLAC: A tool for addressing chaos in the ecology classroom. *International Journal of Mathematical Education in Science and Technology*, 36, 5, 489–496. DOI: 10.1080/00207390412331336247.

Hёsle, V. (1994). *Philosophy and ecology*. Moscow: "Kami" Publishing group. 192 p.

Kostova, Z. (1989). Environmental Education, Research and Practice, in Bulgaria. *The Environmentalist,* 9(2), 85-90. DOÝ:10.1007/BF02241881.

Marchuk, G. I. (1986). *Mathematical Models in Environmental Problems*. Elsevier Science. 216 p.

Martynov, G. P. (2014). *Mathematics for ecologists and cartographers*. Moscow: INFORM-REGISTR, Russia. 92 p.

Mirabile, R.J. (1997). Everything You Wanted to Know about Competency Modeling. *Training and Development,* 51(8), 73–77.

Nicolaou, C.T., & Constantinou, C.P. (2014). Assessment of the modeling competence: A systematic review and synthesis of empirical research. *Educational Research Review, 13*, 52-73. DOI: 10.1016/j.edurev.2014.10.001

Nikitina N.I., Galkina T.E., Tolstikova S.N., Avtionova N.V., Volenko O.I., Grebennikova V.M. (2014). The characteristics of the model for development of communicative deontological culture of school principals in the system of their refresher training. *Life Science Journal*, 11(12), 542-546. ISSN:1097-8135 http://www.lifesciencesite.com/lsj/life1112/104_26738life111214_542_546.pdf

Nikitina, N. I. & Rudko, E. A. (2012). Competence Approach to Mathematics Education of Future Lawyers. *Education and self-development,* 3(31), 60-65.

Podzorova, M. I. (2013). Features of teaching mathematics for ecology students. *Scientific notes of Russian State Social University*, 5, 26-32. http://elibrary.ru/item.asp?id=21240214

Reimers, N. F. (1994). *Greening*. Moscow: ROW Publishing House. 367 p.

Soare, E. (2013). A Pedagogical Model for Evaluation of Students' Competences. *Procedia – Social and Behavioral Sciences, 76*, 1-6. DOI: 10.1016/j.sbspro.2013.04.063

Stapp, W. B., & Polunin, N. (1991). Global Environmental Education: Towards a Way of Thinking and Acting. *Environmental Conservation*, 18(1), 13-18. DOI: 10.1017/S037689290002124X

Tarasova, N. P. & Makarov, S. V. (2006). *Environmental protection of the graduation projects*. Moscow: Mendeleev Russian University of Chemical Technology Press. 218 p.

Vernadsky, V. I. (1991). *Scientific thought as a planetary phenomenon*. Moscow: "Nauka". ISBN 5-02-003505-. 270 p.

Zaripov, S. H. (2010). *Introduction to mathematical ecology*. Kazan: Kazan Federal University Press. 47 p.

Zhukovà, G. S. (2013). *Mathematics for ecologists*. Moscow: Russian State Social University Press. 186 p.

Zimnyaya, I. A. (2003). Key competence – a new paradigm of result of education. *Higher education today,* 5, 34–42.