The system of mathematical education of Russia: problems, tasks, solutions

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Abstract. The article presents a study of the currently functioning system of mathematical education in the Russian Federation. The importance of research areas related to mathematics for the Russian and world community has been substantiated. The analysis of the implementation of the modern Concept of Mathematical Education of the Russian Federation is carried out, achievements and problems are highlighted. The changes that have affected school and university mathematics education from the moment of approval of the Concept of Mathematical Education of the Russian Federation and up to the present, the positive and negative results of these changes are shown. On the basis of a survey conducted by the authors of representatives of the leading mathematical organizations of Russia for the changes necessary from their point of view that need to be introduced into the Concept of Mathematical Education, the most important and significant proposals for improving the quality of this sphere of education have been developed.

1. Introduction
Mathematics is essential to science, socio-economic and scientific-technological development not only for Russian Federation, but the entire world community. Mathematics is a system-forming direction in education, developing logical structural thinking in a person. Knowledge of mathematics is a must for every person aimed at successful activities and development in modern realities [1].

Figure 1. TOP-15 scientific directions by the number of «hot papers» publications in the World.
In order to determine the place of mathematics as a priority scientific direction in the world and in Russia, a study of the publication activity of scientists was carried out, based on the analysis of scientific publications «hot papers» (receiving citations during the first months after publication) [2]. The research results are presented in figures 1 and 2. Hot papers are listed in thousands of items.

It follows from the graph that in 2019, the top-15 includes areas directly related to mathematics: physical chemistry, applied physics, electrical engineering and electronics, etc. Applied mathematics is in 15th place. In general, there is a decrease in the number of «hot papers» in 2019 compared to 2018 in all areas of the top-15. Let's build a similar graph, but only for the Russian Federation (figure 2).

![Figure 2. TOP-15 scientific directions by the number of «hot papers» publications in Russia.](image)

It follows from the histogram that mathematics in Russia is in the Top-5 areas and the number of «hot papers» on it has tripled in 2019 compared to 2018 and actually by 100% compared to 2017, which says about the growth of scientific workers’ activity in this area. Publication activity in various areas of physics is also at a high level.

From the data shown in figures 1 and 2, it can be concluded that mathematics and scientific areas directly related to mathematics are relevant and significant in the world [3]. For Russia, mathematics is also an important scientific area, and Russian scientists are actively publishing with a high citation rate. At the same time, the development of mathematics in Russia has a number of significant problems, which are clearly indicated in the Concept for the development of mathematical education in the Russian Federation (hereinafter - the Concept), approved by the order of the Government of the Russian Federation of December 24, 2013 N 2506-r. First of all, this is the low motivation of schoolchildren and students to study mathematics, due to a lack of understanding of the importance of mathematics in the modern world order [4].

There are also substantive problems, which are characterized by the fact that mathematics education in higher educational institutions and schools is divorced from modern science, i.e. is actually depreciated. Another urgent problem is staff shortage in the educational environment due to the low qualifications of university graduates in the field of mathematics. The most talented university graduates migrate abroad [5]. The teachers working in universities are cut off both from the modern mathematical directions of research and from the application of mathematics in practice [6].

To solve these problems, the Concept provides a number of solutions. Consider the effectiveness of these decisions by analyzing international mathematical ratings since the approval of the Concept.
2. Changes in mathematics education in Russia over the past 7 years

Consider the PISA rating built within the framework of the International Program for the Assessment of Educational Achievements of Students. The rating is compiled every 3 years and is based on data obtained as a result of testing young people aged 15 years. The test assesses the mathematical literacy of schoolchildren and their ability to apply knowledge in practice (table 1).

| Country                      | 2012 | 2015 | 2018 |
|------------------------------|------|------|------|
| Singapore                    | 1    | 1    | 2    |
| Hong Kong                    | 2    | 2    | 4    |
| Taiwan                       | 3    | 4    | 5    |
| The Republic of Korea        | 4    | 7    | 7    |
| Macau                        | 5    | 3    | 3    |
| Russia                       | 32   | 23   | 30   |

The table shows that Asian countries are the undisputed leaders in the field of school-level mathematics. As for Russia, in 2012, our country was on the 32nd line of the rating out of 65. In 2015, Russia rose to 23rd line and in 2018 again dropped to 30.

As for higher education, according to the prestigious QS ranking, in the area of mathematics, Moscow State University named after M.V. Lomonosov. The university ranks 43rd out of 500 in 2020. Also, in the top 100 is St. Petersburg State University, and in the 101-150 group there are three more Russian universities (table 2).

| The name of the university                  | 2013  | 2017    | 2020    |
|-------------------------------------------|-------|---------|---------|
| Lomonosov Moscow State University         | 42    | 33      | 43      |
| Saint Petersburg State University         | 151–200 | 51–100  | 51–100  |
| MIPT / Moscow PhysTech                    | –     | 151–200 | 101–150 |
| HSE University                            | –     | 151–200 | 101–150 |
| Novosibirsk State University              | –     | 101–150 | 101–150 |

At the time of the approval of the Concept of Mathematical Education in 2013, MSU, in the QS ranking, was in 42nd place in the field of mathematics. St. Petersburg State University was included in the group «151-200». MIPT, HSE and NSU were not included in the top list of the best mathematics universities in the world.

3. Conclusions and offers

From the presented ratings it is clear that in the area of «mathematics», over the past 7 years, only in the part of higher education there is a positive trend. Three leading Russian universities moved up in the QS rankings and entered the top 150. St. Petersburg State University rose to the 51-100 group in 2017 and remained at the same level in 2020. The Russian mathematical leader, Moscow State University, climbed to 33rd place in 2017, and by 2020 dropped below the 2013 level [7].

There are no positive dynamics in education at the school level. While growing in 2015 in the PISA rating, in 2020 Russia dropped to its previous level. Based on these data, the article concludes that in the development of mathematical education in Russia there is some stagnation and a downward trend, which indicates the need to modernize the Concept of Mathematical Education [8].

In this regard, the authors of the article conducted a survey of the heads of four international world-class mathematical centers, regarding the problems of the effectiveness of the implementation of the Concept of Mathematical Education.

Centers participating in the survey:
Based on the survey, the authors made the following conclusions:

- It is necessary to reduce the teaching load of mathematics teachers to 600-650 hours.
- It is necessary to prescribe for the preparation of masters-mathematicians, in relation to bachelors, a decrease in the threshold for recruiting a group and a decrease in the teacher/student ratio by 1 rate.
- It is necessary to modernize the content of the curricula of applied mathematical disciplines of universities, considering the areas in which the regions have a significant backlog. The importance of the applied emphasis is described in «I. The value of mathematics in the modern world and in Russia» of the current Concept, and the modernization of the content of the curriculum is the first task in paragraph «III. Goals and objectives of the concept».
- With regard to the implementation of the seventh task of the Concept, the mathematical centers can organize both on their own and by inviting leading specialists in popular scientific mathematical directions periodic lectures for schoolchildren and the public.
- In terms of the implementation of the sixth task of the Concept, the organization of specialized camps and Olympiad fees should be carried out.
- P.3-4, subsection on basic general and secondary education, should be added a phrase about the introduction of a single program (basic and «advanced») and a single corresponding set of mathematics textbooks.
- P.3-4, subsection on basic general and secondary education, should be added a phrase about the need to improve communication between higher education and mathematical centers, on the one hand, and secondary school, on the other hand, in order to stimulate more active study of mathematics in school, motivating students to choose educational trajectories related to mathematical knowledge, and attracting active mathematicians to explain the importance of the role of mathematics in the modern world.
- P.5, subsection on additional professional education, etc., paragraph 2 shall be stated as follows: «It is important to support international organizations in Russia that solve the problem of training researchers and high-level teachers. It is necessary to ensure the development, increase support and strengthen the role of the network of world-class international mathematical centers and regional scientific and educational mathematical centers».
- P.5, subsection on additional professional education, etc., in paragraph 3. exclude the phrase «... to ensure that the mathematical faculties of leading Russian universities achieve high positions in world rankings, as well as an increase in the quality, quantity and citation of works of Russian mathematicians ...», since these indicators will be achieved as a result of creating favorable conditions and developing infrastructure for conducting mathematical research and improving the level of mathematical education. In paragraph 4, delete the phrase: «To solve the problems of this Concept, it is envisaged to finalize the labor assessment system, taking into account the specifics of the activities and international practice of assessing the work of mathematics teachers, scientific and pedagogical workers of educational institutions of higher education and research workers of scientific organizations engaged in the profile of mathematics» since this phrase cannot be attributed to the basic principles, goals, objectives and main directions of the development of mathematical education.
- P.5, subsection on additional professional education, etc., add the following phrases: “An important component of mathematics and education, especially in the activities of mathematical centers, is the development of domestic mathematical journals, providing them with scientific,
organizational and financial support in order to bring them to the upper quartiles of international and Russian citation bases «and» Special attention is required to work on the development of domestic (and integration into foreign) mathematical centers involved in the development of libraries of programs and software systems for widely demanded analytical and computer calculations in the field of algebra, geometry, functional analysis, differential equations, equations of mathematical physics, optimization, optimal control, statistics, econometrics, financial mathematics».

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References
[1] Toomsalu-Stefanova L, Fokina E and Molchanova A 2020 Study of the Quality of Applicants’ Admission to Universities Based on the Results of the Unified State Exam in Russia International journal of instruction 13 73-88
[2] Igoshin V 2018 About the quality of training of bachelors and masters of pedagogical education on the profile “mathematical education” Saratov University Bulletin 4 468-73
[3] Podufalov N and Durakov B 2018 Mathematical education in the context of methodological problems of development of the russian education system Pedagogy 7 3-11
[4] Kogalovsky S 2017 Mathematical education as a component of general education Teaching physico-mathematical and natural sciences at school Tradition and innovation 1 34-5
[5] Dalinger V 2017 Preparation of teachers of mathematics under the conditions of new state standards in the direction “pedagogical education” profile “mathematical education” Modern problems of science and education 1 97-100
[6] Taktarov N, Ladoshkin M and Derbedeneva N 2018 Teaching mathematics of students of a pedagogical university in the school-university-school system Problems of modern pedagogical education 60 297-300
[7] Dalinger V 2017 Final state certification of bachelors “pedagogical education” profile “mathematical education” Scientific Review Pedagogical sciences 4 32-48
[8] Pokornaya I, Titorenko S and Ovsyannikova A 2019 Some issues of improving the training of masters of direction 44.04.01 pedagogical education on the program “mathematical education” Prospects for Science and Education 39 184-95