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**THE USE OF REAL-LIFE CONTEXT IN MATHEMATICS LESSONS AT
SECONDARY SCHOOL LEVEL: AN INTERNATIONAL PERSPECTIVE**

Summary of the PhD thesis

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Journal publications:

1. Tyumeneva, Y. A., Larina, G., Alexandrova, E., DeWolf, M., Bassok, M., Holyoak, K. Semantic Alignment Across Whole-Number Arithmetic and Rational Numbers: Evidence from a Russian Perspective // *Thinking and Reasoning*. – 2018. – Vol. 24. – No. 2. – P. 198-220.
2. Larina, G. S. Analysis of Real-World Math Problems: Theoretical Model and Classroom Application // *Educational Studies*. – 2016. – Vol. 3. – P. 151-168.
3. Larina, G. S. Real-World Math Problems in USE and BSE // *Education and Society*. – 2015. – Vol. 93. – No. 4. – P. 30-34.

Other publication:

1. Larina, G., Markina, V. M. Teachers' beliefs about student diversity: exclusive and inclusive models // National research university Higher School of economics. Series WP BRP "Basic research program". – 2017. – No. 43.
2. Larina, G. S., Kuzmina, J.V. Whether the Russian education has become more effective over period of 8 years? (based on PISA) // Yasin, E. G. (Ed.). XIV April International academic Conference on Economic and Social Development: 4 volumes.– Moscow: HSE Publishing House, 2014. – P. 565-574.

Presentations at conferences:

1. International conference “20 years of Russia’s participating in the international assessment on education quality” (Moscow, 24-25 November 2016). Oral presentation “Real-world math problems in the classroom”.
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3. 60th Annual Conference of the Comparative and International Education Society (CIES) (Vancouver, Canada, 6-10 March 2016). Oral presentation “Math teachers' beliefs and practices towards new curriculum demands”.
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Research Problem

The use of a real-life context in school education could be a source of a wide range of opportunities both for deeper mastering of subject and for the developing cognitive skills. In a number of studies it has been shown that the use of a real-life context in education contributes to problem solving skills, helps students apply gained in class knowledge to real-life everyday life and increases their motivation for learning [Cognition and Technology ..., 1990; Boaler, 1993; Brenner, 1998; Chapman, 2006; Freudenthal, 1973; Gravemeijer, 1994; Pilot, Bulte, 2006].

According to the large-scale international studies TIMSS¹ and PISA², Russian students demonstrate high results at subject mastery level, but they are much less able to cope with tasks embedded in non-mathematical settings. These results seem to be true both for mathematics and science. To solve PISA tasks formulated in the context of everyday life, it is necessary to have the modeling skills - that is, to be able to build a mathematical model of the proposed daily situation [PISA 2012 Assessment..., 2013]. Thus, relatively lower students' results in PISA compare to student's results in TIMSS may indicate, that students in Russia experience difficulties to apply gained in school knowledge in a real-life context.

Such the gap in the students' TIMSS and PISA results in Russia could be explained with the fact how math education is organized in Russia [Bolotov et al., 2012; Kasprzhak and others, 2005]. That is, it was shown that math teacher get insufficient methodological support for the use of real-life context in mathematics at school [Egurova, 2014; Tyumeneva et al., 2015]. Thus, it is important to explore how the work with a real-life context is organized in secondary school in Russia.

It is important to note that the problem identified on the TIMSS and PISA data is relevant for several school disciplines such as chemistry, biology, physics and mathematics. However, this dissertation was focused on studying the use of context in teaching mathematics. Compared to other school disciplines, mathematics is closely connected with scientific and technological progress in the country and is considered as a universal language of all natural sciences. In other words, mathematics is a science of principal and fundamental concepts of the world, and "mathematical literacy is an indispensable element of culture, social, personal and professional competence " for all citizens of Russia [Concept of development ..., 2013]. In addition, within the framework of school education, mathematics is considered to be of a principal importance for successful mastering of other disciplines and is a unique tool of intellectual development of students [Kozlov, Kondakov, 2011].

¹ Trends in International Mathematics and Science Study – international assessment of students' knowledge at 4th and 8th grades. There are two domains in the focus of the study: mathematics and science. Contextual data about the students, their parents, their teachers and their principals are collected via questionnaires. <https://timssandpirls.bc.edu>

² Programme for International Student Assessment – international assessment of 15-year-old students' literacy in three fields: reading, mathematics and science. Contextual data about the students and their principals are collected via questionnaires. <http://www.oecd.org/pisa/>

Federal standard for education in secondary school emphasizes the growth of "a value of mathematics and computer science in the daily life of a person". That is, a person should be able "to model real-life situations in the language of algebra, to study the constructed models by using the algebra conceptions, to interpret the obtained results" and "to apply the concepts, results, methods for solving practical problems and problems from related disciplines". The necessity to develop the abilities of students to use school knowledge in everyday life is emphasized in the "Fundamental core of the content of general education" as well [Kozlov, Kondakov, 2011]. Moreover, since 2013 the math test for the 9th grade students includes the module "Real-life mathematics", and a requirement to pass exam at the minimum level is to solve at least two tasks correctly.

It should be noted, that this research is focused only on the use of real-life context on the material of "Algebra" in the secondary school, since according to the results of PISA 2012, Russian students has lowest achievement in the following three subject areas: Number, Uncertainty and Data. The content of these areas corresponds to the sections "Algebra", "Functions", "Arithmetic" and "Probability and statistics", presented in the course "Algebra" (7th-9th grades in secondary school). Thus, while studying the issues of using real-life in education, a particular attention should be paid to the aspects of using the context in the course "Algebra".

Literature Review

The variety of teaching practices towards real-life context, word problems and related to them effects for the students' achievements are widely studied in the literature. The most widely these questions are considered within the framework of the theory of situational learning [Lave, 1988; Lave & Wenger, 1991; Greeno, Smith, & Moore, 1992], as well as in the context of the transfer of knowledge [Lehman, Nisbett, 1990; Gick and Holyoak, 1980; Bransford et al., 1999]. As concerns Russian literature, learning in context is mainly considered within the framework of vocational education and higher education [Verbitsky, 1991]. Recently, issues of the learning in a context is discussing within a competence-based approach to education [Verbitsky, 2016]. A large number of works have been devoted specifically to the use of real-life context in math education: V.V. Firsova, I.M. Shapiro, M.V. Egupova, J. Boaler, L. Verchaffel, E. De Corte, as well as dissertations, for example, L.E. Haimina, V.P. Kizilova, N.V. Reshetnikova.

Following aspects of using a real-life context in education are studied: teaching practices [Greeno et al., 1997; Lange, 1996; Boaler, 1993; Chapman, 2006] and teachers' beliefs [Meirink et al., 2009; Thompson, 1992; Stipek et al., 2001]. However, a little attention has been paid to a connection between the way of working with a problems' context and a content of problem. Next, math teachers' beliefs about the possibility to use a real-life context in education in Russia have not been explored yet. Finally, the use of a real-life context in math education in Russia has not been considered from an international perspective. Thus, the small numbers of empirical studies devoted to these questions inspired the decision to explore this topic.

Objectives of the Research

The aim of the dissertation was to analyze the use of real-life context in teaching mathematics at secondary school level in Russian and to consider the results from an international perspective of using real-life context at school. The study included the following **steps**:

1. Systematization of the main theoretical and empirical approaches to describe practices and strategies of using real-life context in mathematics lessons;
2. Analysis of math teachers' approaches towards real-world context in Russia;
3. Examination of math teachers' beliefs about role of real-life context in teaching mathematics at secondary school level
4. Analysis of the use of real-life context in teaching mathematics in Russia from an international perspective

Theoretical framework of the study consists of next theories and concepts: situated learning (J. Lave, E. Wenger, Greeno, Smith, & Moore, J.R. Anderson); role of using context in education (R.A. Engle, D. Hammer, O. Chapman, B. Cooper, A.V. Harries, OECD); real-life context in teaching math (H. Freudenthal, A. Treffers, V.V. Firsov, N.A. Tereshin, I.M. Shapiro, M.V. Egupova); word problems (L.M. Fridman, B. Greer, L. Verschaffel, S. Gerofsky, R. Watanabe, B. Ischinger, W. Blum, M. Niss, T. Palm, D.H. Jonassen, Y.A. Tyumeneva, M.V. Egupova); teachers' beliefs (A.G. Thompson, L.R. Van Zoest, J.V. Bohl, D. Stipek, R. Mosvold).

Research Questions

1. Research questions about math teaching practices and its connections with students' results in math:
 - a. Which math teachers' approaches towards real-life context are popular in Russia and what is the difference between them in Russian and other countries?
 - b. What is the relationship between math teachers' practices towards real-life context and the students' results in TIMSS and PISA?
2. Research questions about math teachers' approaches towards real-life context in mathematics lessons:
 - a. What type of real-life word problems do teacher use in math lessons?
 - b. What are the teaching practices and strategies towards real-life context in math lessons?
 - c. What is the difference in the use of real-life context between math teaching in Russia and other countries?
3. Research questions about the math teachers' beliefs about using real-life context in math learning at secondary level:
 - a. What are the math teachers' beliefs about role of real-life context in math learning in Russia?
 - b. What is the difference in teachers' beliefs about using real-life context between math teachers in Russian and other countries?

Methodology

The mixed-method design was chosen to conduct that research.

In order to answer the first group of research questions there were employed datasets of two large-scale assessment TIMSS and PISA, and one panel from a longitudinal survey TrEC³:

1. Math teacher questionnaires from TIMSS 2011 and student questionnaire from the PISA 2012: representative and randomized samples from Russia and 16 other countries (Australia, Israel, Jordan, Italy, Kazakhstan, Republic of Korea, Malaysia, Norway, United Arab Emirates, Singapore, Thailand, Tunisia, Turkey, Finland, Sweden, Japan) were employed.
2. The panel of math teacher questionnaire of TrEC 2014 in Russia (representative randomized sample, N=192).
3. Achievement datasets of TIMSS 2011 и PISA 2012, that were conducted on the same sample within the framework of TrEC. TIMSS 2011 sample consisted of the 8th grade students and PISA 2012 sample consisted of the 9th grade students. The total sample consisted of 4778 from 210 classrooms.

Descriptive statistics, chi-square and linear regression analysis were used.

In order to answer the second and third groups of research questions there were employed qualitative data. In 2014-2016 the additional data was collected in 30 schools from 9 regions in Russia. The sample was non-random and consisted teachers who have participated in TrEC study in 2012. In every school:

1. There was conducted a semi-structured interview with math teacher (N=28).
2. A math lesson in 8th or 9th grade was videotaped (N=25).

The collected data was transcribed and coded. Transcripts of interviews were analyzed with open and axial coding within the framework of the grounded theory analysis. Next, there were analyzed word problems, which teachers used at the videotaped lessons (N=90). In addition, word problem from demo versions of the Basic State Exam 2015 and the Unified State Exam 2015 were considered. Coding schemes were developed in order to code word problems and teachers' approaches towards real-life in math lesson. Descriptive statistics, chi-square analysis, regression and cluster analysis were used.

Main results

In order to answer the first group of research questions the datasets of TIMSS 2011, PISA 2012 and TrEC were analyzed. First, according to TIMSS 2011 data, it was shown that mathematics teachers in Russia and in foreign countries devote a comparable amount of time to many math teaching practices, including working with real-life context. However, in Russia, students at the 8th grades are much less likely to meet a task that require more independent problem-solving activity (solving complex and unfamiliar problems that do not have an obvious method of solution) compare to peers in other countries. And, at the same time, they are much more likely to perform tasks on

³ Trajectories in Education and Careers, <https://trec.hse.ru/en/>

reproductive activity (apply facts, concepts and procedures to solve routine problems). As for math test, Russian students more often needs to solve problems on memorizing rules, procedures and facts than their peers in foreign countries. It is important to note, that the real-life word problems tasks were presented in math tests in Russia with the same frequency as in foreign countries. Thus, in many cases, teachers in Russia use real-life context in teaching mathematics to the same extent as teachers in other countries. However, the number of math problems requiring more independent activity from a student is used less frequently in math lessons in Russia.

However, the results of the international study of PISA 2012 revealed quite opposite results: students in Russia are more familiar with the tasks and concepts that can be attributed to formal mathematics, rather than to applied mathematics. For example, the 9th students in Russia noted that they more often work in math lessons with concepts from algebra (quadratic and exponential functions) and geometry (vectors, polygons), solve equations, than with real-life word problems. Compare to other countries the frequency of formal math problems is one the highest among them.

Finally, the results of the comparison math teaching practices in classes with different TIMSS 2011 or PISA 2012 were ambiguous and contradict to the stated hypothesis. First, the frequency of the using teaching methods in these classes was significantly different only in several cases. But, secondly, teachers' responses about the frequency of using these methods varied significantly in different databases. Thus, based on the results of the analysis, no unequivocal and significant connection between the teaching methods and the students' math achievements has been showed.

Next, the answers for the second group of research questions were obtained. At the first step of the videotaped lesson analysis it was shown that the word problem is the most popular way of real-life connection in math lesson in Russia and other countries. In most cases these word problems involved context structural or interior design, shopping and banking. But, unlike math teachers in other countries, teachers in Russian use integrated problems in math classroom as a demonstration of math application in other school subjects. In addition, the views of mathematics teachers about what tasks should be used in the lessons to demonstrate the applicability of the content of the lesson in everyday life differed. So, in most cases the word problems in math lessons could be solved with mathematical modeling, but they have a cliché formulations and their context were not significant and relevant to the students. In other words, most often in the classroom, students encountered word problems that were not a correct reflection of everyday life.

The analysis of the teachers' approaches towards real-life context in math lesson showed, that in most cases teachers avoided the elaborating the context of the problem (narrative approach) and paid more attention to the overall structure of the problem, its type and the use of the known method of solutions (paradigmatic approach). In general, teaching interventions towards word problems of Russian math teachers are correspond to teaching practices in other countries. In addition, math teachers both in Russia and other countries are more focused on the modeling phase of problem solving than on the

interpretation phase. However, unlike foreign colleagues, Russian teachers do not pay attention to distinguishing relevant and irrelevant information in word problem.

Finally, the interventions towards word problems varied significantly by the type of the word problem. If the word problem's context was significant to a student life and had non-routine formulation, then the teachers were more likely to elaborate the real-life context of that problems. Conversely, if the word problem had to be solved just with modeling the situation, then math teachers devoted more time to the structure of such a problem. Thus, the methods used by teachers towards word problems are related to the characteristics of the word problem.

Next results were obtained answering to the third group of research questions. First, based on the analysis of math teachers interviews, it was shown that a significant part of teachers do not consider the role of real-life context as meaningful and self-contained in teaching mathematics. Although teachers in Russia and in other countries devote almost an equal amount of time to real-life context in teaching math, mostly Russian teachers use word problems in order to support teaching of the theoretical material or even as an entertainment. Math teachers in other countries also consider word problems as an additional source of increasing students' motivation, but, in comparison with Russian teachers, they do not distinguish this type of activity as secondary to the mastery of theoretical material.

Secondly, in math teachers' opinions, an additional difficulty of using real-life context math lessons is the lack of a sufficient number of appropriate word problems. In result, teachers have to spend large resources for searching these tasks or to develop them. Moreover, together with additional time costs for searching word problems, teaching interventions of real-life context is quite time-consuming, in teachers' opinions. Similar difficulties are experienced by math teachers in other countries, which also indicate a great time cost of using the real-life context in math lessons. Finally, math teachers both in Russia and other countries noted the lack of professional training for the work with real-life context in teaching mathematics.

In general, this study allowed us to consider the use of real-life context in teaching mathematics from several points of view, as well as from an international perspective. The conducted analysis and comparison of teaching methods on datasets of TIMSS 2011, PISA 2012 and TrEC have showed us significant differences in the frequency of using tasks with low and high cognitive loads. Further, the analysis of the teachers' approaches towards word problems has demonstrated that math teachers both in Russia and other countries similarly work with the real-life context of word problems. And an analysis of teachers' beliefs has revealed similar attitudes of math teachers both in Russia and abroad to the use of real-life context in teaching mathematics. Thus, the use of real-life context in math lesson is rather similarly organized in Russia and in other countries.

It is important to note, that the real-life context plays a secondary and supportive role in teaching mathematics in school, according to the results of the study. First, due to the teachers' approaches towards word problems, the teacher implicitly signals to students what is relevant to learning math in school. By skipping elaborating the problem

context, a teacher indirectly shows these interventions should not be paid attention to and that learning mathematics in school has nothing to do with real-life context. Secondly, the secondary role of real-life context was shown by the using of those word problems which often were not a correct model of the real-life. Finally, in math teachers' beliefs the real-life context also plays only a supporting role in the math learning process.

The obtained results contribute to the literature on the use of real-life context in education. The scientific novelty of the study lies in next results: 1) teachers' approaches towards real-life context at math lessons in Russia were described and analyzed; 2) a relationship between word problems and the chosen teaching practices towards real-life context were demonstrated; 3) teachers' beliefs about the use of context in math teaching and associated with that practices difficulties were described. In addition, for the first time math teachers' approaches towards real-life contexts were considered from an international perspective.

Practical significance of the study is ensured by the contribution to the understanding of key problems associated with using real-life context in math teaching in Russia: unrealistic word problems, specific teaching practices and the frequency of using tasks with low cognitive load. It is important to note, the obtained in the study connection between the type of word problems and teaching practices explicitly showed, that it is necessary to correct word problems in textbook and upgrade teachers' skills simultaneously.

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