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Interaction between Secondary and Higher Schools: A Basis for Fundamental Chemical Education

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Abstract—Nowadays, within the Russian system of higher education there are two subsystems working fairly independently. One is mass higher education, and other is fundamental (quality) education. The educational reform which has been underway since the mid-1990s only makes worse the situation. Every year higher school teachers note a decrease of the quality of applicants and first-year students, gaps in their knowledge of chemistry, mathematics, and other disciplines. Under such conditions, universities should provide themselves with a corpse of the adequately prepared applicants. What can be done in order to preserve traditions of the Russian fundamental university education? First of all, quality textbooks for school pupils and applicants can be written and published. Further, connections between higher education institutions and secondary school in various regions of the country can be established and developed. Another very important task consists in organizing and conducting science Olympiads for schoolchildren and applicants. All these activities are being undertaken now by the Moscow State University.

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Since the mid-1990s, a systemic educational reform process has been underway in Russia, aimed at marketization of education, with both higher and secondary schools being involved in this process. As a result, the fundamentality level of both natural-sciences and humanities education is declining, which cannot but very adversely affect the national intellectual potential.

With regard to the current state of secondary school education, it would be appropriate to provide the following citation: "… The school reform has created nothing and gave purely destructive results… It has introduced complete chaos into schooling, and there is a need to find a way out thereof. ……. As long as universities will receive from secondary school young people that are not adequately prepared for higher scientific education, there cannot be a solid foundation for higher school. This situation calls for huge continuous work into which the government should attract all the people of education in the country. All the activities of the Ministry of National Education, which is responsible for the collapse of the secondary and higher schools, must change fundamentally. The whole future of Russia depends on school, and there is nothing that could not be sacrificed to secure its proper functioning and growth by the government, if it wishes to benefit the country and raise its own profile." These are the words said more than a hundred years ago by Duke Sergei Trubetskoi, Full Professor at the Imperial Moscow University, its first elected Rector [3], but they sound as if they were uttered today. Over these one hundred years, no visible progress has been achieved in the relationship between the government and the people from the education system.

Today, universities in the world are categorized into those remaining true to the fundamental education and those focusing on the practicality of knowledge.
Daisaku Ikeda [1]

The main difficulty experienced by civilization itself lies in the fact that it has outstripped culture. Today civilization is doing what it wants, i.e., what is easier to sell and what can provide a means to generate revenue. And I am afraid that, in the future, the situation will only worsen. Therefore, today it is necessary to reinstate culture, which means the need to educate, educate, and educate.
Fazil' Iskander [2]

Fundamental and Mass Education

We have necessarily got used to the fact that, nowadays, within the Russian system of higher vocational education, there are two subsystems working in parallel and fairly independently. One is fundamental (quality) education which was very adequately described by Academician V. A. Sadovnichii, Rector of the Lomonosov Moscow State University: "The fundamentality of higher education means a combination of scientific knowledge with education process, which provides us with understanding of the fact that we all are living in accordance with the laws of nature and society, whose ignoring by an illiterate or unintelligent person is dangerous to surrounding persons" [4]. The other subsystem is mass higher education which arose from the premise of the change in the very lifestyle pattern in Russia. Today, there exist a large number of jobs (mostly in the management and service providing sphere) which do not require any special knowledge expect for a minimum command of foreign language and elementary computer skills. However, the legislative paradox consists in the fact that these job places can be occupied only by graduates from higher education institutions (more precisely, by those who have a certificate of graduation from a higher education institution, rather than by those who have a professional expertise). Like in many other cases, the demand gave rise to supply, and numerous higher education institutions, figuratively speaking, sprouted as mushrooms after a summer rain. The admission rules at such institutions are very simple, and any secondary school graduate, even an underachiever, is able to study therein. It should be noted in this connection that, in the USSR, there were ca. 700 higher education institutions against over 1100 state and non-state higher education institutions in Russia as of beginning of the 2009/10 academic year (Fig. 1). Moreover, numerous branches of state and non-state higher education institutions were established. For example, at the beginning of the 2009/10 academic year there were 571 branches of only non-state higher education institutions in Russia. The administrative measures aimed to put under control the number of higher education institutions were inefficient. Over the year 2009, e.g., Russian higher education institutions decreased by 20 in number (1.8% of the total amount) [5]. Notably, graduates from all Russian higher education institutions got uniform diplomas.

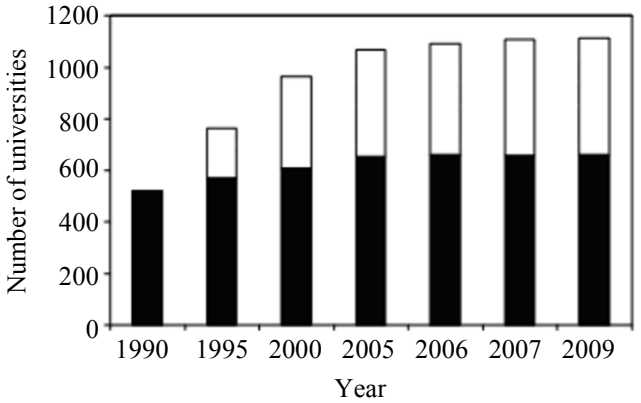

Fig. 1. Variation in the number of higher education institutions in Russia [5]. (■) State and (□) private higher education institutions.

The result was that the society became incapable of understanding what is essentially meant by higher education.

The situation is aggravated by the fact that the desired quality of fundamental education is to be maintained by universities against background of a number of unfavorable factors acting today in Russia.

The first factor is the steadily declining motivation to obtain a fundamental natural-sciences education: Young people tend to increasingly strive to get professions that, in their opinion, will provide them with a good salary in a short time and without major efforts. As to chemical education, the situation is aggravated by chemophobia "fed" by not always competent mass media personnel.

The second factor is the unfavorable, from the viewpoint of obtaining higher education, demographic situation. Today, the number of Russia's citizens aged 17, who constitute the majority of the enrollment, only insignificantly exceeds the number of places available for the first year of study at Russian higher educational institutions. The result is that a great number of Russian higher education institutions, even including major classical universities, are chronically underenrolled, which makes them reduce the number of students enrolled at their natural-sciences departments. For example, the Chemistry Department, St. Petersburg State University, whose traditional enrollment was 120, had to reduce it to 80 in the last two years. According to predictions, further trend in the number of persons aged 17 in Russia will also be toward decline [5].

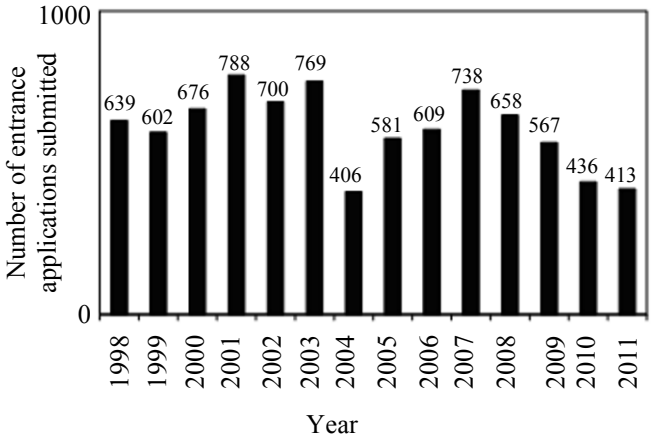

Fig. 2. Number of entrance applications submitted in different years at the Chemistry Department, MSU.

The third factor deals with constantly introduced (in many cases on the eve of the admission campaign) modifications to the admission procedure and list of tests for higher education institutions. An example can be found in the suggestion to change the set of Unified State Examination (USE) certificates to be submitted for several specialties, which was made in April 2011 and gave a shock to applicants and their parents throughout Russia. A good illustration to the above-said can be found in the trends in the number of entrance applications submitted to the Chemistry Department, MSU, over the last years (Fig. 2).

The unexpected drastic modifications to the admission rules for higher education institutions, introduced in 2004 and subsequently in 2010, have caused an abrupt decrease in the number of entrance applications submitted. The behaviors of applicants and their parents is quite understandable: They wish to avoid a risk and not to apply to universities that tend to constantly modify their admission procedures and require that applicants pass a test additional to USE (e.g., a written test in chemistry at the Chemistry Department, MSU, and at the prestigious Department of Fundamental Medicine, MSU).

Lastly, the rapid and ill-considered decision to introduce the two-level education system according to the Bologna process principles [6, 7] is perceived antagonistically for a number of reasons by the professionals' society.

Considering all these unfavorable novelties in Russia's higher education system, it will be very much to the point to mention the collection of works, edited by V.A. Sadovnichii, MSU Rector, with the meaningful title "The Education that we Can Lose" [8].

Academician E.N. Kablov, a well-known scientist, Director of the All-Russia Research Institute of Aviation Materials, expressed his opinion of the current situation as follows: "Essentially, we are destroying the system, which has proven its effectiveness, by replacing it by a two-level system… As applied to engineering specialties, this approach means the appearance of a large number of half-educated students in the figures of bachelors ... Certainly, a "bachelor" sounds much better than "a half-educated student," but these terms have essentially the same meaning [9].

It is sometimes argued that the two-level system is fairly suitable for training humanitarians and managers, but V.V. Mironov, a well-known philosopher, RAS Corresponding Member, thinks differently: "Is it possible to train a philologist specializing in Germanic or classical philology within 3–4 years of study under unspecialized philology program and 2 years of study under specialized master's program? Certainly, this is impossible" [10].

Similar problems are faced today by virtually all former Soviet Republics, e.g., by Ukraine, as characterized by A.N. Postupnoi [7] as follows: "Actually, the situation with Ukraine's accession to the Bologna process is unique and amazing. During the years of independence, there were no examples where such a massive and radical changes in one of the most important sectors in society were introduced so rapidly (naturally, except for the state property privatization). Several years ago, Bologna process was not even mentioned not only in the media but also in specialized publications, while today specifically the "Bologna" dimension represents the coordinate system within which the reforming of the entire system of higher education has already begun with the aim not only to achieve harmonization of the European and Ukrainian education systems but also to create a "common space" for higher education. This step will have direct implications for the future of Ukraine. Before making this step, it would not be out of place to dust off the idea "measure twice, cut once," but this did not happen" [7]. Certainly, this equally holds true for Russia.

Interaction of Higher and Secondary Schools under Conditions of Reforming Russia's Education System

Due to the above-mentioned reasons, Russian universities are experiencing ever increasing difficulties in

providing quality education to their students. At the same time, many Russian classical universities still have scientific capacity and human resources sufficiently high to assure quality fundamental education. For example, the Chemistry Department, MSU, has 10 Full Members and 8 Corresponding Members of RAS, over 250 Doctors and 700 Candidates of Sciences among its staff; also, there are

Table 1. Chemical, physical, and mathematical "cycle" disciplines in the academic curriculum of the Chemistry Department, MSU

Disciplines	Number of classroom hours					
	For cohort as a whole	For specialized groups				
		09	10	11	12	13
Chemical disciplines						
Inorganic chemistry	444	444	412	394	444	444
Analytical chemistry	358	306	306	306	306	340
Organic chemistry	444	356	444	304	356	376
Physical chemistry	340	340	340	356	340	340
Crystal chemistry	54	54	54	72	72	54
Molecular structure	72	72	126	72	54	126
Colloid chemistry	108	108	108	108	108	108
Macromolecular compounds	111	111	111	111	111	111
Chemical engineering	120	120	90	120	120	120
Quantum chemistry				64		
Theoretical inorganic chemistry	136					
Percentage of chemical disciplines in the 'cycle" curriculum	40	40	35.5	33	36	35.5
Physical disciplines						
Mechanics. Electricity	96	64	64	64	64	64
Oscillations. Optics	144	72	72	72	72	72
Theoretical mechanics	48	48	48			48
Theoretical and quantum mechanics					48	
Classical mechanics and field theory				96		
Foundations of quantum mechanics	48	48				
Quantum mechanics				72		
Quantum mechanics and structure of matter			126			126
Elements of the structure of matter	32	32	32			32
Methods of mathematical physics				96		
Elements of statistical physics					54	
Solid state physics					64	
Real structure of solids					48	
Statistical thermodynamics				72		
Percentage of physical disciplines in the "cycle" curriculum	8.0	7.5	7.9	11.2	8.2	7.9

Table 1. (Contd.)

Disciplines	Number of classroom hours					
	For cohort as a whole	For specialized groups				
		09	10	11	12	13
Mathematical disciplines						
Mathematical analysis	324	324	324	380	340	324
Analytical geometry	54	54	54			54
Analytical geometry and vector algebra				72	72	
Linear algebra	48	48	48	96	80	48
Probability theory	72	72	54	48	48	54
Differential equations				72	54	
Equations of mathematical physics	48	48	48		48	48
Programming and computer science	102	102	102	48	86	102
Applied mathematical statistics	32	32				
Computing methods and programming						68
Mathematical methods in chemistry			100			120
Percentage of mathematical disciplines in the "cycle" curriculum	11.8	11.8	13.4	13.1	13.6	15.0

nearly 300 postgraduate students and over 1000 students. Up to two hundred highly-skilled professsionals in the key domains of chemistry science ranging from theoretical quantum chemistry to chemical engineering and biotechnology, who graduate every year from the Chemistry Department, MSU, are demanded both in Russia and in major universities and research centers around the world.

Generally, the human resources of an educational institution belong to the key components of the education system, which primarily decides the teaching quality. In this context, the teachers' and students' (certainly, everything starts with applicants!) resources are equally important. A high-quality first-year students' corps is one of the major factors contributing to fundamentality of higher education for a number of reasons.

We will discuss these reasons, once again, by the example of the Chemistry Department, MSU, whose specialty's (not bachelor's!) degree program is designed for six years of study and includes a number of disciplines which can be grouped into several "cycles" (chemistry, physics, mathematics, and humanities). There are ten mandatory chemical disciplines (apart from special courses) against fourteen "physical" disciplines and twelve "mathematical" disciplines (Table 1; for details, see [11]).

Along with the general cohort, the Chemistry Department offers study in five specialized groups which provide training under advanced programs.[1] Clearly, mediocre students are unable to achieve the mastery of these courses.???

A precondition to high quality of students is the high quality of the pre-university training of applicants, which is primarily determined by the general condition of secondary school education. This suggests the need in close interaction between higher and secondary schools.

Currently, the quality of mass school education in Russia (there are about sixty thousand general education schools) has significantly deteriorated. Schools were forced to introduce the Unified State Examination system and reduce the number of teaching hours dedicated to natural sciences

[1] These are groups no. 9 (academic group, RAS), no. 10 (chemistry of living systems and nanobiotechnology), no. 11 (physical chemists, theoreticians), no. 12 (advanced processes and materials), and no. 13 (mathematical chemistry).

(chemistry, biology, physics, etc.). This has resulted in significantly worsened quality of applicants and, correspondingly, of the first-year students' performance. It will suffice to note that, in the recent years, at the Chemistry Department, MSU, up to 30 students out of 235 enrolled were annually expelled in the first year of study only. The quality of first-year students' training in physics and mathematics has also deteriorated. It should be noted that the Chemistry Department, MSU, is the only chemistry department among those at the classical universities in Russia, where applicants must submit four, rather than three, USE certificates (in chemistry, mathematics, and Russian language and also in physics). This leads to stalemate situation: On the one hand, applicants need to have an adequate background in physics and mathematics, because otherwise there could be no fundamental education, and, on the other hand, many students, who wish to get chemical education are deterred from MSU by the need to pass an additional USE exam and, further in summer, an additional exam in chemistry (which behavior is quite understandable).

What can be really done by higher school in order to improve the education in chemistry?

Schoolchildren's Science Olympiads

One of the goals pursued by chemistry education at secondary school level is to attract gifted young people into studying chemistry and create conditions for them to continue education at higher school. In this context, of much importance is the practice of holding schoolchildren's Olympiads in chemistry, which was suggested by the MSU as a strategic alternative to USE and was supported by the Russian Rectors' Union [12]. It should be noted that a long-standing practice of holding schoolchildren's science Olympiads exist not only in Russia [13, 14].

Over the last decade, the MSU has been undertaking a purposeful work aimed to develop its own system of multi-subject Olympiads intended as a tool of selection of gifted schoolchildren, two of which will be discussed below.

The Lomonosov multi-subject Schoolchildren's Olympiad has been conducted by the MSU since 2005. Intended originally specifically as an internal university Olympiad, it has become an event which is regarded as the cessionary undertaking creative development of the "MSU Applicant" correspondence–on-site Olympiads that were con-ducted at the MSU

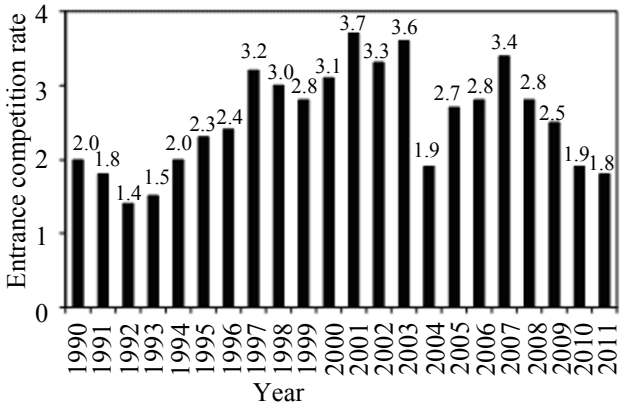

Fig. 3. Variation in the entrance competition rate (number of applicants per place) at the Chemistry Department, MSU.

earlier. Below, we present a brief retrospective analysis of this original event in the Russian education system, a schoolchildren's science Olympiad held by a university.

In the early 1990s, an unfavorable situation had developed at the Chemistry Department, MSU (like in many other natural sciences-oriented Russian higher education institutions), with decreased number of applicants and record-low entrance competition rate of 1.4 persons per place (Fig. 3). Specifically at that time, the Chemistry Department developed and successfully introduced a correspondence–on-site admission system, further transformed into the "MSU Applicant" Olympiad.

In the period 1993–1997, the admission exams at the Chemistry Department, MSU, were conducted twice in a year: in-advance exams (in mathematics and chemistry) in May, and the main exams, in July. Those applicants who gained ≥17 scores on a 10-point scale at both exams were admitted to the Chemistry Department in advance, before their passing the school graduation exams. The correctness of the new admission strategy was confirmed by its successful functioning and constant growth of the entrance competition rate at the Chemistry Department, MSU, in the period 1992–1997. This system was applied by other departments of MSU and gained popularity at other higher education institutions. However, in 1998 the reforming of the Russian education system was begun, and the Ministry of Education and Science of the Russian Federation forbade in-advance (prior to school graduation exams) admission to higher education institutions and, hence, in-advance entrance exams. Instead, the MSU got a permission to carry out the "MSU Applicant" correspondence–on-site chem.-

ical-mathematical Olympiad whose winners and prize-winners were granted admission privileges.

This Olympiad included a mandatory correspondence round: a written test in chemistry, mathematics, and physics to be completed in November-April period and sent by regular mail to the Chemistry Department, MSU. The Olympiad assignment was published in "Khimiya v Shkole" magazine, "Pervoe Sentyabrya" newspaper (in selected years, also in such popular many-million periodical as "Komsomol'skaya Pravda"), and at the Chemistry Department website. Also, the assignment was distributed among the schools that closely collaborated with the Chemistry Department. For example, in 2001, the correspondence round assignment of the "MSU Applicant" Olympiad in chemistry consisted of 38 problems of different complexity levels: 18 problems on chemistry, 12, on mathematics, and 8, on physics. The maximal score for solution of the entre kit was 100. Those schoolchildren who gained the necessary scores (50 and above) received a personal invitation to participate in the on-site round to be held in May, which consisted of two examinations: in mathematic and in chemistry. The on-site round winners (the sum of 17 points and above on a 10-point score for both exams) could submit these points as the entrance competition scores for the corresponding subjects. At the main entrance examinations held in July they had only to pass the exam in physics and write an assay, after which with the sum of the scores gained they could participate in the general competition. Since 2000, the Olympiad winners have been allowed to choose between the score for assay and that for exam in Russian language or literature in their school graduation certificate, depending on which is better. By 2003, the entrance competition rate at the Chemistry Department, MSU, became stable and exceeded 3 persons per place. It should be noted that the developers of the correspondence–on-site admission concept (Prof. N.E. Kuz'menko, Prof. V.V. Eremin, and RAS Academician V.V. Lunin) received RF Presidential award for its successful implementation. The Olympiad had existed in this format until 2004.

Unfortunately, this university enrollment system, that has demonstrated its effectiveness, had a short-lived existence: The year 2004 has become a make-or-break and dramatic year. After the correspondence round of the "MSU Applicant" Olympiad (whose participants were over 600 applicants) was finished, the RF Ministry of Education and Science unexpectedly cancelled the on-site round. In 2004, the entrance exams to MSU were carried out in July only, and in a fairly specific manner: Prior to traditional exams, the winners of the intermediate (3rd and 4th) rounds of the All-Russia Schoolchildren's Olympiad in chemistry passed special written exams in mathematics and physics. The exams were carried out over two consecutive (very fatiguing for the schoolchildren) days; in the years that followed, this practice was abandoned.

In 2005, the multi-subject "Lomonosov" Olympiad began its life at the MSU. The chemistry Olympiad was carried out in middle May; simultaneously, uniform variants of assignments were offered by all the MSU departments having chemistry among its entrance exams (Chemistry, Biology, Soil Sciences, and Bioengineering and Bioinformatics Departments). The Olympiad assignment was a question paper comprising ten tasks, with the maximal score for their evaluation indicated. The tasks were evaluated on a case-by-case basis, depending on their complexity level (the number of logical operations needed for arriving at the correct answer) and nature (productive or reproductive). Winning Olympiad in each subject was equated to getting the maximal score at the entrance examination in the corresponding discipline. The Lomonosov Olympiad in chemistry proved to be among the most highly demanded competitions, which attracted hundreds of schoolchildren annually.

In 2009, the admission to all higher education institutions in Russia was for the first time based on the sum of the USE scores for examinations in the major disciplines, and only selected higher education institutions (more precisely, selected departments, and even more precisely, only selected specialties at selected departments, e.g., only at three departments of MSU) were granted a permission to carry out additional testing. At the Chemistry Department, MSU, no chemistry entrance examination was carried out. Clearly, the continuously introduced modifications to the admission rules directly affect the competition rate and, certainly, the quality of the first-year students. The inevitable decline of this quality was prevented in 2009 specifically due to the system of Olympiads on different subjects whose winners and prize-winners were granted appreciable privileges with respect to MSU admission. In particular, like in previous years, the "Lomonosov" science Olympiad winners were admitted to the corresponding departments out of competition, and prize-winners were provided with 100 points instead of their USE score

Table 2. Geographic coverage of the Mendeleyev Chemistry Olympiad

Year	Venue	Number of participating countries	Number of participants
1992	Samara (Russia)	9	200
1993	Pushchino (Russia)	4	29
1994	Pushchino (Russia)	9	43
1995	Pushchino (Russia)	11	63
1996	Pushchino (Russia)	12	85
1997	Yerevan (Armenia)	8	48
1998	Issyk-Kul (Kyrgyzstan)	12	68
1999	Minsk (Belarus)	11	65
2000	Baku (Azerbaijan)	10	54
2001	Moscow (Russia)	13	80
2002	Almaty (Kazakhstan)	14	85
2003	Pushchino (Russia)	12	76
2004	Chisinau (Moldova)	14	77
2005	Dushanbe (Tajikistan)	15	87
2006	Yerevan (Armenia)	15	82
2007	Minsk (Belarus)	16	91
2008	Tashkent (Uzbekistan)	15	85
2009	Ашхабад (Туркменистан)	13	87
2010	Baku (Azerbaijan)	14	87
2011	Ashgabat (Turkmenistan)	15	96

for the corresponding subject. The very "Lomonosov" Olympiad assignments, though preserved their structure, since 2009 have been evaluated on the basis of a 100-point scale, like USE assignments.

In the year 2011, another novelty was introduced into the "Lomonosov" Olympiad procedure. Specifically, according to the "Procedure for Conduct of Schoolchildren's Olympiads" and "Regulations on the "Lomonosov" Schoolchildren's Olympiad," the "Lomonosov" Olympiad-2011 consisted of two rounds: a selection (correspondence) and a final (on-site) round. The kit of problems for the correspondence round (12 problems) was published in the fall, 2010, at the websites of the MSU and the Russian Council for Schoolchildren's Olympiads. The participants had to send by post, or email, the completed assignments to the MSU before January 28, 2011. Only laureates of the selection (correspondence) round (no larger than 35% of the total number of the correspondence round participants, according to a resolution of the RF Ministry of Education and Science) were allowed to participate in the final round. One thousand and sixty seven schoolchildren took part in the correspondence round. The on-site round was held at the Chemistry Department, MSU, on March 14, 2011, and gathered 366 participants. The number of on-site round laureates was also strictly regulated: no greater than 10% of the on-site round participants (37 persons) for winners (1st place) and no greater than 25% (89 persons) for prize-winners (2nd and 3rd places). Thus, 126 schoolchildren from various Russia's regions got appreciably better chances to be admitted to a chemical or medical higher education institution in Russia. For example, the "Lomonosov" Olympiad winners can be admitted to the Chemistry Department, MSU, without passing exams, and the winners applying to the Department of Fundamental Medicine, MSU, automatically get 100 points instead of their USE scores on chemistry. Now, among the active participants of the "Lomonosov" Olympiad which enjoys a federal status, there are not only senior

Table 3. Mendeleev Chemistry Olympiad winners and prize-winners enrolled out of competition at the Chemistry Department, MSU

Country	Number of students
Azerbaijan	7
Armenia	3
Belarus	26
Bulgaria	2
Kazakhstan	22
Kyrgyzstan	6
Moldova	7
Tajikistan	3
Turkmenistan	1
Uzbekistan	5
Ukraine	17
Estonia	3
Total	103

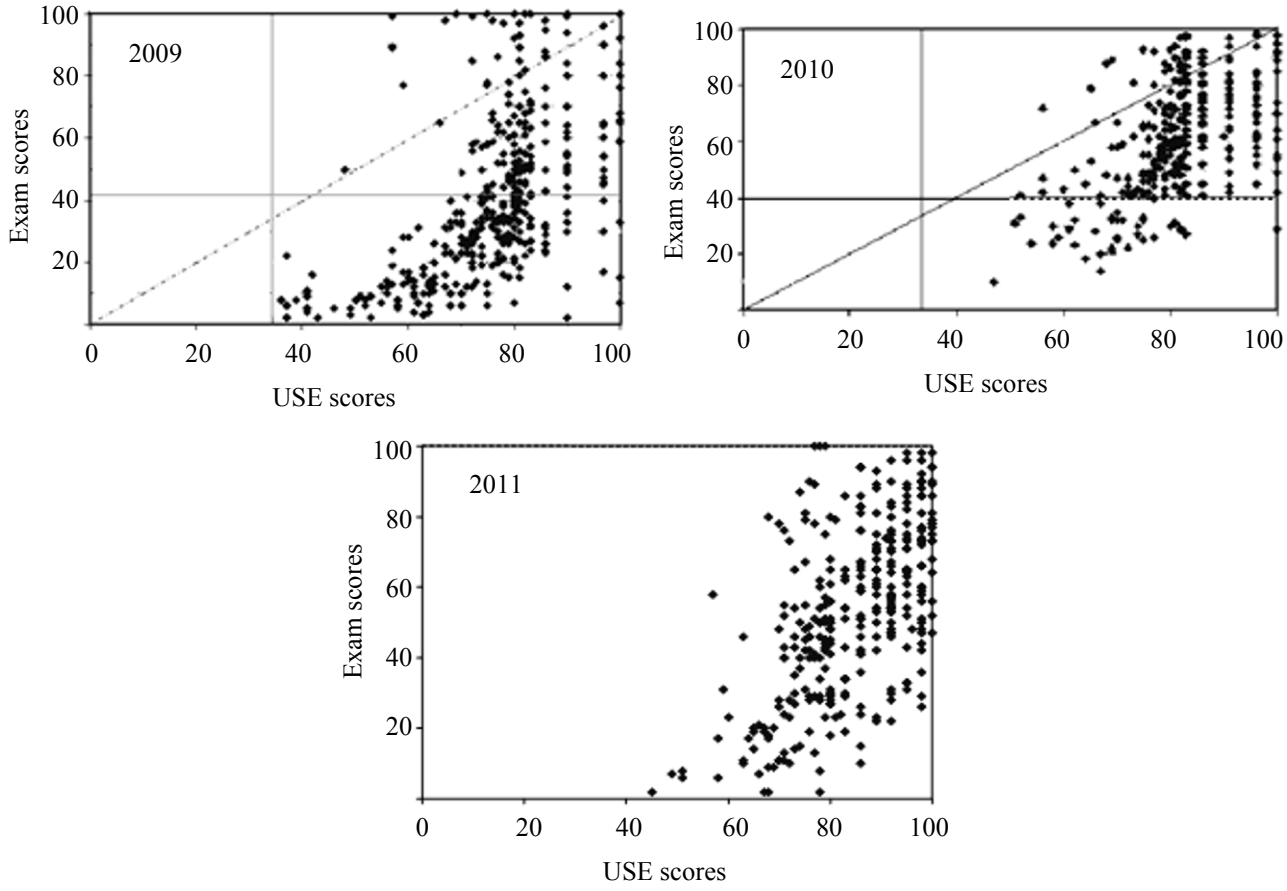

Fig. 4. USE scores against chemistry exam scores for applicants of the Department of Fundamental Medicine, MSU, in 2009–2011.

schoolchildren wishing to enter MSU but also everyone for whom this subject is important (e.g., potential applicants of medical higher education institutions actively participate in "Lomonosov" Olympiads in chemistry and biology).

The "Conquer Sparrow Hills" competition, first organized in 2005 and very popular since then, is a joint project of the MSU and "Moskovskii Komsomolets" Publishing House. Its primary goal is to allow schoolchildren and applicants from most distant places of Russia to become students of Russia's top-ranked university. By contrast to "Lomonosov" Olympiad, this competition from the very beginning consisted of two, one correspondence and one on-site, rounds.

First, the participants compete in solving problems on various disciplines, developed by the subject commissions of MSU and published in "Moskovskii Komsomolets" newspaper and on the Internet. The completed assignments are to be sent to the newspaper editorial office by the deadline fixed. In the first years of its life, the "Conquer Sparrow Hills" competition was carried out separately at each MSU department; the list of subjects and the corresponding assignments were also published in "Moskovskii Komsomolets" newspaper whose editorial office submitted all the received assignments to the MSU.

The participants selected by MSU experts on the basis of evaluation of the correspondence round assignments were invited to take part in the on-site round which was held in April in several Russia's cities simultaneously. The on-site round was a one-day event whose participants completed assignments including tasks on different subjects (mathematics, physics, and chemistry in the case of the Chemistry Department). The on-site round winners were admitted to the corresponding MSU department without entrance exams. For example, the Chemistry Department, MSU, enrolled 9 "Conquer Sparrow Hills" competition winners in 2005, 12 in 2006, 12 in 2007, and 21 in 2008.

In 2009, the "Conquer Sparrow Hills" competition was introduced into the official Federal List of Olympiads, and since 2010 the "Conquer Sparrow Hills" federal multi-subject Olympiad has been held in various subjects (chemistry, physics, mathematics, etc.) rather than at different departments. The Olympiad laureates are granted privileges in admission to any Russia's higher education institution whose list of entrance exams comprises the subject in question. The winners of this "young" Olympiad (jokingly called "alpinists" by their course mates) are now successful students of various MSU departments. It should be noted that the contribution from the "Moskovskii Komsomolets" newspaper is not limited to the information support but includes covering the travel and accommodation expenses of those Olympiad participants who reached the final round.

The above two examples demonstrated that university Olympiads, which were initially intended as internal events pursuing exclusively enrollment purposes, have consolidated their positions and developed into nationwide intellectual contests.

The Chemistry Department, MSU, has traditionally paid much attention to schoolchildren's chemistry Olympiads of various levels, from Moscow City to the International Chemistry Olympiad. Each country has its national chemical Olympiad systems, and the top-level Olympiad (a kind of "world chemistry championship" for schoolchildren) is the International (World) Chemistry Olympiad. Based on results of national Olympiad, four top young chemists are selected by each participating country for the International Chemistry Olympiad. This chain (National Chemistry Olympiad – selection and additional special training of participants for the International Chemistry Olympiad – International Chemistry Olympiad) has been operating in the participating countries for many years.

In parallel, Russia has the International Mendeleev Chemistry Olympiad, a unique event among intellectual schoolchildren's contests. Chemistry proved to be the only natural-sciences domain for which the traditions of the former All-Union Olympiad were preserved. After collapse of the USSR, the All-Union Chemistry Olympiad has developed along two independent pathways: the All-Russia Chemistry Olympiad and International Mendeleev Chemistry Olympiad. The latter attracts schoolchildren from the former USSR Republics (Table 2). In the 38th Mendeleev Chemistry Olympiad (2004), Bulgaria and Romania were new countries, and in the 40th Mendeleev Olympiad, Macedonia. The last 46th Mendeleev Chemistry Olympiad was held on April–May 2012, in Kazakhstan.

The Mendeleev Chemistry Olympiad is held annually in April–May and consists of three (two theoretical and one experimental) rounds whose participants accomplish the same assignments irrespective of their age and grade at secondary school. The Methodological Commission of the Olympiad, comprised of researchers and teachers of the chemistry departments of national universities and schools of Russia, Belarus, Kazakhstan, Ukraine, and Moldova, undertake development of assignments in Russian or English languages [15, 16].

In the last decade, the Mendeleev Chemistry Olympiad has become a noticeable international-scale cultural event, contributing to creation of a common space for education in the participating countries. After graduation from secondary school, the Mendeleev Chemistry Olympiad winners and prize-winners are admitted to any chemistry-oriented higher education institution without entrance examinations. Over the last decade (2002–2011), only the Chemistry Department, MSU, enrolled 103 Mendeleev Chemistry Olympiad winners and prize-winners from twelve countries, which makes nearly a half of the enrollment (Table 3).

Nearly a quarter of the first-year students enrolled at the Chemistry Department, MSU, without exams in the last two years are winners of different high-level Federal Olympiads. The academic performance of those students is higher than average over the cohort, and the more so higher than that of the MSU chemistry students admitted by the standard procedure. The academic progress demonstrated by the Olympians fully confirms the validity of this strategy of attraction of gifted applicants into leading higher education institutions of Russia [17–19].

Additional Entrance Tests at Moscow State University

The set of disciplines provided for the entrance examinations at the Chemistry Department, MSU, remains unchanged (the same as before the collapse of the USSR); only the form of the examinations was modified. Examinations are conducted in four disciplines: mathematics (until recently, this was the major subject at all natural-sciences departments of

MSU), physics, Russian language and literature (in the form of an essay), and chemistry. The mathematics and essay exams were taken in written form, and physics, orally. The exam in chemistry till the late 1980s was taken orally, and in 1990 a decision was taken to change to the written exam.[2]

The MSU has consistently opposed the widespread implementation of USE as a tool (having no alternative) for selection of applicants to higher educational institutions, and until the middle of the first decade of the XXI century the MSU preserved the traditional system of competitive selection process, which has existed in our country for decades and has proven to be effective. However, in 2007, the MSU gradually began to change to a different admission procedure: The USE scores were submitted by university applicants initially for selected subjects, and in 2009, the applicants submitted USE certificates exclusively, and only three MSU departments conducted additional written tests. There was no admission test in chemistry at the Chemistry Department; a written exam in chemistry was conducted only at the General Medicine Division, Department of Fundamental Medicine, MSU. Figure 4 compares the scores gained at this exam with the corresponding USE scores in chemistry.

Certificates of the results of USE in chemistry were submitted to the Department of Fundamental Medicine, MSU by 535 applicants (in 2009, the minimum acceptable score for the chemistry exam was 33 points), of which one hundred and seventy failed to turn up; the remaining 365 applicants participated in the chemistry exam. Like with USE, the exam in chemistry was evaluated using a 100-point scale; the minimum acceptable score was 41 points.

Comparison of the USE scores with the exam scores gained by the applicants shows the following. Over 60% of the applicants received unsatisfactory ratings, among which there was a significant number of applicants who submitted high and very high USE scores (from 70 to 100). But for the additional exam, at least one half of those enrolled (out of those with very high exam scores; see Fig. 4, 2009, top right, close to the diagonal line) would not have become students: Their places would have been occupied by those who gained 80–100 USE points (though failed at the exam). In other words, high scores for chemistry in USE certificates do not always mean that the applicant has mastered the material to the degree sufficient for admission to the MSU.

In 2010, the MSU was allowed to conduct one entrance exam, additional to USE, in the major subject at each department. In July, a written exam in chemistry was held for students of the Chemistry and Physical Chemistry Departments, as well as of the Department of Fundamental Medicine. The exam was also evaluated on a 100-point scale; the minimum acceptable score was 40 points (against 33 points for USE on chemistry).

The number of unsatisfactory ratings was low, ~14%, among which there was only insignificant number of applicants who submitted high USE scores.

In 2011, 325 applicants took part in additional written entrance exam in chemistry at the Chemistry Department, MSU. Compared to the previous year, the proportion of unsatisfactory ratings markedly increased (~27%), among which a significant number of unsatisfactory ratings were accounted for by applicants who submitted high and even very high USE scores.

These data speak for themselves: They fully justify the admission campaign scenario implemented in the recent years. Practice has shown that the current system of competitive selection of applicants, which combines three essential components (USE scores, additional competitive entrance examinations, and science schoolchildren's Olympiads) is fairly productive. Obviously, if the admission to the MSU had followed the standard procedure imposed from above on the entire country, i.e., based on USE scores exclusively, several tens of places would have been occupied every year by underachievers having high USE scores (80–100).

School Textbooks and Manuals for Applicants

Russian secondary school has long experienced the need in textbooks to reflect the latest achievements of the chemical science and describe in plain language the role of chemistry in nature cognition, as well as its beneficial influence on the life of society. A team of faculty members of the Chemistry Department, MSU, has prepared a study kit in chemistry for general education and special secondary schools, edited by Prof. N.E. Kuz'menko and RAS Academician Prof. V.V. Lunin (for details, see [20]).

[2] Before the USE system was introduced, virtually all leading higher education institutions in Russia organized specifically written examinations in chemistry, whose assignments contained a significant proportion of calculational tasks.

The authors of the study kit, highly experienced in writing not only popular-scientific books, manuals, and reference guides for applicants but also textbooks for higher school, sought to create a substantive line of textbooks, in which the textbook for 11th grade would smoothly turn into higher-school courses of general, inorganic, analytical, physical, and organic chemistry. The underlying concept of this kit is one of the author's global ideas concerning specialized line of textbooks, providing consistent study of chemistry, from definition of elementary chemical concepts to systematic presentation of the most important chemical disciplines.

Along with creation of textbooks, the focus of much attention at the Chemistry Department, Moscow State University, is on preparation and publication of teaching aids for senior schoolchildren and applicants. Methodologically, these teaching aids are based on "Introduction to Chemistry," a universal manual for higher-school applicants, which went through fifteen editions [21]. It contains extensive theoretical material presented at the modern scientific level and numerous problems and exercises. The "Chemistry: The Success Formulas for Entrance Exams" monograph, in which a team of faculty members summarized the university exam and Olympiad materials of 2003–2005, is widely recognized as a popular and highly demanded publication [22]. Similar materials, collected over the last five years, were presented in a more recent publication of 2011 [23]. Those materials provide the criteria to be satisfied by Moscow State University applicants, which will not be leveled down despite all the "ups" and "downs" of the national reform of general secondary and higher education systems. Simultaneously, they serve to transfer the experience accumulated, preserve the long-accumulated bank of examination problems, and prevent the disappearance of the very genre of written entrance test in chemistry in the coming era of universal testing which received a popular bitter nickname "noughts-and-crosses." Otherwise, today's "crosses" will turn into tomorrow's "noughts" in real life.

Certainly, one article cannot cover all the issues concerning modern chemical education system. For a number of fundamental issues that were not addressed in this study, see a series of publications by MSU faculty [7, 10, 24–26].

We have considered only a few possible solutions to the problem of preservation and development of Russia's fundamental education in chemistry and demonstrated that only through close interaction of higher and secondary schools it will be possible to achieve high quality of education not only in chemistry but also in other natural sciences.

The Russian scientific and educational community should direct its efforts toward preservation and augmentation of one of the most important traditions of Russian education, its fundamentality. This applies above all to knowledge-intensive natural sciences, chemistry in the first place.

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