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Science, Technology, Engineering and Mathematics: Issues of Educational Policy in Russia

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Executive summary

The key political document of the Russian government declares that by 2020 Russia will have a leading position, defined as 5-10 per cent, in the global markets for high technological products and intellectual services. Russia has a science and technology policy but it does not have a broad-based and active policy on the STEM disciplines and their take-up in the labour markets. Educational policy is focused mostly on the structural, institutional and financial restructuring of the educational system, paying less attention to the content of educational programs. There is no coherent, consistent or even loosely focused educational policy towards STEM fields. STEM-specialist strategies and programs play a relatively minor role in education policy and provision.

Russia inherited from the Soviet era, which finished two decades ago, an education system and economy that were geared to what was, for the time, high levels of literacy in mathematics and science. Soviet Russia produced high quality science and technology specialists, and considerable research, mostly in the Academy of Sciences and public research institutes rather than the universities.

Participation in tertiary education has increased since the Soviet time and is now (59-77 per cent of the age cohort, depending on the basis of the calculation), amongst the highest levels of tertiary participation in the world. For most people, higher education is seen to have instrumental value in the job market, rather than being seen as a source of valuable general education.

National performance in the TIMSS international comparisons of school students' maths and science achievement remains high. In TIMSS, in both math and science sections, Russian secondary school students demonstrate above average achievements for each of the 4^{th} and 8^{th} grades. In TIMSS 2011, Russia achieved 542 and 549 in math for 4^{th} and 8^{th} grades respectively, and 552 and 542 in science in the same cohorts. Russia also received top scores in the PIRLS study of the achievement of primary school students. However, performance in 2009 PISA, which emphasizes applications and problems solving more than does TIMSS, with less focus on knowledge per se, was below the international average. Performance in international rankings of research universities is regarded in Russia as poor. Though research activities in universities have grown – the relative importance of the Academy of Science has diminished since the Soviet period - there is only one university consistently listed in the world top 200, Moscow State University.

The government hopes that emphasizing project-oriented and inquiry-oriented learning, and enhancing the focus on STEM disciplines within the curriculum, can improve PISA performance. It gives little attention to encouraging STEM aspirations in primary and junior secondary schooling. The strategy of development of research in various sectors, including higher education, has been implemented in several ways. First, the attempts of government to strengthen research in higher educational institutions, where it was traditionally weak, by stratification of the institutional landscape: "excellence programs", other support for leading institutions, and mergers of a number of regional institution in order to concentrate regional resources for further development. Recent measures include programs to stimulate universities to engage in commercialization and technology transfer, and encourage interaction of universities and industry aiming at development of innovation in businesses, and measures assisting Russian higher education institution to open up opportunities to attract leading researchers in order to set up world class laboratories.

At the level of secondary general education the more intensive curriculum in certain fields begins in pre-profile education in Years 8-9 and continues in the final Years 10-11 in 'profile' education: several profiles entail intensive teaching in their respective subjects: maths, physics, biology, chemistry and technology. The study of mathematics is compulsory to the end of school. A small number of specialist schools focus on higher learning in STEM. In secondary vocational education a third of students are enroled in programs in STEM fields. However, only about one quarter of senior secondary students aspire to a STEM-related career. One in ten aim for Engineering. Few aspire to science. The quality of STEM teachers is not seen as a significant issue. One problem is that few high quality teacher trainees in STEM end up working as classroom teachers because other opportunities are more attractive.

Study of data on average higher education admission scores by discipline (Appendix 1) shows that entry into journalism, languages, law and economics is more competitive than entry into STEM fields. In recent years higher education enrolments in STEM have been stable at about one fifth of students. Areas of declining enrolments are metallurgy, technology of food production and consumer goods, automation and control, chemical and biotechnology. In electronic/radio engineering and communications, and information security, enrolments are stable. Data on students entering programs show partly different patterns: a decline in informational security, and in metallurgy, technology of food production and consumer goods, automation and control, chemistry and biotechnology; upward movement in sciences, physics and maths. Women comprise only 28.6 per cent of STEM students. Predominantly female fields are technology of food production and consumer goods (67.2 per cent women) and sciences (64.4 per cent). Women comprise about half the students in chemical and biotechnology (50.6 per cent), reproduction and processing of forest resources (46.6 per cent), and instrumentation and optical engineering (44.4 per cent). Areas of low female share include energy and energy engineering (14.7 per cent), information security (18.3 per cent), electrical engineering and communications (19.9 per cent), metallurgy, machinery and materials processing (20.4 per cent), computer science and engineering (22.4 per cent), and physics and maths (35.2 per cent).

The STEM fields are growing slightly at postgraduate level, in both absolute and relative terms. The fastest developing postgraduate field is technology/engineering, the most populated of the STEM fields and probably seen as the easiest in which to get a degree. The growth of enrolments at postgraduate level is the consequence of higher admissions in the technical/engineering field, not physics/maths, chemistry, biology and geosciences. Women's enrolments on the path to PhDs in STEM have been relatively stable in recent years. The highest proportions of women are in biology (58.6 per cent) and chemistry (47.2). Engineering is more traditionally male dominated and only 20.0 per cent of its students are women. In all fields except chemistry less than 30 per cent of students complete their dissertations.

There has been a significant decline in the size of the R&D workforce since 1995. R&D funding fell drastically in the 1990s but has grown again since 2000. In the R&D sector, STEM areas are dominant. Research staff in sciences and maths comprise 24 per cent of all researchers and 61 per cent are researchers in technology and engineering fields. Most of R&D funding goes to STEM areas: science and maths (20 per cent), technology/engineering (71 per cent) with the rest allocated within medicine, agriculture, social sciences and humanities. In sciences and maths women are 41.8 of staff, in technology and engineering 37.3 per cent, while for other fields the proportions vary from 55.6 per cent in agriculture to 63.4 per cent in humanities.

Analysis of the labour market outcomes for STEM graduates suggests that these differ by field of education. In medicine, the actual occupation mostly correlates with the field of degree received at the higher educational institutions. Among STEM graduates, most specialists in maths and computing enter jobs related to their educational specialization. Specialists in biology and agriculture are most likely to change their field in the labour market. But these graduates also have relatively high percentages for upward mobility, as do engineers and architects. Engineering graduates more likely than many other graduates to work in a position not requiring higher education at all. Those with technical vocational education are even less likely to get a job in the area of training, than are those with university degrees.

The Presidential Program for enhancing the qualifications of engineering cadre for 2012-2014 is a retraining program for 15,000 engineers. In 2013 higher educational institutions will adopt a new per capita funding scheme with an increased norm of funding for leading universities that provide programs in engineering, medical and science fields. There will also be a special focus on maths education. Other measures and programs to enhance STEM include competitions to identify highly talented students for targeted support, and the funding of supplementary education. All of these schemes have a relatively modest impact.

1. Attitudes to STEM

The key political document of the national government declares that by 2020 Russia will have a leading position, defined as 5-10 per cent, in the global markets for high technological products and intellectual services. It recognizes that the potential of a raw materials-based economy has been largely depleted, and the national economy needs to be restructured (Kontseptsia dolgosrochnog, 2008).

The government's eight priorities for development in science and technology are as follows: security and counteraction of terrorism; nano-system industry; information and telecommunication systems; life sciences; surveillance weaponry, military and special equipment; the rational use of natural resources; transportation and space systems; energy efficacy, energy saving and nuclear energy. The list of twenty seven critical technologies comprise those in military technology, energy, biology, bioengineering, medicine, nano-technology, telecommunications, environment sphere, transportation and space (Prioritetnye napravlenia razvitia nauki, 2011).

In this framework, the development of human capital is seen as a key factor in economic development, and an essential resource for the formation and modernization of a knowledge-based, innovative economy in Russia (Kontseptsia dolgosrochnog, 2008; Kontseptsia Federal'noi tselevoi programmy razvitia obrazovania na 2011-2015 g. 2011, Strategy of development of information society, 2008).

According to government policy it is essential to make a transition from a mass system of education appropriate to the industrial economy, to the kind of system that is necessary in building an innovative, socially oriented economy. This is a life-long individual learning system, one that is closely connected to global level basic research, and one that aims to form creative and socially responsible personalities (Kontseptsia dolgosrochnog, 2008).

Thus, the government acknowledges the importance of, on the one hand science and technology, and on the other hand the educational and vocational qualifications of the population, in the further economic development of Russia and in enhancing the quality of life in the country.

The government uses the results of international assessment exercises to understand the nation's education and research in a comparative perspective. This includes international tests such as PISA and TIMSS in secondary education. In TIMSS, in both math and science sections Russian secondary school students demonstrate above average achievements for each of the 4th and 8th grades. In TIMSS 2011, Russia achieved 542 and 549 in math for 4th and 8th grades respectively, and 552 and 542 in science in the same cohorts. Russia also received top scores in the PIRLS study of the achievement of primary school students.

However, the results for 15-year old Russian students in PISA, just one year older than the average 8th grade students tested in TIMSS, have been less successful. In each of the PISA assessments, in all three domains, reading, maths and science, Russia had lower scores than average. In 2009, the Russian maths score was 468 (the OECD average was 496), and the science score was 478 (OECD average 501). The most positive aspect was that there were no achievement gaps between boys and girls in PISA. The explanations for the higher TIMSS and lower PISA scores in part lie in the fact that the orientation of Russian secondary school maths programs is more academic than applied. The secondary curriculum tends to neglect the need for students to apply academic knowledge in practice, in their everyday lives. PISA captures the capacity to apply mathematical knowledge in solving problems, more than does TIMSS.

The government recognizes the successes of Russian students in TIMSS and international competitions for students, but notes concerns about the persistent disparities in achievement between different certain social groups and the fact that residents of some territories have insufficient access to a high quality general education (Gosuparsvennaya programma RF “Razvitie obrazovania 2013-2020, 2012). It also states that the lagging behind in PISA can be overcome by implementation of different learning and teaching approaches, such as project-oriented and research-oriented learning; and by further development of profile education, that is, streams in which the curriculum focuses on certain subjects in high secondary schools, especially science and technology subjects.

At the level of higher education one way to compare the competitiveness of institutions is by international rankings. The outcome of rankings is a concern for many governments around the world, including the government of Russia. In the Shanghai Academic Ranking of World Universities during the years 2004-2012, among the top 500 institutions, Moscow State University was located between the 66th and 80th positions (it was 80th in 2012) and St. Petersburg State University was located in the 400-500 group. The Times Higher Education-QS version of the world’s top institutions in the years 2004-2009 was also disappointing for Russia: MSU’s ranking varied from 79 to 231. In 2012, THE-Thomson Reuters ranking placed MSU, and Moscow State Engineering Physics Institute, in the 200-300 group. In the now separate QS ranking, MSU was 116th in 2012.

The President stated that he was unsatisfied with the position of Russian universities in the international rankings. He set a target of no less than five institutions in the top 100 by 2020 (O merakh po, 2012).

One of the traditional characteristics of Russian society is the high value placed on education. Russia demonstrates one of the highest participation rates in higher education in the world, between 59 and 77 per cent of the age cohort (Smolentseva, 2012). Higher education is now seen as a norm even among people in those groups under-represented in higher education, such as the rural population (Dubin, 2004; Abankina, 2011; Konstantinovsky, 2008). One recent survey found that 72 per cent of respondents saw higher education as a requirement for career and life success (72 per cent); while over 80 per cent believed that higher education was necessary for their children and grandchildren. Higher education was seen as important from a practical point of view, and in narrowly specialized terms – respondents saw it as a provider of skills critical for future work (64 per cent) rather a way to broaden perspectives through general education for further personal development (28 per cent) (WCIOM, 2011).

The expansion of the higher education system was especially striking in the 1995-2005 period. However, perhaps inevitably, it was accompanied by the lowering of quality and the widening of the gap between the elite and mass sectors of education.

Moreover, the STEM fields have lost their previous prestige during the last twenty years, due to the post-Soviet decline of the economy as a whole, the decline in the research-intensive industries and R&D, and also the drastic decline in salaries in the research-related sectors. It is not surprising that among higher education students the most popular fields are economics, law, social science, and training for services and trade. That can be seen in Table 1 which contains data on the life plans of secondary school students in the 2011-12 academic year. Among all senior students (Years 8-11), 23.2 per cent stated they were planning to pursue an education in STEM fields. The most popular field was applied engineering. Science was attractive to only a small number of young people (3.5 per cent).

Table 1. To which field your child is going to apply after secondary school? (per cent, survey of parents of school students of Years 8-9 and Years 10-11)

	Year 8-9	Year 10-11	Total
Number of respondents	*430*	*454*	*884*
Social sciences (economics, law, management, sociology etc.)	16.0	30.2	23.3
Engineering and technical fields (construction, communications, technologies of production etc.)	9.8	10.8	10.3
Math, IT	7.4	11.2	9.4
Humanities (philosophy, philology, Russian language, history, etc.)	8.1	6.6	7.4
Medicine	7.9	6.8	7.4
Cultural studies, arts, design, architecture etc	7.7	5.1	6.3
Foreign language	5.8	6.6	6.2
Science (physics, chemistry, biology, geography, ecology etc)	3.3	3.7	3.5
Vocational occupations in services and sales (salesperson, etc.)	3.0	1.1	2.0
Service, tourism, advertising	2.3	1.8	2.0
Pedagogics/education	1.2	0.9	1.0
Vocational occupations (welder, machinist, etc.)	1.4	0.4	0.9
Physical education	0.9	0.7	0.8
Agronomy, agriculture, forestry	0.2	0.4	0.3
Other	2.8	3.7	3.3
Undecided	15.1	7.0	11.0
Parents do not know about the plans of children	7.0	2.9	4.9
Total	100,0	100,0	100,0

Source: Calculated by author from the data of Monitoring the economics of education, a study conducted by the National Research University – Higher School of Economics, 2011-2012 academic year.

The OECD's 2006 PISA study of the aspirations of 15-year olds in relation to science-related careers found those aspirations were high: 28.7 per cent of all students, including 31.8 per cent of boys and 26.2 per cent of girls. Occupations in computing and engineering (excluding architects) were less popular: 9.6 per cent of students, with a gender gap: 17.1 per cent of boys and 3.5 per cent of girls) (OECD 2012). This contrasts sharply with the Russian results for 2011-12. However, the difference in the results between the Russian and OECD surveys can be explained partly by the instrument and sampling used. In the Russian survey the question was about field of study, and the survey was of parents. In the OECD survey the question was about career at the age of 30, and the survey was of students.

The comparatively low interest in STEM higher education programs can be observed further by examining the data from Monitoring the quality of admissions. This is a database of enrolments indicators based on national test scores which contains average (as well as minimum) numbers for institutions and fields of study. It covers the majority of public higher educational institutions. The minimum scores necessary for admissions are set by each institution, and are set separately for the two different kinds of enrolment: public and tuition-paying. Performance is measured on a 100-point scale. Thus in the Monitoring data the two panels of first year students are considered separately. Free public slots are considered to be more prestigious and the most competitive, especially in entry into elite institutions. For the tuition paying slots the institutional requirements are usually lower than for free slots. The technical universities admitted students with a comparative low average score (61.6). The classical universities, the usual providers of education in sciences and technology, demonstrated a somewhat higher average indicator (65.0). At the same time, the most competitive admissions can be observed in medical and socio-economic institutions (74.2 and 71.1 respectively).

Table 2. Average admissions score by type of Higher Education Institutions (HEIs), tuition free enrolments, 2012

Specialisation of HEIs	Average score	Number of HEIs
All institutions	63.5	496
medical	74.2	52
socio-economic	71.1	65
humanities	66.2	24
classical universities	**65.0**	86
architecture	62.9	17
technical	61.6	139
pedagogics/education	**61.0**	61
agriculture	53.7	52

Source: Monitoring kachestva priema. Retrieved from http://www.hse.ru/ege/second_section2012/vuz_stata

The distribution of scores by field, regardless of the type of institution, provides a more complicated picture (Monitoring kachestva priema 2012; Table 1 in Appendix 1.). The data shows that the most prestigious fields are in international relations, journalism, languages, law, and economics. In these fields the average score ranges from 83.0 to 68.7. The first STEM field appears at 21st in this ranking – information security (68.5). Close to it are the oil-gas field, nuclear physics and technology, maths, chemistry and physics. Some engineering and transportation fields are at the bottom of the list with scores as low as 51.1.

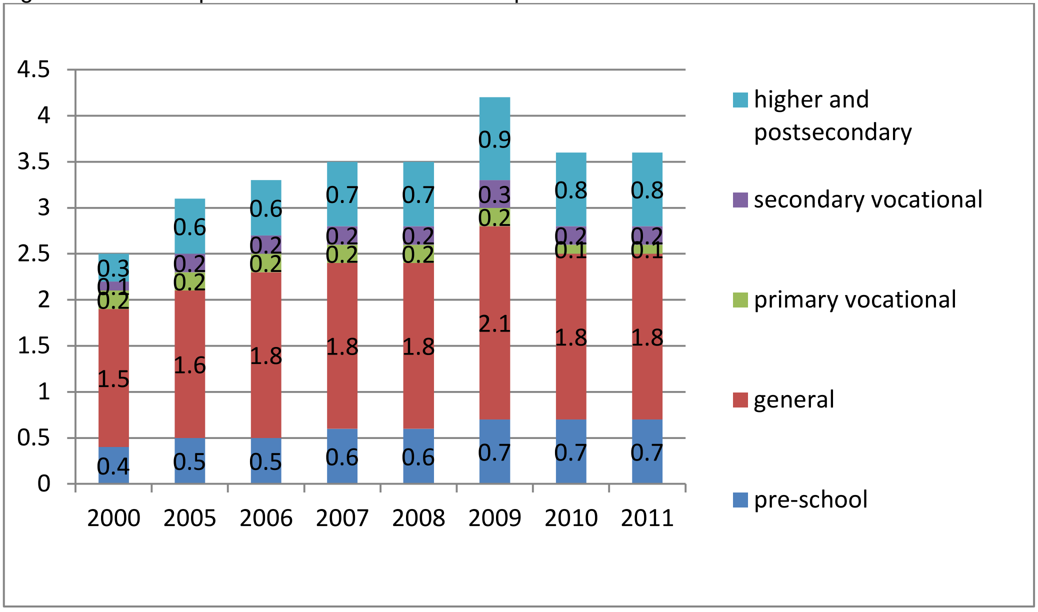
The government is concerned with the quality of education in the science and engineering fields strategically important for the development of an innovative economy. It emphasizes the importance of those fields in public discourse. But policy is largely concentrated on the outcomes of STEM education, such as building an innovative economy, research-industry cooperation in developing innovations, fostering research in higher educational institutions so as to integrate research and education, and the systems of selection of students for higher education admissions. In short government focuses on the tertiary level of education, or preparation to it. It gives less attention to the earlier stages of education. Yet these early stages are crucial in determining the influx of top quality students into higher educational institutions, and creating an environment which will encourage the best higher education graduates to work in the country's STEM professions and occupations.

2. Patterns of STEM provision and participation

Overview of educational system in Russia

The education system in Russia is predominantly public. Public funding of education in relation to GDP decreased from 2009 to 2011 and comprised less than 4 per cent of GDP in 2011 (Figure 1).

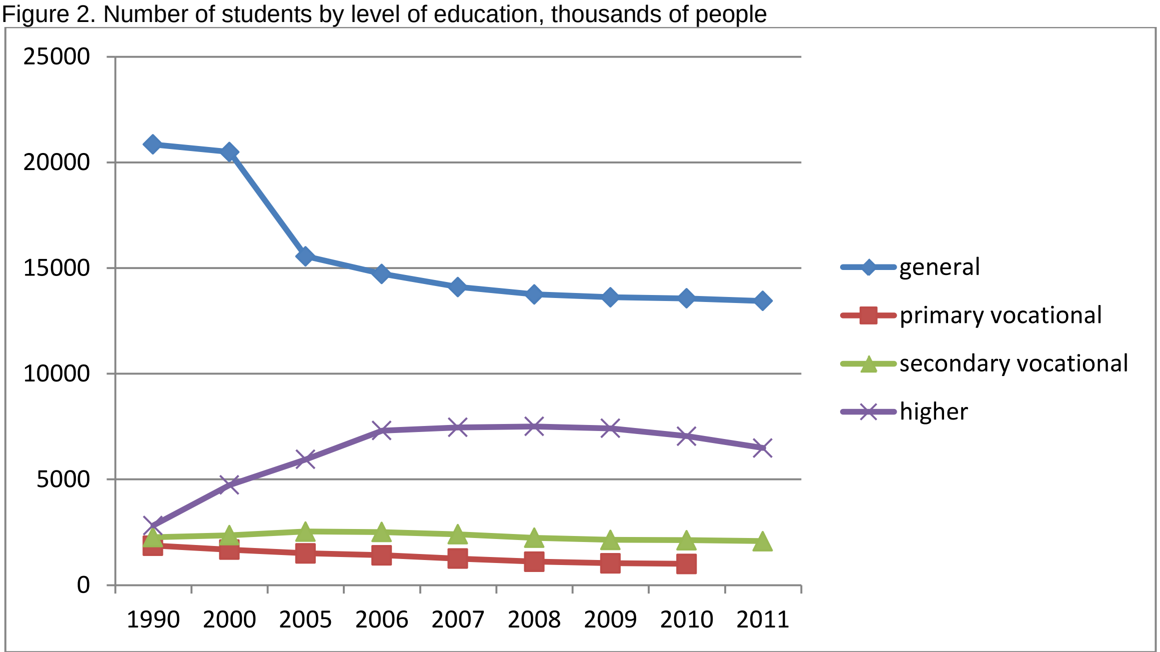
Figure 1. Public expenditures on education as a per cent of GDP



Source: Obrazovanie v RF: 2012, 2012.

One of the major challenges facing the system is demographic decline, due to a low birthrate which began in the 1990s. Demographic decline began to affect enrolments at secondary level in early 2000s and reached the tertiary level in the late 2000s.

Figure 2. Number of students by level of education, thousands of people



Source. Russian statistical committee.
Note: Since 2011 primary vocational education institutions have been transferred into secondary vocational education as programs.

Public expenditures per student decreased from 2009 to 2011 for primary and secondary vocational education, in terms of constant 2000 (from 19,800 to 16,600 rub. for the former, and 24,100 to 20,700 for the latter). Funding increased for general education (from 16,000 to 16,200) and higher and postgraduate education (49,100 to 49,800) (Obrazovanie v RF, 2012).

Although the number of non-state institutions is relatively high, the number of students enroled in this sector is not large: 0.6 per cent at the level of secondary schools (general education schools), 5.0 per cent in secondary vocational education and 16.0 per cent in higher education institutions.

Postgraduate education prepares students for the academic degrees of Candidate and Doctor of Sciences. It is provided by higher education institutions (89 per cent of enrolments), the research institutes of Academy of Sciences and sectoral institutes (10 per cent) and institutions of advanced professional training (1 per cent).

Table 3. Number of institutions and students in Russian educational system, 2011

	Public		Non-state		Total	
	Institutions	Students, thousands	Institutions	Students, thousands	Institutions	Students, thousands
general education (ISCED 1, 2, 3)	46,459	13,362.3	687	83.5	47,146	13,445.8
secondary vocational education (ISCED 3, 4, 5B)	2665	1984.0	260	97.7	2925	2081.7
higher education (ISCED 5A)	634	5453.9	446	1036.1	1080	6490.0
postgraduate education, for Candidate of Science degree (ISCED 6)	n/a	n/a	n/a	n/a	1570	156.0
postgraduate education, for Doctor of Science degree (ISCED 6)	n/a	n/a	n/a	n/a	608	4.6

Source: Russian statistical committee.

STEM provision by level of education

Educational standards at all levels of education are determined by the state, although they imply some variation and there are some opportunities for individual trajectories.

Pre-primary and secondary general education

The standard of pre-primary education involves acquiring basic knowledge in math and science, however there is no emphasis on STEM fields. Besides, one out of three children of pre-school age does not participate in the system of pre-primary educational institutions. The admissions to primary education school (general education) start at the age of six and a half years.

In secondary education all students do maths to the end of school (Year 11), though it may be a basic levels of maths. Students who sit the unified national examination (tests) at the end of Year 11 must include Russian and maths. The same is true of the tests at the end of Year 9.

At the level of secondary general education the more intensive curriculum in certain fields begins in senior years – in Years 8-9: pre-profile curriculum/stream, in Years 10-11 (final years): profile education (Kontepsia profil'nogo obuchenia na starshe stupeni obrazovania 2002). According to the Concept of profile education, there can be several profiles which involve more intensive teaching in their respective subjects. The science/math profile entails an extended time for studying the maths, physics, biology, chemistry and technology profile, i.e. an emphasis on math and informatics. The content of profiles can vary by school. No statistics were found on profile education in open access. Profile education has yet to be implemented throughout all institutions of secondary education.

Another form of specialized secondary education provision was previously developed in the USSR – schools with advanced study of certain subjects. Especially prominent in this group were schools focused on maths and physics. Again, there are no data on the number of those schools and students, but on the national scale the numbers are unlikely to be high. Some approximation can be drawn from the statistics of the number of schools with advanced study of certain subjects (gymnasiums, lyceums, schools with specialisation). Lyceum (*litsei*) is a form of general education that provides an extended/additional education in science and technology fields, as well providing general education at primary level. Gymnasiums are focused on advanced study in social sciences and humanities, so they are not considered here. Among those advanced schools there are former Soviet special schools that offer advanced study. The number of public lyceums in 2011 was 1074, enroling 736.2 thousand students. The non-state sector included 42 institutions with a total of 6.3 thousand people. This indicates that the advanced institutions sector is rather small and elite, and only about 5 per cent of secondary education enrolments within the sector can be treated as STEM profile education. However, the enrolments in those institutions have grown over last years (Table 4).

Table 4. Number of institutions and students in secondary schools with advanced study in STEM (lyceums)

Lyceums	2004	2009	2010	2011
Public institutions	769	1045	1058	1074
Number of students, thousands	511.1	667.3	698.7	736.2
Non-state institutions	n/a	n/a	42	42
Number of students, thousands	n/a	n/a	4.5	6.3
Total number of institutions	n/a	n/a	1100	1116
Total number of students	n/a	n/a	703.2	742.5

Source: Russian statistical committee gks.ru; Russian education statistics stat.ed.ru

Secondary vocational education

Secondary vocational education systems have shared the demographic decline, so the absolute number of students has decreased, but the share of STEM enrolments has not changed in recent years and comprised 31.9 per cent in 2010. A small increase can be observed in the fields of geology and development of minerals, transportation, marine technology and automation and control.

Table 5. Enrolments in STEM in secondary vocational education, thousands

STEM fields	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Physics and maths	1.6	-	-	-	-	-	-
Sciences	2.1	2.1	2.0	1.8	1.6	1.6	1.7
Information security	0.2	0.6	1.0	1.4	1.7	2.1	2.5
Geology and development of minerals	33.0	33.3	33.3	35.9	36.4	**37.7**	**40.5**
Energy, energy engineering	85.5	84.9	83.3	81.2	75.4	74.0	75.4
Metallurgy, machinery and materials processing	137.7	133.1	127.1	119.2	107.7	101.5	100.4
Aviation, rocket and space technology	8.7	8.7	8.4	8.0	8.2	8.3	8.3
Marine Technology	18.2	18.0	17.4	17.3	15.9	**15.5**	**16.1**
Transportation	223.3	225.3	220.4	215.9	201.9	**196.6**	**200.2**
Instrumentation and optical engineering	8.0	7.6	6.9	6.3	5.3	4.8	4.6
Electronic engineering, radio engineering and communications	51.4	50.3	47.9	43.8	38.1	35.1	33.7
Automation and Control	34.4	32,8	31,6	30,4	28	**27,6**	**28,5**
Computer Science and Engineering	131.1	146.2	149.3	147.9	137.0	127.9	125.2
Chemical and Biotechnology	23.8	22.8	21.4	19.8	17.6	16.9	16.7
Reproduction and processing of forest	28.9	28.4	27.5	26.0	23.9	23.2	23.4

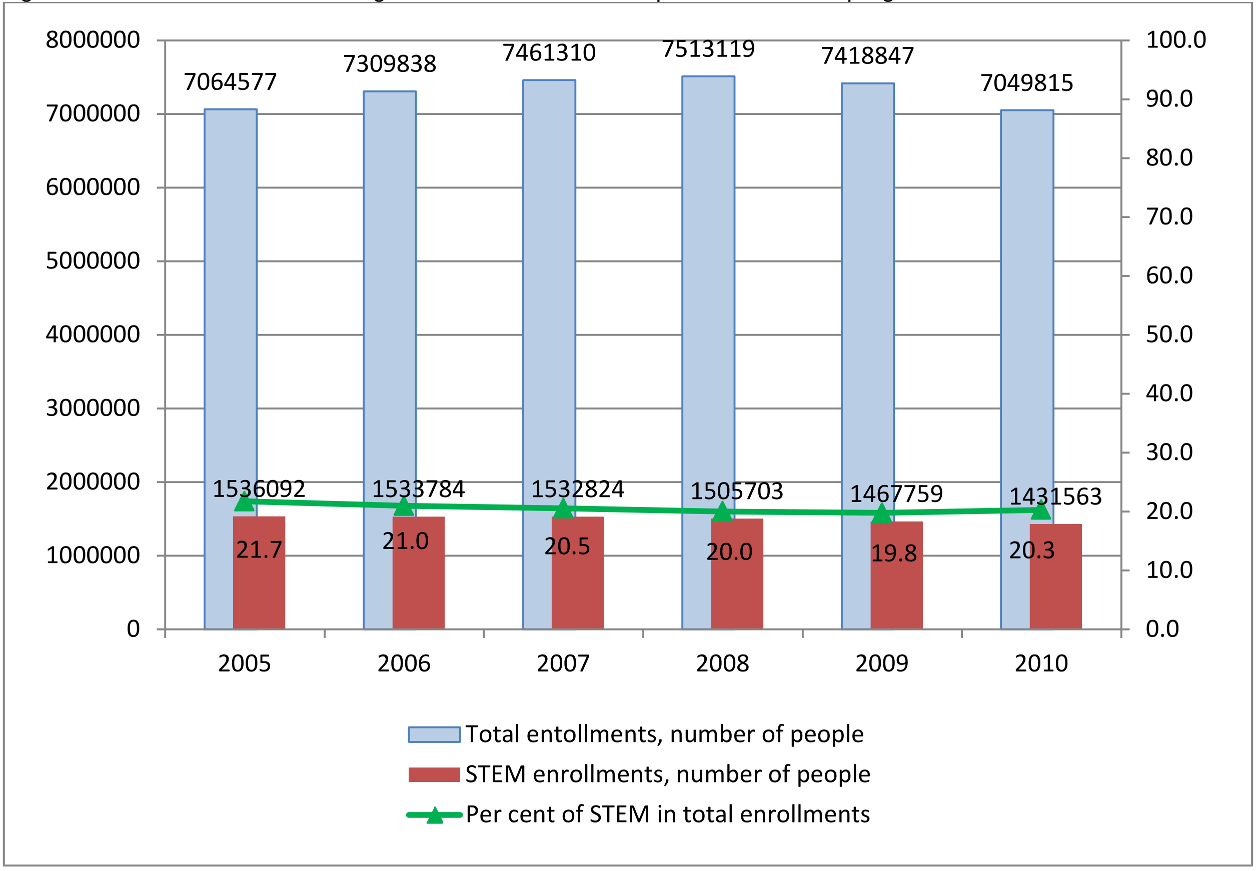
resources							
Total number of students	**787.9**	**794.1**	**777.5**	**754.9**	**698.7**	**672.8**	**677.2**
Per cent of total enrolments	**31.0**	**30.7**	**30.9**	**31.3**	**31.1**	**31.4**	**31,9**

Source: Obrazovanie v RF: 2012, 2012

Higher education

In the last few years higher education enrolments has been shrinking due to the demographic decline, but the decrease in STEM enrolments has been relatively small, from 1.54 million in 2005 to 1.43 million in 2010. As a proportion of all higher education students in the country, STEM students have been relatively stable, at about one fifth (20.3 per cent in 2010, a slight fall from 21.7 per cent in 2005).

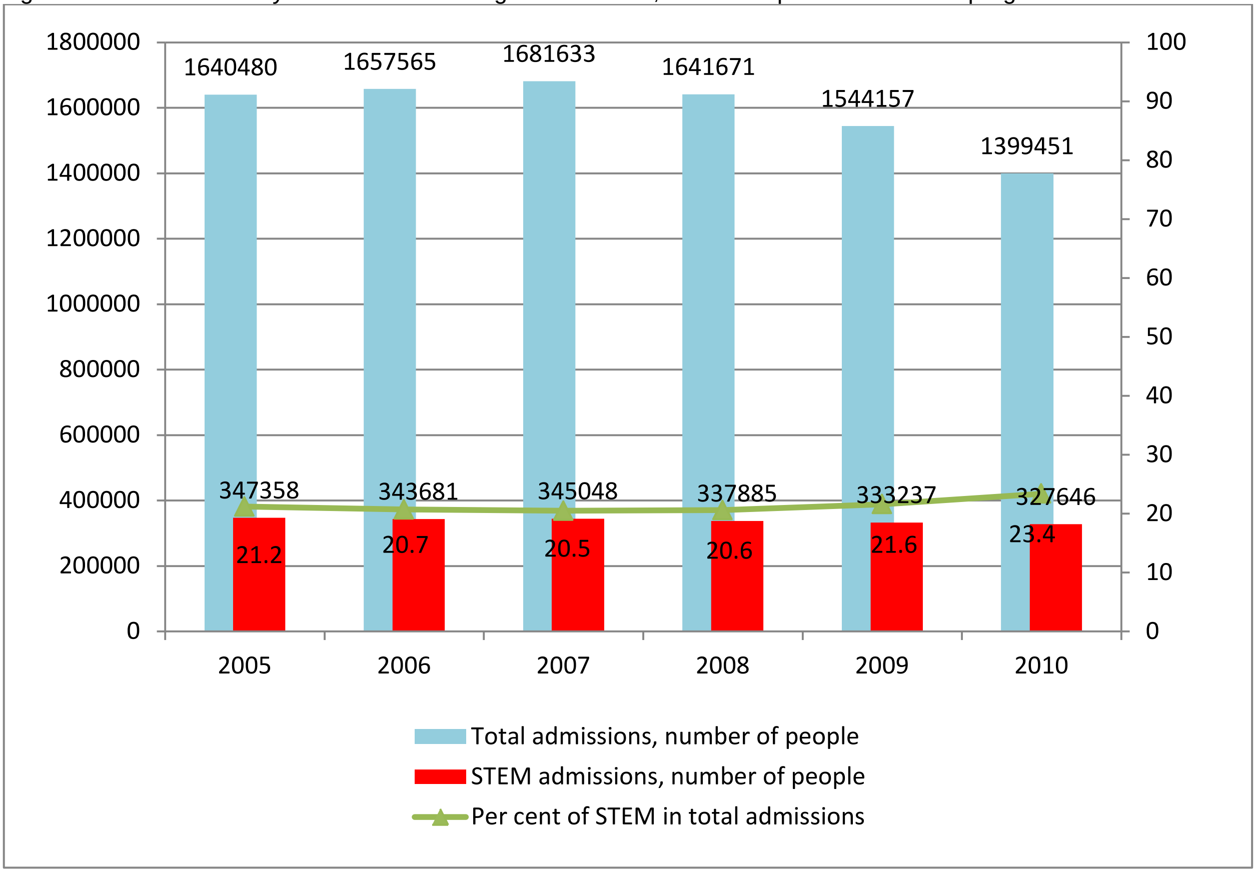
Figure 3. Enrolments in STEM in higher education, bachelor/specialist/master's programs



Source: Obrazovanie v RF: 2012, 2012

The effects of demographic decline are more obvious while looking at the number of students entering higher education. STEM entry tended to be more durable than entry as a whole; and between 2009 and 2010 the share of STEM admissions even increased, from 21.6 to 23.4 per cent. This can be partly related to the government discourse about innovation policy, and the need for engineers, and also small cuts in free slots in social science/humanities/pedagogics.

Figure 4. Admissions/entry rates in STEM in higher education, bachelor/specialist/master's programs

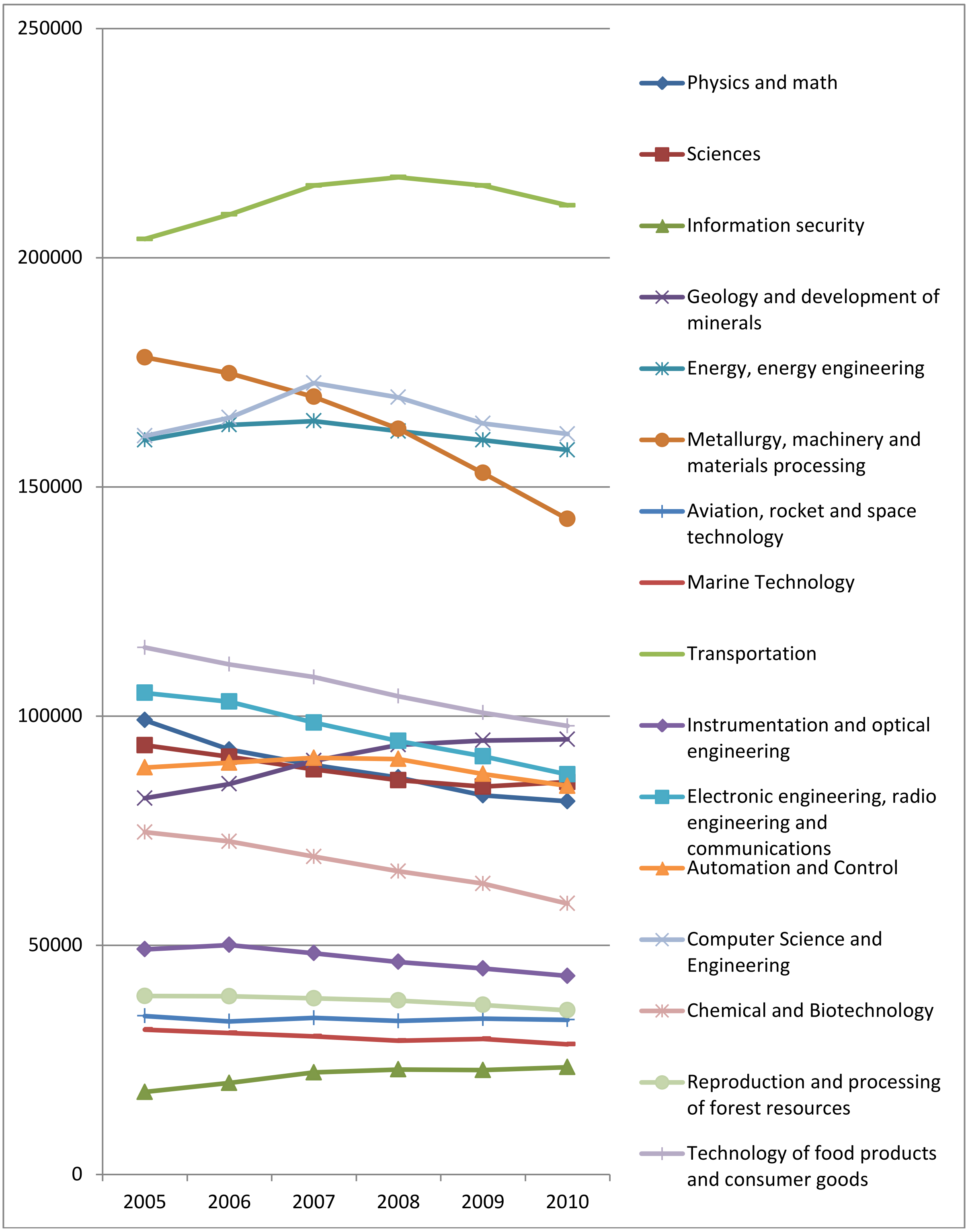


Source: Obrazovanie v RF: 2012, 2012

For the same time period, the OECD's data for 2010 show that the sciences' share of tertiary student entry in Russia was 7 per cent, while the share for engineering, manufacturing and construction was 23 per cent. These data includes both 5A and 5B level students. However in Figure 4 we use only 5A students, those at degree level, and we do not include construction.

Among STEM fields areas of declining enrolments are metallurgy, technology of food production and consumer goods, automation and control, chemical and biotechnology (Figure 5). In electronic/radio engineering and communications, and information security, enrolments are stable.

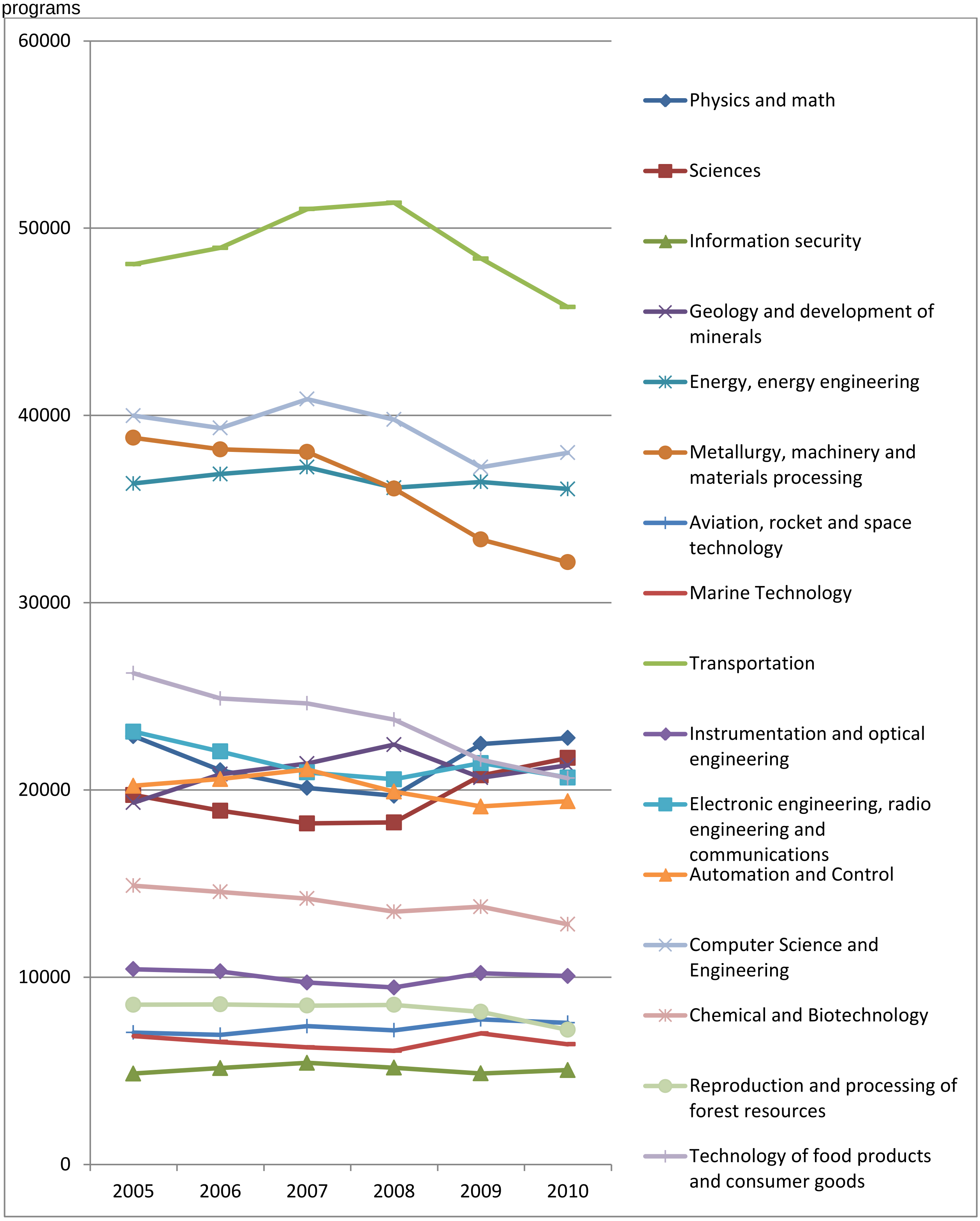
Figure 5. Enrolments in STEM in higher education, by field, bachelor/specialist/master's programs



Source: Obrazovanie v RF: 2012, 2012

Data for the number of students entering programs show a partly different pattern: a decline in informational security, and also again in metallurgy, technology of food production and consumer goods, automation and control, chemical and biotechnology (Figure 6). There is upward movement in sciences, physics and maths.

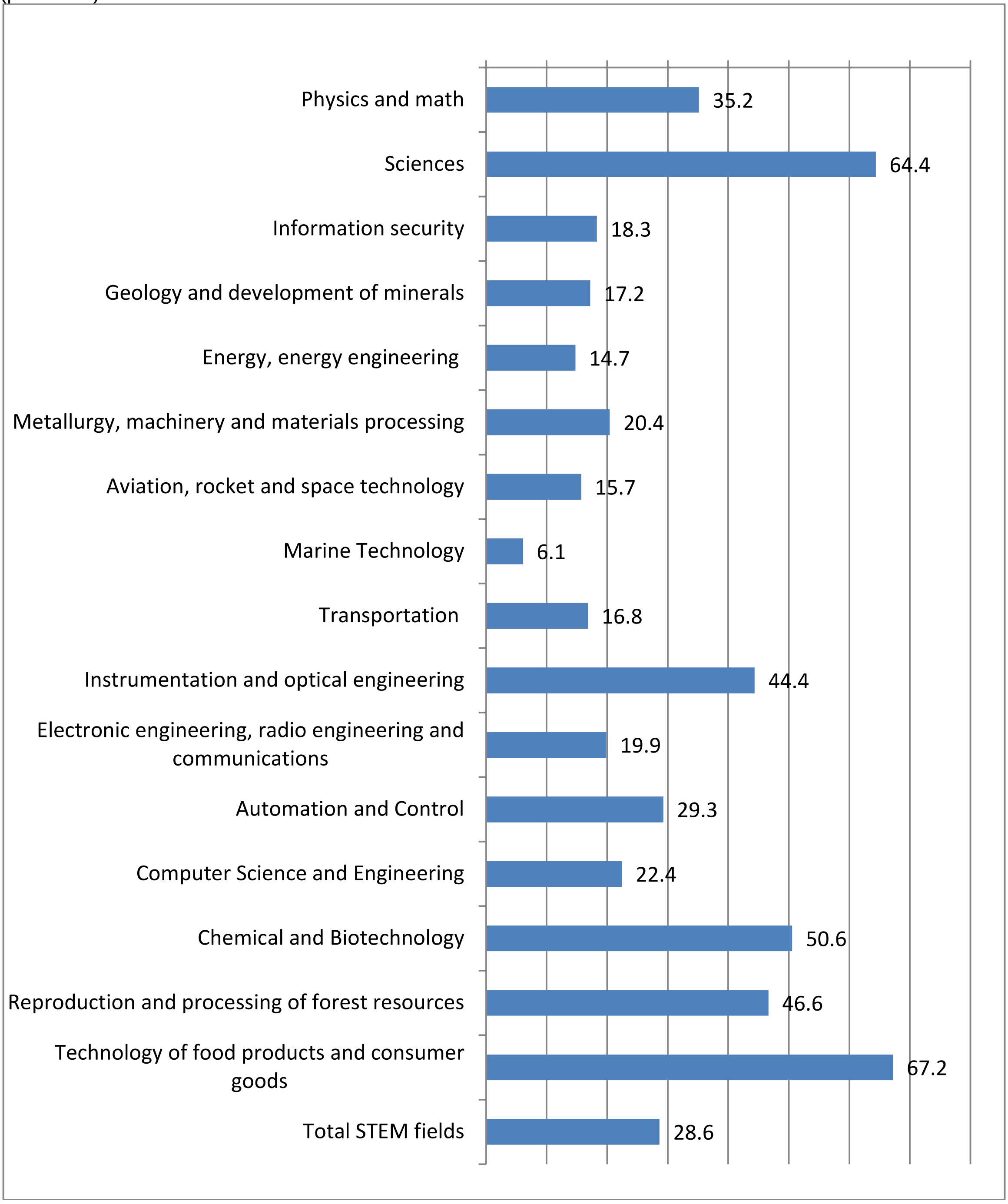
Figure 6. Admissions/entry rates in STEM in higher education, by field, bachelor/specialist/master's programs



Source: Obrazovanie v RF: 2012, 2012

Women are certainly underrepresented in STEM fields (Figure 7), comprising only 28.6 per cent of the student body. The predominantly female fields are technology of food production and consumer goods (67.2 per cent women) and sciences (64.4 per cent women). Women comprise about half the students in chemical and biotechnology (50.6 per cent), reproduction and processing of forest resources (46.6 per cent), and instrumentation and optical engineering (44.4 per cent).

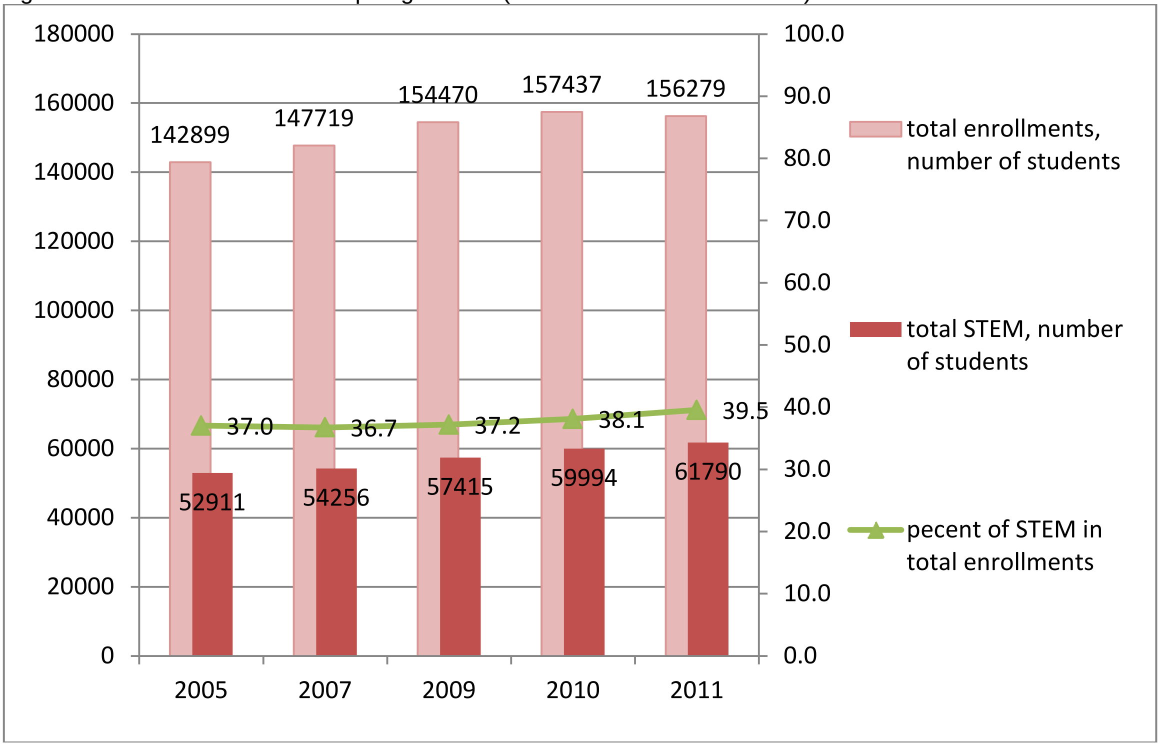
Figure 7. Women's enrolments in STEM in higher education, by field, bachelor/specialist/master's programs (per cents)



Postgraduate level

Postgraduate enrolments have also experienced some decline, but the STEM fields are growing in absolute and relative terms, although only slightly (Figure 8).

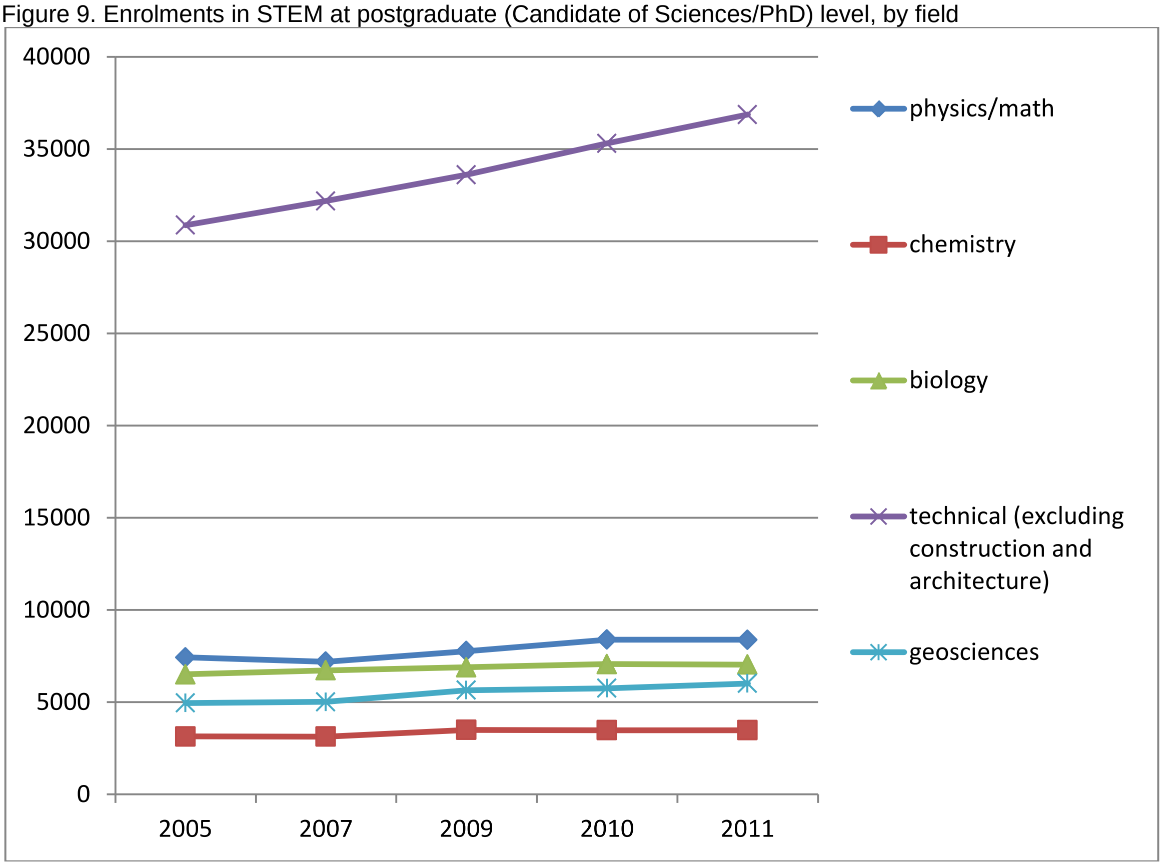
Figure 8. Enrolments in STEM at postgraduate (Candidate of Sciences/PhD) level



Source: Podgotovka nauchnykh kadrov vysshei kvalifikatsii v Rossii 2012.

The fastest developing postgraduate field is technology/engineering, which is the most populated of the STEM fields and probably seen as the easiest in which to get a degree. The growth of enrolments at postgraduate level is the consequence of higher admissions in the technical/engineering field, not in physics/math, chemistry, biology and geosciences.

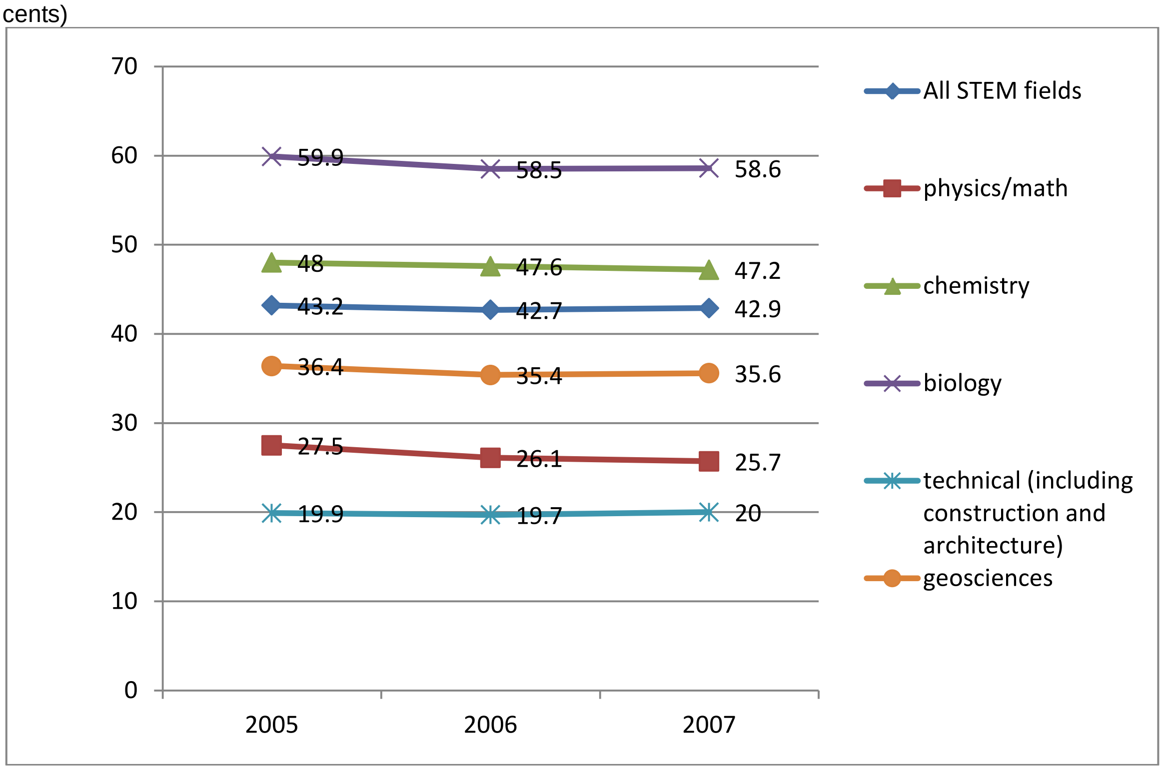
Figure 9. Enrolments in STEM at postgraduate (Candidate of Sciences/PhD) level, by field



Source: Podgotovka nauchnykh kadrov vysshei kvalifikatsii v Rossii 2012.

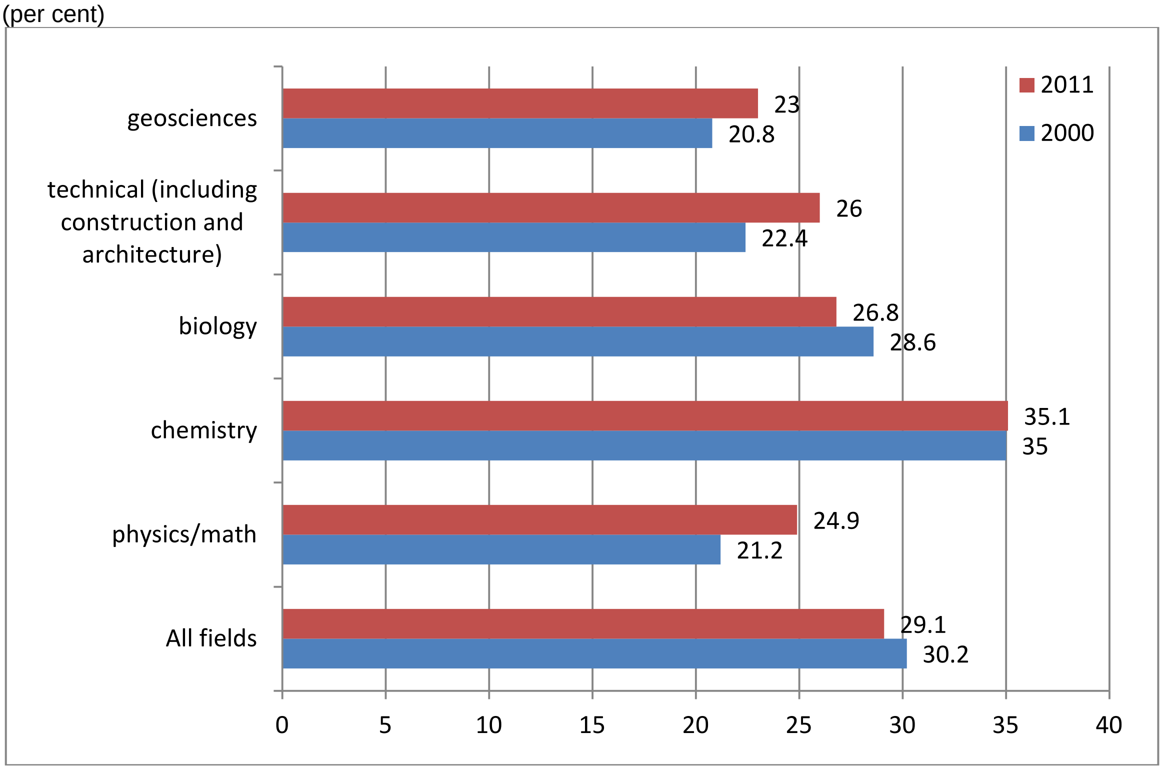
Women's enrolments on the path to PhDs in STEM have been relatively stable in recent years. The highest proportions of women are found in biology (58.6 per cent) and chemistry (47.2). Engineering is a more traditionally male dominated specialization and only 20.0 per cent of students are women (20.0).

Figure 10. Women's enrolments in STEM postgraduate (Candidate of Sciences/PhD) level, by field (per cents)



Source: Obrazovanie v RF: 2010, 2010

Figure 11. Students graduated with the defended dissertation (Candidate of Sciences/PhD level), by field (per cent)



Source: Obrazovanie v RF: 2010, 2010

The effectiveness of postgraduate programs, measured by the number of graduates who defend their dissertation, has been a long standing concern for educational policy. An average indicator is 29.1 per cent. Some fields in STEM do better than the average, including chemistry with 35.1 per cent. The other STEM fields demonstrate lower than average numbers.

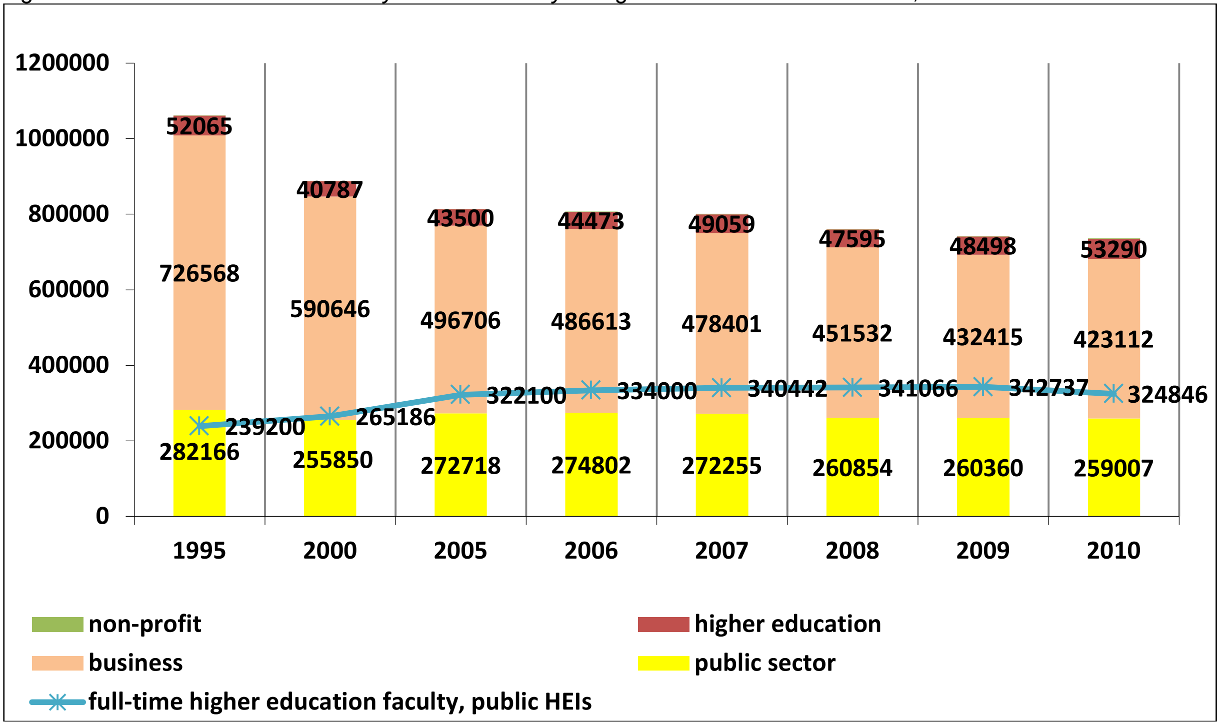
3. Uses of STEM beyond education

Research and development

The research and development sector is the first sector implied for higher education graduates in related fields. In the Soviet Union, sectoral research institutes under various ministries were dominant in the R&D sphere, judging by the number of staff and levels of funding. They took 79 per cent of all R&D expenditures in the country, while Academies of Sciences had 10 per cent, higher educational institutes 6 per cent, and industry 5 per cent (calculated by author from Nauka Rossii v tsifrakh, 1994, 41). The size of these sectors can also be presented in terms of their respective number of staff: 11 per cent in Academies of Sciences, 7 per cent in higher education, 75 per cent in sectoral institutes and 7 cent in industry (calculated by author from Nauka Rossii v tsifrakh, 1994, 25). However, it was the Academy of Sciences that concentrated in its institutes the most qualified staff: 52 per cent of all had Doctoral degrees and 29 per cent had Candidate's degrees.

The decline in staff within the total R&D sector since 1995 has been significant. Note also that a recent trend towards growth in the number of research staff in the higher education sector can be observed. The number of staff of the Russian Academy of Sciences, included in the public sector in Figure 12, declined from 128,519 in 1992 to 105,699 in 2000, and further to 95,280 in 2010 (Nauka Rossii v tsifrakh, 1999, Nauka Rossii v tsifrakh, 2011), and is now approximately twice the total number of staff in higher educational institutions. The teaching mission of higher education has expanded in the Post-Soviet period, which has been reflected in an increased number of faculty. This has helped to create some additional faculty jobs for those trained in STEM.

Figure 12. Number of staff in R&D by sector + faculty of higher educational institutions, 1990-2010



Source: Nauka Rossii v tsifrakh 2011.

The funding for R&D fell drastically during the 1990s, but in 2000 gradually began to grow. Federal R&D funding has slightly increased over the last few years from 0.36 per cent to 0.57 per cent of GDP, and has also increased as a share of federal expenditures (Table 6). There has been a minor decline in federal funding for basic research, which took place in 2010, while expenditures for applied research have noticeably grown over the same period.

Table 6. Federal funding for R&D, 2000-2010

	2000	2005	2006	2007	2008	2009	2010
Federal expenditures, mln.rub	**17396.4**	**76909.3**	**97363.2**	**132703.4**	**162115.9**	**219057.6**	**237656.6**
Including:							
Basic research	8219.3	32025.1	42773.4	54769.4	69735.8	83198.1	82173.8
Applied research	9177.1	44884.2	54589.8	77934.0	92380.1	135859.5	155482.8
In %:							
to federal expenditures	1.69	2.19	2.27	2.22	2.14	2.27	2.35
to GDP	0.24	0.36	0.36	0.40	0.39	0.56	0.57

Source: Russian statistical committee.

The national statistics also show that only 8.7 per cent of total expenditures for R&D are spent in the higher education sector (Table 7). Nevertheless, the expenditures on R&D within higher education have grown three times since 2000, while in other sectors the increase was between 1.5 and 2 times (Nauka Rossii v tsifrakh, 2011, 95).

Table 7. Expenditures for R&D by sector 2010

	Mln.rub.	%
Public sector	151,825.1	31.0
Business sector	294,103.8	60.0
Higher education	42,552,2	8.7
Non-profit	969.6	0.2
Total	489450.8	100.0

Source: Nauka Rossii v tsifrakh 2011.

In the R&D sector, STEM areas are dominant. Research staff in sciences and maths comprise 24 per cent of all researchers and 61 per cent are researchers in technology and engineering fields (Nauka Rossii v tsifrakh, 2011).

Most R&D funding goes to STEM areas: science and maths (20 per cent), technology/engineering (71 per cent) with the rest allocated within medicine, agriculture, social sciences and humanities. In sciences and maths the funding is distributed largely to support basic research (52.7 per cent), with less financing to applied research (28.3 per cent) and development (19.0 per cent). In contrast, technology and engineering fields fund mostly development (80.0 per cent), with small shares for basic (6.6 per cent) and applied research (13.4 per cent) (Nauka Rossii v tsifrakh, 2011).

Women are represented to a lesser extent in STEM disciplines of R&D compared to medical, agricultural, social science and humanities fields. In sciences and maths women are 41.8 per cent of staff, in technology and engineering 37.3 per cent, while for other fields the proportions vary from 55.6 per cent in agriculture to 63.4 per cent in humanities.

Labour market outcomes and social mobility

Analysis of the labour market outcomes for STEM graduates suggests that these differ by field of education (Gimpelson, Kapelyushnikov, 2011). By comparing the field of the degree with the actual graduate occupation (using national qualifications classificators, OKZ), and using two definitions of the field of training, broad and narrow, it is possible to investigate the extent to which the actual occupation correlates with the field of degree received at the higher educational institutions. Although the graduate workers most correlated to the field of training were specialists in medicine and teaching staff at secondary general and vocational education, among STEM graduates, most specialists in maths and computing were in jobs related to their educational specialization. For computer scientists that was true while using both the narrow and broad definition. Specialists in biology and agriculture were those most likely to change their field in the labor market. But they have relatively high percentages for upward mobility, as did engineers and architects.

Table 8. Distribution of workforce with higher education by actual occupations, 2006, per cent

Field of degree	OKZ-2	Actual occupations, per cent of working according to the field of degree		Upward mobility (OKZ-1_	Downward mobility (OKZ-3/OKZ-9)
		Broadly defined	Narrowly defined		
Average for those with higher education	59.6	49.6	37.0	16.4	24.1
Specialists in science, technical sciences	52.8	42.1	8.1	18.0	29.2
Mathematicians, statisticians etc.	72.7	61.0	1.4	10.1	17.2
Specialist in computing	74.3	66.6	54.7	10.1	15.6
Architects, engineers, etc	46.0	35.9	31.9	24.6	29.4
Specialists in biological and agricultural sciences	38.2	21.6	10.2	22.5	39.3

Source: Gimpelson, V., Kapeliushnikov, R. (Eds.) (2011). Rossisskii rabotnik: obrazovanie, professia, kvalifikatsia [Russian Worker: Education, Profession, Qualification]. Moscow: Higher School of Economics.

Thus, about half of the workforce with higher education qualifications does not work in the field they chose in higher education. The scale of discrepancy between education and occupation is mostly significant for those having degrees in engineering and biology/agriculture. The analysis also does not confirm the thesis, frequently repeated by some, of an over-production of economists and lack of engineers in the Russian economy. The engineering workforce trained in Soviet or Post-Soviet time is less successful in the labor market and engineering graduates more likely than many other graduates to work in a position not requiring higher education at all. Those with technical vocational education are even less likely to get a job in the area of training, than are those with university degrees (Gimpelson, Kapelyushnikov, 2011).

At the same time, dissatisfaction with the degree can be observed already at the stage of receiving higher education, among students of all fields. Almost half of first degree students surveyed nationally reported that they planned to obtain further and second higher education. For those studying in STEM disciplines, it was 48 per cent of students in maths and computer science, 44 per cent of those in sciences, 40 per cent in engineering and technology. The indicators are also high for those enroled in economics/law/management/sociology (45 per cent), and humanities (58 per cent) (Smolentseva, 2012).

4. Strategies, policies and programmes used to enhance STEM

Government policy towards STEM education

Despite the fact that research, development and innovations have been declared as a priority for national development, educational policy is focused mostly on the structural, institutional and financial restructuring of the educational system, while paying less attention to the content of educational programs. There is no coherent, consistent or even loosely focused educational policy towards STEM fields.

In higher education the STEM theme indirectly can be recognized as a key one. Research and development, innovations and new technologies have become critical for higher education development. Governmental documents set targets for increasing the competitiveness on the global scale of the leading Russian universities; for example the targets of five top 100 universities by 2020; increasing expenditures on R&D to 1.77 per cent of GDP, with growth of the share of higher educational institutions in those expenditures so it reaches 11.4 per cent by 2015; increasing of share of publication of Russian authors in the total number of publications in international journals indexed in Web of Science up to 2.44 per cent by 2015 (O merakh… 2012).

The strategy of development of research in various sectors, including higher education, has been implemented in several ways. First, the attempts of government to strengthen research in higher educational institutions, where it was traditionally weak, by stratification of the institutional landscape: 'excellence programs', other support for leading institutions, and mergers of a number of regional institution in order to concentrate regional resources for further development. Recent measures include programs to stimulate universities to engage in commercialization and technology transfer, and encourage interaction of universities and industry aiming at development of innovation in businesses, and measures assisting Russian higher education institution to open up opportunities to attract leading researchers in order to set up world class laboratories.

There are three initiatives of government related to the education in STEM:

1. The Program for enhancing the qualifications of engineering cadre for 2012-2014, under the President of Russian Federation, was adopted in 2012. This is a retraining program for 15,000 engineers already working in the economy in Russia or abroad.
2. By December 2013 it is planned to develop and adopt the Concept of development of mathematical education in Russia at the basis of analytical data of state of art maths education (O merakh po realizatsii, 2012).
3. Also, in 2013 higher educational institutions will adopt a new per capita funding scheme with an increased norm of funding for leading universities that provide programs in engineering, medical and science fields.

Nevertheless, this does not add up to a comprehensive and coherent approach to developing STEM. Why is there no consistent STEM policy in Russia?

First, policy is primarily focused on institutional and structural reforms, as already mentioned, even though in recent years new standards have been adopted at all levels of education.

Second, there is a lack of holistic vision of the quality of Russian education on the global scale. As it was noted, TIMSS and PIRLS demonstrate high achievements of Russian secondary education, while results of PISA exhibit more modest performance. In policy documents, after mentioning the performance of those tests, the concluding remarks mention priorities in improving quality of education mostly in other fields – arts, social sciences, foreign languages and as a last one, technology. Nevertheless, at the level of higher education, the results are seen as less ambiguous while considering the position of Russian universities in global universities rankings and publication activities tables.

Third, maths and science has been considered as traditionally strong disciplines in the USSR, and this appears to be confirmed by relatively good performance in international tests and competitions in those fields. That is why the idea of improving teaching and learning in those areas has been treated as relevant and necessary.

However, more in-depth analysis of data from the international assessments TIMSS and PIRLS show that Russian secondary school students demonstrate higher performance in those parts of tests where knowledge and typical tasks are required, and lesser performance in tasks measuring application of knowledge, and are weakest in the reasoning section. This picture is contrasting to the result of Japanese students, which are also in the top group: students in Japan are stronger in solving non-standard tasks, and reasoning, less strong in application, and demonstrate lowest scores in tasks measuring knowledge (Kovaleva et al, 2013).

This approach to education – strongest in knowledge, in memorizing standard tasks, weaker in application, and failing in reasoning and integration – is seem to be a Soviet tradition. Similar results can be found in the data of one of the first comparative assessment attempts (1991 IAEPP-II science), in which USSR took part (Kovaleva et al, 2013). This bias could also be a result of the broad use of Soviet textbooks in contemporary schools.

The experts (Kovaleva et al, 2013) also note other sides of Russian education which impact the success and failure at the tests. In TIMSS it is strong preparation in chemistry, by which the average score is improved, and to a lesser extent, physics. The lowest performance is in biology and geography. The weak points are also tasks requiring lab and experimental work, partly because of the curriculum not implying such experience and partly because of equipment shortages in Russian schools (about 85 per cent schools reported about adequate availability of equipment, while this number is about 100 per cent in countries with top scores). The difficulties with the integration of knowledge from different fields are also an indicator of the Russian education system, as curriculum is built on the basis of field specialization. The application of knowledge in real life is also one of the challenges facing national education; as is the learning to perform tasks requiring not multiple choice, but extended response. The latter problem could be the result of lack of development of the system of ongoing control of learning in classroom and abuse of the forms of final control, such as national tests taken at the end of Years 9th and 11th.

The performance of Russian students improved in TIMMS and PIRLS in 2011 compared to previous assessments. The experts note that this improvement could be a result of changes in educational standards and introduction of measures of final assessment in the above mentioned national tests: the introduction of elements of probability theory and statistics in 2004, adding probability/statistics and geometry national test for Year 9th requirements. Introduction of national tests has fostered clarification and standardization of the requirements and objectives of education, which have become clearer to teachers and families and become a landmark of academic achievement, while improving motivation to learn.

We can also mention several other features of the Russian educational system and its policy that might impact its performance and the situation with the STEM education.

Selection and recruiting

Governmental policy puts special emphasis on the issue of finding gifted children. In the Soviet period this emerged in the form of schemes of national and regional competition in certain fields, skills and talents. The federal program for educational development for 2011-2015 states further development of those measures: organization of competitions ('Olympics'), festivals of national, regional and municipal levels, launching a national database of gifted children and their support. It implies establishment of a center of support of gifted children at federal universities, and distance education schools at several federal and national research universities.

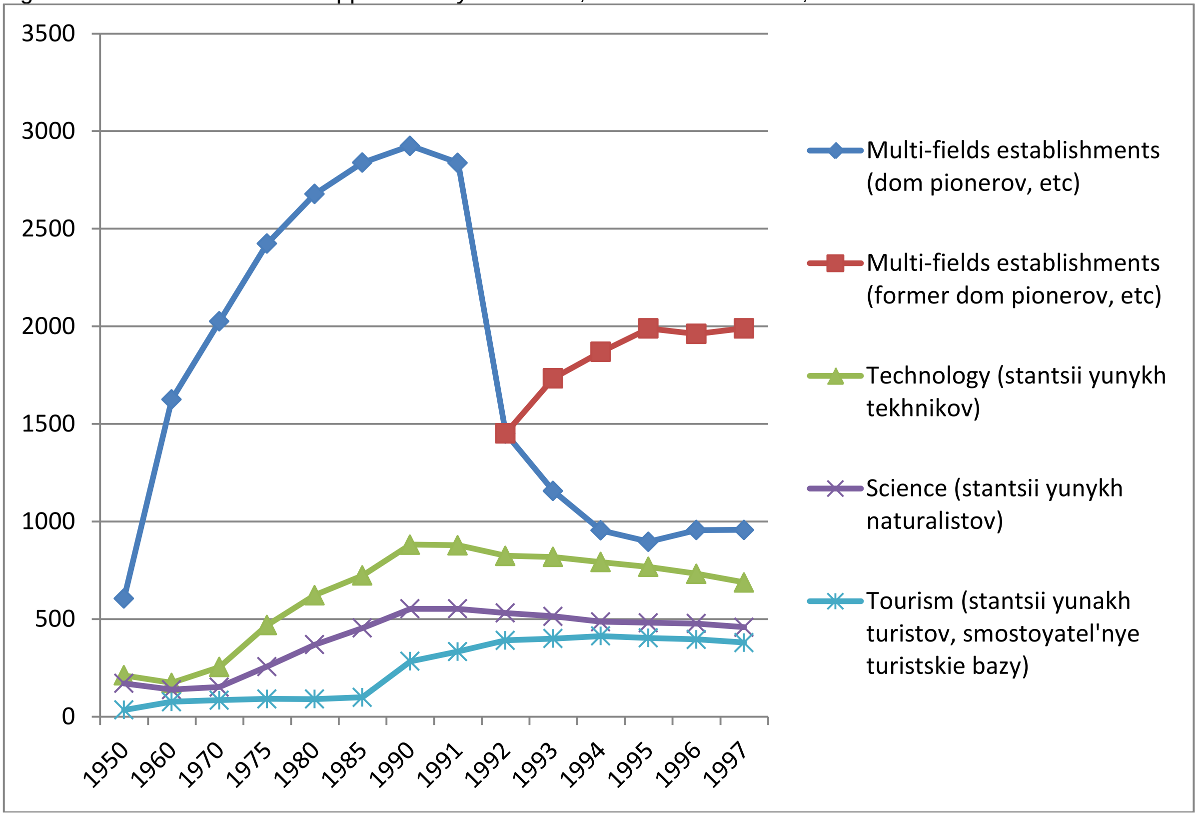
The programs intend to expand the number of regions participating in the final round of competitions from 64 to 80, increase the number of competitions organized by two or more universities (from 17 to 50 per cent), increase the number of regions where there are programs of support of gifted children from 20 to 100, and expand participation in distance education schools (from 5 to 15 per cent). It is significant that winners of certain subject competitions are entitled to priority admission to higher educational institutions.

Supplementary education *(dopolnitel'noe obrazovanie)* at secondary level

An important element of the Russian educational system is the network of institutions for supplementary, extra-curricular education – in arts, music, sports, general education, etc. Russia is one of the few countries where that kind of education is funded by government. About half of children aged 5-18 years are involved in this system (Strategy 2020). Currently supplementary education is included into the standard general education, which as expected increases participation rates. However, after the Soviet time the institutions of this system were underfunded and declined in many ways. Although the majority of institutions are not in STEM fields, it is still important to mention this type of activity.

Figure 13 shows the growth and decline of this system over the last decades. Multi-field establishments (dom pionerov) were partly reorganized in 1992 (red line) into centers/complex of child creativity and development.

Figure 13. Establishments of supplementary education, STEM related fields, 1950-1997



The data can be disaggregated to identify the institutions related to STEM fields, in technical and ecology/biology orientations (Table 9). The number of institutions and students has been decreasing.

Table 9. Establishments of supplementary education and students, STEM related fields, 2000-2010

		Total number of institutions of supplementary education	including	
			technical	**ecology/biology**
Number of institutions	2000	8699	**570**	**467**
	2005	8876	**536**	**445**
	2006	8936	**534**	**433**
	2007	8857	**513**	**427**
	2008	8762	**491**	**414**
	2009	8440	**388**	**365**

	2010	8531	**327**	**331**
Number of students, million	2000	7.9058	**0.4342**	**0.3676**
	2005	8.4437	**0.4355**	**0.3808**
	2006	8.4238	**0.4203**	**0.3664**
	2007	8.3432	**0.4067**	**0.3570**
	2008	8.2754	**0.3790**	**0.3363**
	2009	7.9708	**0.2998**	**0.2930**
	2010	8.0833	**0.2684**	**0.2812**

Secondary schools of advanced study in math and science

Secondary schools for advanced study were first announced in the late 1950s, first of all in math and physics, with later establishment of those in chemistry and biology. The first four schools were organized at the leading universities (such as Moscow State University) in early 1960s by leading Soviet mathematicians. Those schools continue to exist up to now and function as residence establishments thus overcoming the territorial and financial barriers to the provision of top quality education for best students. The graduates of these schools are expected to reproduce researchers in higher education and science, not just to develop the economy but to develop the military sector. Residence schools have been few, at leading universities. Non-residence schools are more common around the country, but are not evenly distributed across the regions.

Teachers

The level of education of Russian teachers is higher than the OECD average. However there are notable gender and age misbalances: men comprise 12 per cent, and teachers of pension age are 18 per cent of the total. According to TIMSS-2011, about 70 per cent of Russian teachers have more than 20 years of professional experience, which sharply contrasts with the other top countries in the assessment.

An international study of the quality of maths teachers' education, TEDS-M, conducted among students of pedagogical institutions, has shown that Russian future teachers of maths demonstrate very high results. This can be found both in the knowledge of the subject and knowledge of pedagogical approaches to teaching maths. However, only 10 per cent are planning to work in schools (Kovaleva, 2011). That could be the result of the low salaries of teachers, and low prestige of the profession. Only in half of Russia's regions is the salary of teachers higher than the average salary in the regional economy (Program of development of education for 2013-2020).

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Appendix 1.

Table A1. Average admission score by field, tuition free enrolments, 2012 (STEM fields in grey color)

	Field	**Average scores**	**Number of students admitted on the basis of national test**	**Number of HEIs in the group**
1.	Asian and African studies	83.0	346	15
2.	International relations	82.2	903	64
3.	Arts theory	81.6	235	17
4.	Journalism and creative writing	79.3	1332	90
5.	Political science	79.2	753	57
6.	Linguistics and foreign languages	76.9	2805	111
7.	Publishing	76.1	141	16
8.	Law	76.0	5798	156
9.	Advertising and public relations	75.2	743	76
10.	Philosophy	74.9	527	33
11.	Health care	74.8	21,451	76
12.	History	74.0	1687	83
13.	Philology	71.7	2565	77
14.	Economics	71.3	13,035	302
15.	Design	71.0	1542	85
16.	Business informatics	70.7	1427	105
17.	Cultural studies	70.3	327	33
18.	Architecture and construction	69.4	3024	71
19.	Sociology	68.9	2285	106
20.	Management	68.7	11,687	334
21.	Information security	68.5	4196	126
22.	Religion studies and theology	68.5	185	24
23.	Public administration	68.1	2131	128
24.	Oil and gas	67.5	1522	32
25.	Nuclear physics and technology	67.3	1133	13
26.	Services	67.1	3947	159
27.	Library and archives	67.0	580	48
28.	Math	66.4	9723	159
29.	Chemistry	66.1	2916	84
30.	Heritage conservation	65.9	193	18
31.	Physics	65.4	5206	93
32.	Social work	65.3	3347	142
33.	Psychology	65.2	2353	132
34.	Informatics and computer science	64.7	17,156	297
35.	Chemical and biotechnology	63.4	7420	95
36.	Biology	62.8	3946	105
37.	Automation and control	62.5	7431	139
38.	Electronic engineering, radio engineering and telecommunications	61,9	9449	108

39.	Geography	61,8	1974	53
40.	Pedology	61,7	303	13
41.	Pedagogical education	61,6	27007	130
42.	Energy, energy engineering	61,4	11675	153
43.	Physical education	61,3	1063	57
44.	Instrumentation and optical engineering	61,2	4233	77
45.	Construction	61,2	13770	117
46.	Aviation, rocket and space technology	59,8	3683	32
47.	Aviation systems (exploitation)	59,5	1608	23
48.	Geology	59,1	5258	62
49.	Geodesy and land administration	58,9	3203	96
50.	Quality management	58,8	3387	138
51.	Materials	57,9	2509	65
52.	Vocational education	57,6	2108	64
53.	Educational psychology and special (defectology) education	57,3	6545	123
54.	Ecology	57,1	10268	261
55.	Food technology	57	4072	82
56.	Machinery and equipment	56,5	7555	139
57.	Transportation	56,4	12203	158
58.	Weaponry	55,9	1174	15
59.	Printing and Packaging	55,9	491	18
60.	Mechanical engineering	55,2	2163	57
61.	Metallurgy	54,2	1534	28
62.	Technology of light industry	53,8	901	23
63.	Forestry	53,2	3375	64
64.	Waterway transport	52,6	921	12
65.	Agriculture and fishery	52,2	16195	85
66.	Marine technology	51,1	1795	19