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On the Research of the Methodology of Mathematization of Pedagogical Science

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ABSTRACT

Topicality of the study is driven by the fact that the new fundamental mathematical ideas and methods of mathematics arise in the new era of mathematization of science and have a great influence on the formation of methodological culture of educational research in recent decades. The aim of the article is to identify the important aspects of the methodology of mathematization of pedagogical science. The leading approach to the study of this problem is a philosophical and mathematical analysis of aspects of the methodology of mathematization of pedagogical science that allows to consider in complex the aspects revealing in the light of matematization of sciences. The analysis of the specified aspects describes the main features of a methodological interaction between mathematical and pedagogical science, the influence of the ideas and methods of modern mathematics and mathematical culture on pedagogical research, on the formation of conceptual and terminological bases of correct logic and of the reasoning of pedagogical research. The materials of the article can be used in the correct use of ideas and methods of modern mathematics during the study of the characteristic features of pedagogical objects, processes and phenomena.

KEYWORDS
Aspects of mathematization of pedagogical research, methodology, pedagogical science

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Introduction

The analysis of works by J. Glass & J. Stanley (1976), M.I. Grabar & K.A. Krasnyanskaya (1977), L.B. Itelson (1965), L.V. Chuyko (2006), A.N. Khuziakhmetov et al. (2016), V.G. Zakirova & E.E. Purik (2016) shows that in the studies in many humanities, including pedagogy, the powerful arsenal of mathematics is still rather restricted. The vast majority of researches use, as a rule, only the ideas and methods of mathematical statistics, which are applied

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most often in the processing of experimental results. At the same time the process of science mathematization and new fundamental mathematical ideas and methods of mathematics, arisen as a result of this process, had a great influence on the formation of methodological culture of researches in the humanities (Ruzavin, 2014; Khuziakhmetov & Steinberg, 2016; Zakirova & Gilmiyarova, 2016). As a result, the mathematical psychology, sociology, ecology, history, linguistics, and some other "mathematized" sciences were formed on the boundary of teaching science and education theory. Therefore, the research of the methodology of mathematization of pedagogical sciences is relevant.

Methodological Framework

Research methods

The following methods were used to carry out the research: theoretical (research methods of mathematization of science and methodology of mathematical knowledge, methodology of pedagogy, theory of systematic approach in education, the theory of education integration); diagnostic (the study of monographs and theses on pedagogy, the questionnaire survey of masters and post-graduate students, the analysis of interviews with the masters, post-graduate students and scientists-mathematicians, and pedagogues and other members of the mathematical and educational seminars, and of the workshops on the stylistics of the scientific speech); experimental (observation over the process of training of masters and post-graduate students and their work on the theses and the process of their writing, experiments on preparation of reports at seminars).

Experimental resources of the research

Russian State Vocational Pedagogical University (Ekaterinburg) and Ural Federal University named after the First President of Russia B.N. Yeltsin (Ekaterinburg) were used as experimental resources of the research.

Research stages

The problem was studied in three stages:

the first stage dealt with the theoretical analysis of existing approaches in the study of the methodology of mathematization of pedagogy in philosophical, mathematical, psychological and pedagogical scientific literature, in theses on the issue; as well as the theory and methodology of educational research were analyzed; the problem, aim and research methods were determined and a plan of experimental research was drawn up;

the second stage focused on the study of philosophical and mathematical aspects of the research of the methodology of mathematization of pedagogical science; conclusions, acquired during the experimental work, were checked and confirmed.

the aim of the third stage was to finish the experimental work, confirm theoretical and practical conclusions, generalize and systematize the results.

Results

On the philosophical aspects and the results of research of mathematization methodology

From a philosophical point of view, in the process of science mathematization, including the improvement of its conceptual and categorical construct, the following situations typically occur, V.I. Kuptsov (1986). Either there is no adequate mathematical apparatus in the science that covers the features of this distinct scientific field. Either the science is not yet sufficiently developed in order to use the appropriate mathematical apparatus. Either, there are certain features of the science that do not allow its mathematization in some aspects. However, the increasing penetration of the ideas and methods of mathematics in pedagogical research does not fit into this scheme.

Firstly, the pedagogy as a science is so broad and diverse that it is very difficult to describe the proper mathematical apparatus that covers the features of this scientific field (Slastenin, Isayev & Shiyanov, 2002; Kuznetsova, 2001). In this regard, it is sufficient to refer to only one area of modern mathematics, playing an important role in educational research, which is the space of mathematical modeling by using a computer. It can be likened to a boundless ocean with many hundreds of islands scattered on the map, corresponding to the specific types of tasks and specific mathematical apparatus which is involved in their solving. That why, there are entirely various ways that are used in educational researches such as the interpretations, treatments, reductions and transformations of many types of mathematical models, such as the graphs and multigraphs, models with partial order relations, equivalence, models of fuzzy mathematics.

Secondly, it is impossible to state V.V. Krayevsky & E.V. Berezhnova (2006), V.S. Lednev (1991) that the pedagogical science with a thousand years of history, as well as the mathematics, is not sufficiently developed to use the appropriate mathematical apparatus. Certainly, just some representatives of pedagogical science simply does not have sufficient knowledge of mathematics in order to distinguish and to apply adequately the mathematical apparatus, which is required in pedagogical research. It has to be emphasized in this regard, that the mathematical apparatus which is appropriate to the problem of study is especially necessary in the classification, structurization and analysis of the information on the researched subject, in the ensuring of the logic correctness and argumentation of studies. A.V. Borovskih & N.H. Rozov (2010) and other leading pedagogues-mathematicians have concluded that the current state of pedagogical reasoning is clearly unsatisfactory. "It is especially common the scholastically-compilative argumentation. It is an abundant citation of works of various (past and present) authorities with subsequent compilation of those statements that are desirable to confirm (Borovskih & Rozov, 2010). It uses a variety of logical systems, often contradicting each other already in the initial prerequisites.

Third, the pedagogy is the science with certain features which do not allow its mathematization in some aspects. Rich pedagogical reality with its entire variety of the personalities of teachers and students allows only artistic and imaginative description of the reality, creative researches and doubts, through which the teachers and students passed, for an example, in the process of a unique experiment, described in the "A Pedagogic Poem" by A.S. Makarenko (1935), which can not be put in the “Procrustean bed” of scientific pedagogical language.

In this regard it has to be emphasized, that the problem of comprehension of artistic origins of the teaching process which is inseparably associated with training and education, dates back to N.V. Gogol, who was the first proposing the statement on the artistic nature of teaching, L.P. Grossman (1970). Being an associate professor of St. Petersburg University, he realized for the first time that only acceptance and understanding of the artistic nature of teaching can afford to raise the professional and pedagogical *culture of teaching* to the level of art, that is especially necessary in the training and education. That is why, abstract texts with dominating various diagnostics, sections, regressions, correlations, etc., showing, for example, the "right" changing pupils and students during the process of training and education, are nevertheless the lifeless ones and are the complete opposite to a live teaching reality despite their external scientificity.

On the mathematical aspects and the results of the research of mathematization methodology

From a mathematical point of view, the next points are important for the implementation of the mathematical line in the formation of methodological culture of educational research.

Firstly, in the implementation of the mathematical line an important role is played by the *reduction* method of the knowledge which is gained in pedagogy to the knowledge of mathematics that is more studied, more amenable to precise analysis (Schedrovitsky et al., 1993). Thus, it is a reduction to the knowledge that serves as the conceptual and terminological basis of correct logic and argumentation of studies, classification, structurization, organization and analysis of the information on the studied problem and its representation in the computer etc. This plays an important role in the modernization of the definitions in the methodology of pedagogy in agreement with the current model methodology which is formed as a result of the mathematization of science. As is known, the subject of model methodology is the statement of arising problems, their translation on the adequate scientific language, as well as a rational development of corresponding models for the studied objects and/or phenomena, and efficient algorithms and computer programs for solution of the problems on the basis of devised models (Neuimin, 1984). Thus, it is based on the generalized systems of interdisciplinary knowledge of various sciences, which play a fundamental role (Derkach, 2004). Therefore, the model methodology serves as the basis for solution of specific problems on new, qualitatively higher level of concepts and ideas in comparison with the pre-computer era. It seems that this reduction method is well developed in the methodology of mathematics education methods which are based on the concept of methodical system of subject (discipline) education, that is formed as a result of the reduction. This important concept was revealed in the analysis of different interpretations of the concepts of a mathematical structure (system), different types of relations between its elements and the specific interpretations of structure (models). In particular, an important role in the study of methodical system of teaching the subject (discipline) is played by various educational analogues of demonstrative mathematical structures, originated as a result of the reduction, such as already mentioned various graphs and multigraphs, the structures with different relationships between elements (partial order, equivalence and et al.).

Secondly, indirect normalization for methodology of pedagogical research is necessary, meaning the orientation on the ideas and methods of mathematics, which play an important role in the identifying the methodological standard of the study correctness. In the identification of these ideas and methods of mathematics the fundamental role is played by modern mathematical culture with its most striking manifestations, such as the mathematical modeling, mathematics of discrete variables and computational processes (Perminov, 2011).

These manifestations of mathematical culture, which are reflected in many sciences, play an important role in adjusting of conceptual and terminological construct of pedagogy on the interdisciplinary basis (clarification of teaching laws, regularities and theories, etc.). They are important in the formation of the group of scientific pedagogical knowledge, which, in the opinion of V.V. Krajewski & E.V. Berezhnova (2006), V I. Zagvyazinsky (1976) are the rules, regulatives of activity, knowledge of how to plan and implement the pedagogical research. Normative role of mathematics terminology that underlies the modern mathematical culture plays a fundamental role in the "sequence of transitions from the empirical description of pedagogical reality ... to its representation in the theoretical models and normative form (standard models)" (Krajewski & Berezhnova, 2006).

Inadequate possession by teachers of the basics of modern mathematical culture of research generates a number of common weaknesses in logic and argumentation of studies. As the analysis of V.A. Popkov (2013) research shows, there are widespread the typical disadvantages of incompetent (in terms of mathematics) classification of pedagogical objects, inappropriate causal analysis of pedagogical phenomena (reasons of their appearance), the definition of new concepts, the illegality of hasty generalizations, application of the induction, analogy, etc. In particular, this paper provides examples of violations of the completeness of objects classification, which is based on the concept of "equivalence relation on the set" (of pedagogical objects), in accordance with that the belonging of the detected object to only one classification unit is revealed.

The language of mathematical structures and schemes (in general scientific terminology, they are tools, research methods) is especially important in pedagogical research. The language plays a fundamental role in the implementation of structural and logical approach, allowing "to build on conventional (contractual) basis a hierarchic system of conceptual and terminological construct of pedagogy, without which the conceptualization of new knowledge can not be obtained" in an era of avalanche-like increasing information flows (Orlov, 2013).

Basic mathematical structures and their various interpretations - models play an important role in the analysis of the structural properties of the pedagogical research subjects and, on this basis, in the correlation of the result with the original problem and the initial hypothesis. That is why the problem and hypothesis usually vary, sometimes quite substantially. Therefore, the basic concepts of the language of mathematical structures such as the relations (interrelations) between the elements of the structure, isomorphism (similarity) of mathematical models, the concept of mathematical logic are important to track changes in the problem, hypothesis, methods of research, design and

implementation, object, the subject of activity. They play an important terminological role in methodological context of research.

Thirdly, in the process of implementation of mathematical line should be based on ontological and methodological equity of pedagogy and mathematics, as both are the sciences non-reducible to each other and have the great practical importance. In this case, the interaction of knowledge in educational research in these sciences will be realized in the entirety of their functions (Zakirova, 2015). Meanwhile the interaction of knowledge is limited to a distinct area of study, and can be suitable only for the solution by clearly restricted practical issues.

It has to be noted that the methodological (figuratively speaking) "equality" of pedagogy and mathematics is evidenced by the fact that the development of mathematics as a science is impossible without pedagogy, as the training of mathematicians-researchers is a very long and complex pedagogical process, which can not be carried out without possessing a profound pedagogical culture.

Apparently, for the deepening of methodological interaction of pedagogy and mathematics the preparation of pedagogy's "mathematizators" (Perminov, 2013) became necessary. This is a specialist in the field of mathematics, working at the intersection of mathematics and pedagogy, who became an pedagogue-researcher, and at the same time maintaining the specificity of mathematical thinking. "Mathematizator" is needed for the training of the future pedagogue-researcher, which has a sufficient knowledge in the mathematics and the style of thinking for an adequate mathematical support of research work in the pedagogical study, for example, in dealing with complex tasks in the field of education, and who knows how to perform properly the experimental work in the process of these tasks decision.

As it follows from the above, a fundamental role in logic and the correct implementation of the pedagogical research is played by a content-scientific interaction of ideas and methods of pedagogy and mathematics as a translation of mathematical knowledge in the educational one. The interaction is carried out in its different features and modifications, starting form the adoption and acceptance of ontological and axiological principles and values of mathematics - from the axiomatic method to modern model methodology as a basis for specific tasks solution on a new, qualitatively higher ideological and conceptional level.

Discussions

When any complex problem arises in the pedagogical science, it requires a comprehensive approach and the *system* analysis, the knowledge arsenal comes from several sciences, including the mathematical science. However, as it was noted above, the vast majority of educational researches still use only the ideas and methods of mathematical statistics. At the same time, as it was already noted above, the possession of the fundamentals of modern mathematical research culture is needed to deploy a constructive methodological work on the cultivation of a new paradigm of educational research in the era of the mathematization of science. The possession of these basics requires, in particular, the knowledge of mathematical basics of the *system* analysis (Mesarovic & Takahara, 1978) based on the language of mathematical structures (systems) and schemes. The knowledge of the language of these structures and schemes play a fundamental role in the logic and reasoning of pedagogical research, including the classification, structurization,

systematization and analysis of information on the researched pedagogical problem. As it is already noted above, this fundamental language allows to compose a hierarchic system of conceptual and terminological construct of pedagogy.

The analysis of a number of common weaknesses in the logic and argumentation of a research indicates the non-formedness of *cognitive structures or schemes* (widely known in psychology) in the thinking of researchers. They are the *reflection* of mathematical structures and schemes in thinking that present the structural levels of the organization's ability to act in the "mind" and ready-made logic programs of reasoning. As it is justified by E.A. Perminov (2012; 2014), the language of these structures and schemes play a fundamental role in the formation of the basic intellectual operations of the thinking, those are the abstraction, comparison, classification, analysis, synthesis, generalization, systematization, disclosure of the relationships, identification, coding, categorization, distinction, matching, logical operations of reasoning, judgment, conclusion and some others.

Conclusion

Apparently, due to a number of important features of pedagogical science, including the mentioned above, it is unlikely that in the visible future it will be possible to talk about the birth of mathematical pedagogy. But there are many pedagogues who are not "waiting for the moment when the mathematics will present their ready-made instrument of analysis, but generate it within yourself, sharpen it on their tasks and use it to solve their problems" J. Glass & J. Stanley (1976), as it is already occurred in psychology, sociology, ecology and some other "mathematized" sciences. Therefore, a specialized training of that teachers ("mathematizators" of pedagogy) is needed in graduate and postgraduate education, taking into account the subject area of their scientific specialization in general, age, branch pedagogy and/or the other sciences in the system of pedagogical sciences. They should get rather high enough preliminary mathematical training on the mathematical faculties of universities and pedagogical institutes and show the good abilities to creative research in the pedagogy.

Disclosure statement

No potential conflict of interest was reported by the authors.

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