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Natural-Sciences Education in Secondary School in the USSR and Russia: History, Trends, and Challenges of Modernization

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Abstract—Changes in teaching natural sciences (physics, chemistry, and biology) and mathematics in secondary school in the USSR at different times and in post-Soviet era were analyzed. The trends of these changes were discussed and analyzed. The results of passing the Unified State Examination in these classroom disciplines in recent years, as well as the results shown by Russian secondary school learners in the Program for International Student Assessment in 2000, 2003, 2006, and 2009 were discussed. A conclusion was made that teaching natural sciences is deteriorating year after year. The causes of this phenomenon were analyzed, and measures to improve the training of secondary school learners on these subjects were proposed.

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It is not infrequent that the authors of Russian printed media publications dedicated to secondary school take up the position that the standard of secondary education in the USSR was very high. This position is supported by the opinion expressed by American analysts that it was at the school-desk that Russians won the competition in space development with Americans. Indeed, this fair conclusion was made by the Administration of the US, but this happened in the early 1960s, shortly after the launch of Sputnik (1957) and Gagarin's flight (1961). However, it is not all that simple when it comes to analyzing the standard of the Russian secondary school education.

Here, we considered the changes in teaching natural sciences at secondary school in our country, that took place in the period from the 1950s till the present, and analyzed measures taken by the RF Ministry of Education and Science with a view to modernizing the secondary school education system.

Secondary School Education in the USSR: The Best in the World? (1950–1991)

The highest level of secondary schooling was achieved in the USSR in the 1940s and 1950s [1]. Though widespread in that period, complete general secondary education was not at all universal [2]. For example, according to the 1959 census, there were 1 million 930 thousand people aged 17–18 in the USSR. Those were young people who received general secondary education (420 thousand), vocational secondary education (16 thousand), incomplete secondary education (372 thousand), seven-year education (661 thousand), incomplete seven-year education (209 thousand), or primary education (220 thousand); also, there were 33 thousand young people without primary education, including 5 thousand illiterates. Clearly, those data varied greatly from region to region of the USSR.

In the second half of the 1960s, the USSR leaders set a target of transition to universal secondary education of young people in order to meet the needs of economy and match the trends observed in the industrialized countries, particularly in Japan. The introduction of universal secondary education was implemented within nearly 10 years [3, 4]. In 1975, 97% of the eight-year school graduates were admitted to educational institutions providing secondary education (day-attendance secondary schools, evening and correspondence schools, technical schools, secondary vocational schools).

There appeared new industry sectors, e.g., defense industry enterprises which were staffed exclusively by

young people whose education level was no lower than secondary. Approximately 40% of incomplete secondary school graduates received secondary education courses at vocational schools.

The introduction of universal secondary school education in the USSR was underlain by the ideological concept of social equality of all Soviet people. However, people, including young learners, have different abilities, and not all of them are able to master the secondary school program in full. In this context, citing V.I. Lenin will be appropriate [5]: "When it is said that experience and reason suggest that people are not equal, in this context the equality implies identical abilities or identical physical and mental capacities of people. It is self-evident that, in this respect, people are not equal."

False interpretation of the principle of social equality and its spread to abilities had led to a major decline in the academic background of secondary school graduates of the 1970s compared to the previous two decades. Previously, those adolescents who were slow learners or did not wish to learn could terminate their school study after graduation from 7–8th grades, but in the 1970s they had to graduate after 10 (subsequently, 11) years of study. The natural result of that reform was a sharp decline in the criteria posed on learners' knowledge level. Nevertheless, a certain proportion of learners still could not master the secondary school program. To veil the decline in the academic background of schoolchildren, the conversion exams were cancelled, and the number of graduation exams was significantly decreased under the pretence of the need to reduce the "excessive load" (which term had not existed previously) imposed on schoolchildren (in the 1940s–1950s, learners had to take the conversion exams after the end of each grade, starting from the 4th grade). The "excessive load" was combated using the simplest and yet effective method of reduction of the secondary school program material. However, a part of the teaching corps, who remained true to their principles, continued to adequately assess the learners' knowledge, which gave birth to the infamous thesis: "There are no bad learners, there are bad teachers."

Shortly afterwards, a gap arose between the requirements posed on the academic background of applicants to higher educational institutions and that of ordinary school graduates. That gap was filled through the services of "couches" (private lessons teachers) whose institution was almost lacking earlier in the USSR) and without whose assistance an average graduate of mass school could not enter any prestigious higher educational institution.

The natural response to a major increase in the number of schoolchildren in senior grades, along with the general population growth, consisted in attracting more school teachers to secondary schools. A lot of poorly-trained persons who had no inclination to the teaching profession (graduates of pedagogic higher educational institutions which they entered simply because it was easier to enter a pedagogic than a technical or humanitarian higher educational institution) fell among school teachers who followed their vocation. In parallel, school teaching positions underwent mass-scale feminization due to low wages, low prestige of the teaching profession, and lack of career prospects.

Soviet School Education – the Best in the World? (The period from 1950 to 1991)

The highest level of schooling has been made in the USSR in the 1940s and 50s. [1]. Upper secondary education was of then widespread, but it was far from universal. [2] Thus, according to the 1959 census, the population of the USSR 1 million 930 thousand young people aged 17–18 years. Of those with secondary education was 420 thousand, specialists with secondary education – 16 thousand, with incomplete secondary – 372 thousand to seven years – 661 thousand, with unfinished seven-year – 209 thousand, with an initial – 220 thousand, not with primary education – 33 thousand (in the latter category was 5 thousand illiterates). It is clear that in some regions of the USSR data varied greatly.

In the second half of the 1960s. leadership of the country has set a target of transition to universal secondary education of youth, which is dictated by the needs of the economy and to coincide with the trends observed in the industrialized countries, particularly in Japan. The introduction of universal secondary education was implemented in about 10 years [3, 4]. In 1975, 97% of the eight-year school graduates were accepted to schools that provide secondary education (senior high school day, evening and correspondence schools, technical schools, secondary vocational schools).

There are entire industries, such as defense enterprises, which were completed with young staff

with the level of education is not lower than average. Approximately 40% of the graduates of junior high schools receive a course of secondary education at a vocational school.

Introduction to the Soviet Union of Universal Secondary Education

The Soviet school totally rejected methods of psychological testing of schoolchildren, which were declared a bourgeois perversion as early as 1936 in a Resolution of the Central Committee of the All-Union Communist Party (Bolsheviks). The need in training gifted children was ignored (except for education in the arts domain).

The public response to the secondary school reform consisted in the appearance in big cities of elite schools (very few in number), that offered intensive foreign language programs. They typically provided excellent training at the level satisfying the highest world standards.

Thus, the problem of decline of school standards dates back to four decades ago, when complete secondary education became universal. As a result, secondary school was forced to promote all young people (including those who did not wish to learn) till they received their graduation certificates. The academic background of secondary school graduates in our country began to deteriorate in the 1960s, and this process was not associated exclusively with the devastating effects of the current administration's activities.

Meanwhile, there was increased demand for improved teaching natural sciences and mathematics in secondary school due to science and technology progress and economy development in the country. In this situation, further attempts were made to reform the secondary school education system via chemization program announced by N.S. Khrushchev (1958–1964) (it also affected the secondary school system), polytechnization of secondary school (1958–1974), and the mathematics education reform (1970s).

The implementation of the chemization program resulted in better teaching of chemistry at the secondary school level: This subject received increased attention; secondary schools were better supplied with chemicals and laboratory equipment items; the entrance exam on chemistry was made mandatory for most technical higher educational institutions; and the competition rate in chemistry- and chemical technology-oriented higher educational institutions increased.

Table 1. Fragments of typical curricula of Soviet secondary school [2]

Subject	Number of academic hours per week		
	1950s	1970s	1985
Mathematics	64.0	60.5	60.5
Physics	14.5	17.0	14.5
Chemistry	10.5	10.0	9.5
Biology	13.5	11.0	10.5
Astronomy	1.0	1.0	1.0

As to polytechnization of secondary school, its results were a somewhat increased role of mathematics and natural-sciences education and, at the same time, a lowered status of humanitarian education. The educational reforms of the late 1950s, aimed at combining the general and polytechnic education with vocational training (production labor) in senior grades failed, with the results being a sharply deteriorated academic background and a poor level of vocational background. Schools did not have well-equipped training workshops and suffered from shortage of masters of vocational training [6]. The supply for realization of polytechnic education was far from sufficient, and the idea of imparting the polytechnic training function to secondary school remained mostly on paper.

In the 1970s, an attempt was made to fundamentally reform the content of the mathematics education. Unfortunately, this reform initiated by Academician A.N. Kolmogorov, a major modern mathematician, was also unsuccessful: Kolmogorov failed to adequately consider the negative effects of universality of education and poor teaching staff, bankrupt of new ideas.

Importantly, in the late 1960s, Lysenko's teaching, which had tragic implications for domestic biological and agricultural sciences, was finally refused state support. The content of the secondary school course and textbooks of biology was finally brought into line with classical scientific concepts.

Thus, in the second half of the Soviet era, permanent attempts were undertaken to reform the natural-sciences and mathematics education at the

Table 2. Results of USE in natural sciences for 2008 (parenthesized items are the data for 2007)

Subject	Number of examinees on indicated subject in 2008	Percent of examinees who gained indicated grade			
		unsatisfactory	satisfactory	satisfactory	excellent
Physics	59799	9.7 (12.3)	41.0 (43.2)	37.1 (32.5)	12.2 (14.5)
Chemistry	30809	10.4 (14.9)	36.8 (36.6)	34.7 (31.7)	18.1 (16.8)
Biology	74280	6.7 (9.2)	45.5 (43.5)	34.9 (33.4)	12.9 (13.9)

secondary school level, which were of little success for the most part. Nevertheless, despite significant reduction in the academic background of Soviet secondary school graduates of the 1980s compared to the 1960s, the national secondary school held fairly good positions in the world (it should be noted that no statistically significant comparison of the academic background qualities of Soviet and foreign schoolchildren was carried out at that time).[1]

However, it is a well-known fact that, as of the late 1970s, there were only 0.2% illiterate persons among the population of the USSR against 0.5% in the US and Japan, 0.7% in the United Kingdom, and 2.3% in Europe as a whole.

To conclude the discussion of the 1950–1991 period, we present fragments of typical Soviet secondary school curricula (Table 1), in which a serious place was given to mathematics and natural sciences.

Thus, despite a number of shortcomings, the natural-sciences education in the Soviet secondary school was kept at a fairly high level. This is also evidenced by the fact that the number of the academic hours assigned to natural sciences remained unchanged for several decades.

Secondary School Education in the Post-Soviet Era (1992–2010)

Perestroika and the subsequent collapse of the USSR have resulted, among other things, in destruction of the Soviet secondary school education system, which fact had dramatic implications for secondary schools in Russia:

– sharp decline in the prestige of education, especially, of natural-sciences education;

– liquidation of a common space for education; decentralization of secondary school education;

– emergence of school curricula assigning a minimum number of academic hours to natural sciences;

– unfair competition among multiple parallel textbooks;

– optional graduation examinations in natural sciences;

– universal elimination of laboratory practical courses from secondary school curricula;

– chemophobia actively promoted by the media;

– mysticism, obscurantism, and pseudoscience on TV and the Internet, in newspapers, and in radio programs; and

– active promotion of religion and, hence, of dogmatic thinking.

In the late 1980s–early 1990s, the trend to weakening of the traditionally strong desire for education was preserved in people of our country. In 1989, only 10% of secondary school graduates showed interest in further learning. In young people's questionnaires, education was pushed away from advanced positions by pop music, money, friendship, love, sex, power, etc. State regulation of education was conducted in a hit-and-miss manner, by `trial and error.

The major changes that occurred in the first post-Soviet years were deideologization of education and elimination of a state monopoly thereon. In the USSR, secondary school was part of the system of ideological institutions, whose activities were directed and controlled by the Central Committee of the Communist Party of the USSR and by local party bodies to a greater extent than the activities of many other systems. In these matters, there was no ambiguity: The

[1] It is not a rare event that, today (like decades ago), the authors of some printed media publications assert that the school standards in Russia are high, as allegedly validated by the achievements of Russian participants of international schoolchildren Olympiads in different subjects. In fact, these are the proper system of selection and good pre-training of the team members behind the relatively high places won by our schoolchildren. However, this fact has only indirect relation to the ordinary school. Moreover, the problems suggested to schoolchildren at top stages of Olympiads have little to do with the secondary school program. International Olympiads are a kind of a "sporting competition," and the achievements demonstrated by individual learners at high-level Olympiads provide as little evidence of the achievements in secondary school education as do victories of our Olympic athletes of sports training in the general population.

Constitution of the country cemented the principle of the Communist Party's leading role in running the country, whereby the Communist Party's resolutions were made mandatory.

Some positive trends observed since 1991 can be mentioned, e.g., local authority's participation in secondary school education, greater autonomy of educational institutions, and collaboration of teachers, learners, and parents. At the same time, the lack of adequate funding caused highly qualified teachers to drift from secondary school. The declared democratization of education remained mere wishful thinking. There still exists a system of centralized management of education and, as a consequence, a cumbersome bureaucracy.

In the post-perestroika period, a unified education system was replaced by its opposite, a multitude of autonomous programs, curricula, and textbooks, in which situation teaching secondary school disciplines was provided in a variety of ways.

In the late 1980s, complete secondary education was no more universal, though remained free and generally accessible. As to subjects to be taught, secondary schools could reject the state minimum of mandatory subjects.

In the early 1990s, a nine-year system of mandatory and free education was introduced, which did not provide guarantees of gaining free complete secondary education by all learners. Thereby, secondary school education was automatically switched to a two-level system in which no social protection measures were envisaged for 15–16-year adolescents, with the result being that, in 1996, 10% of Russians neither studied nor worked.

The RF Law on Education of 1992 introduced state educational standards which envisaged mandatory federal and regional minima. The new version of the law provides generally accessible and free complete secondary education, with no less than 10% of national income to be spent for educational purposes. In reality, this proportion lies within 4–5% only, contrary to the law.

What is the Net Result?

Let us sum up the twenty years of continuous reforming of the secondary school education system in Russia. For analyzing the standards of natural-sciences education in Russia, we will take the official data on the Unified State Examination (USE) scores gained by graduates in 2007 and 2008 (Table 2). In 2008, there were ca. 1 million secondary school graduates (it should be noted that the evaluation criteria were relative rather than absolute; they were determined depending on their results of already finished examinations).

The plain truth is that the mastery of the secondary school course of physics, chemistry, and biology was achieved by 3, 1.5, and 3.5% graduates, respectively (those who were scored good and excellent).

In 2009, the USE was declared compulsory; USE exams were taken by 995295 secondary school graduates of 2009 and previous years. Unfortunately, we failed to find online information about the number of graduates scored good and excellent on natural sciences and, therefore, restricted ourselves to the average score data.

The examination in physics was taken by 205400 graduates (20.4% of the number of prospective applicants); the average test score was 48.9 (out of 100); 6.2% failed to get the lowest passing grade (were graded unsatisfactory). The chemistry exam was taken by 7.4% of graduates and passed with the average score of 54.3 (like in the case of the exam in physics, this corresponds to the "satisfactory" grade); 9.5% failed, which fact, along with low average scores, arouse concerns. The biology exam was taken by 15.5% of graduates and passed with the average score of 52.3, which is slightly better than "satisfactory" (51 points); 8% failed.

Thus, in 2009, the average score in all natural sciences, gained by graduates, corresponded to the "satisfactory" grade. As to knowledge level on these subjects, possessed by those who did not take the respective exam, it can only be guessed at [7].

Thus, despite numerous debates initiated and resolutions taken, the domestic teaching at the secondary school level has been increasingly aggravated over the last half-century [1], especially in the last decade. The faculty of higher educational institutions, including Moscow State University (MSU), note that the academic background of graduates tends to decline from year to year.

By way of example, we will cite the opinion of V.V. Zagorskii, Cand. Sci. (Chem.), Dr. Sci. (Pedag.) from the Advanced Educational Scientific Center, Moscow State University (AESC MSU), whose

students are about three hundred schoolchildren in their senior grades from different parts of Russia, having outstanding abilities in natural sciences: "Unfortunately, the academic background of AESC MSU applicants is ever declining; they solve with difficulties those problems that were considered easy previously. The task of graphically representing the answer to a question even from the "elementary chemistry" course is completely intractable for applicants! The AESC MSU seems to skim the cream off, but this cream is becoming ever more diluted ..."

The opinion expressed by L.G. Lunyakova, Senior Researcher at the Institute of Social and Economic Studies of Population, RAS, is as follows: "In Soviet times, there was a fairly effective system of identification, selection, and training of gifted children who were socialized in free special educational institutions for talented children under the guidance of highly qualified professional teachers. Also, children could develop their creativity in free groups at houses and palaces of pioneers, community centers, summer camps, and institutions of additional education. The prospect is cheerless: Soon we will sense the lack of not only skilled workers but also of members of the intellectual and artistic elite ..." [8].

Today, an effective system of educational work with schoolchildren is operative only in a few higher educational institutions, in particular, at MSU.

Personal and subjective assessments of the current situation are many, but there exist assessments based on some different criteria. One of them is the Unified State Exam, whose scores, though unsuitable as a truly objective criterion for assessing the standard of education (due to corruption at different levels, as well as to "local patriotism"), still allow making some generalizations.

As noted above, the analysis of the USE scores gained by secondary school graduates in 2009 shows that the physics, chemistry, and biology courses were mastered (with "good" and "excellent" scores) by a few percent of all graduates solely. According to the Head of the Federal Service for Supervision in Education and Science (Rosobrnadzor) L.N. Glebova, the situation improved slightly in 2010. Based on scores gained in 2010, it was concluded that graduates demonstrated a higher academic background. There was increased number of graduates who showed intermediate results (up to 60 points). Also, the number of graduates who gained high scores (from 80 to 100) was stabilized. Overall, in 2010 the number of graduates who gained a score of 100 points at a USE exam was higher than that in the previous year (recall, however, that the "value" of a USE point is determined only after the exam is finished).

Also, one must be very careful about the results of those graduates who gained 100 points. For example, in recent years the competition rate at the Department of Fundamental Medicine, MSU (which in one of the most prestigious MSU departments), ranged from 6 to 11 persons per place; more than half of the competitors were medalists and/or applicants who submitted very high USE scores. To prevent "random people" from entering the MSU, the Department of Fundamental Medicine (like the Chemistry Department) conducted an additional written exam in chemistry (this is a privilege enjoyed by MSU). Comparison of the USE scores with the results of that additional examination [9, 10] revealed a stunning result: A significant number of unsatisfactory ratings were received by applicants who submitted high and very high (80 to 100!) USE scores. Thus, it is apparent that high USE scores on chemistry (and, possibly, on other subjects) by no means suggest a mastery of the material by applicants, at least to the degree sufficient for them to be admitted to the MSU.

A useful tool for assessing the success of a national system of secondary education is provided by the Program for International Student Assessment (PISA) [11]. This is an international study that was launched by the Organization for Economic Cooperation and Development (OECD) with the aim to evaluate education systems worldwide, whose focus was on 15-year-olds' capabilities in reading, mathematics, and science literacy. The PISA study was first performed in 2000 and since then has been repeated every three years. It assesses how far students near the end of compulsory education have acquired some of the knowledge and skills that are essential for full participation in society. "The study does not test how well a student has mastered a school's specific curriculum; PISA looks at students' ability to apply knowledge and skill in real-life situations. This reflects the current trends in the evaluation of educational achievement" [11].

In 2000, 32 countries participated in PISA studies, including the principal countries of Europe, North and South America, Australia, and New Zealand. In Russia, the RF Ministry of Education and Science and the Institute of General Secondary Education, Russian

Academy of Education, were involved in PISA-2000. Subsequently, Russia participated in PISA studies of 2003, 2006, and 2009; the RF National Training Foundation and the Center for Education Quality Assessment (at the Institute of the Content and Methods of Teaching, Russian Academy of Education) were also among the participating institutions. Below, brief comments on the results of those studies are provided.

PISA-2000. In the reading literacy study, Russia scored one of the lowest, 27–29th out of 32 (the place uncertainty is associated with the measurement error). A low level of scientific literacy (26–29th place) did not satisfy the basic requirements set forth by the world's leading experts in the field of natural-sciences education at the secondary school level [12]. One of the reasons is that, in Russia, schoolchildren are offered only very few interdisciplinary tasks; they successfully accomplished tasks on reproduction of knowledge in simple situations but found it difficult to use this knowledge in realistic situations. In Russian secondary school, learners do not receive training needed by them to address issues at the intersection of multiple disciplines and to handle nonroutine situations, to appeal to their own experience, and to link the desired solution with the real-life situation. Experts compared the results of Russian learners with those of participants from other countries and concluded that the Russian education priorities differ from those dominating in the OECD countries [13].

PISA-2003. Russian participants showed below the average results: 25–30th place. The mathematics literacy of Russian schoolchildren was scored the 29–31st place. This may be indicative of inadequate attention paid by Russia's secondary school to practical application of knowledge, rather than of poor training in mathematics, received by Russian schoolchildren.

The conclusion made by the Center for Education Quality Assessment was as follows [14]: The materials of international comparative studies are not in line with, and sometimes are contradictory to, traditions of the Russian education system; middle school is the weakest link of Russia's general education system.

PISA-2006. In all domains, the Russian participants displayed results that, as previously, were statistically significantly lower than the international average results: 33–38th place in science literacy, 32–36th place in mathematics literacy, and 37–40th place in reading literacy. Compared to previous studies, the scores on mathematics were nearly the same, and those on reading, statistically lower.

The assessment of science literacy in 2006 showed that a large proportion (22.2%) of Russian learners did not possess even the basic knowledge level. Notably, the results demonstrated by American participants were nearly identical, on the average. However, this still constitutes an issue for concern to Russia, by contrast to the US where the disadvantages of the educational system are compensated by inflow of well-educated immigrants.

The Russian participants still experienced difficulties with those PISA tasks whose accomplishing required the use of interdisciplinary connections or those inviting them to read a text, compare different viewpoints on a particular problem it described, and justify their own position. Used to get ready information and ready solutions, many of Russian schoolchildren do not possess critical assimilation skills; it is difficult for them to accomplish nonstandard, nonroutine, tasks.

Again, these are average results shown by learners from various schools across the country. Certainly, out top schoolchildren possess all the necessary competences, as evidenced by the results of numerous subject and multi-subject schoolchildren Olympiads.

PISA-2009. Like previously, the average score of Russian participants was significantly below the average level of schoolchildren from OECD countries: 37–40th places (out of 65 countries). Only 4.2% demonstrated a high level of science literacy.

The overall result of PISA-2009 study was summarized as follows: "The science literacy scores gained by Russian schoolchildren did not reveal any changes relative to the previous study in terms of both the average results and the science literacy level distribution for learners: 479 points in 2006 against 478 points in 2009." Russian schoolchildren still have poor, or totally lack, skills for "searching information based on key words; analyzing the research process; preparing forecasts using the data available; interpreting scientific facts and research findings; identifying scientific facts and research findings underlying the evidence and conclusions; interpreting graphical information; and conducting assessment calculations and estimations" [15].

As to the US, where schoolchildren of the same age did not demonstrate significantly better results, it

should be mentioned that the secondary education system in the US is aimed at achieving socialization for all learners and at providing an opportunity to move forward indefinitely to those who wish and can do it. "The goal pursued by the secondary school in the US consists, at a minimum, in training a person adapted to the society, who is ready to live for the society's and his/her own benefit, and hence with pleasure, and at a maximum, in raising another Edison or James Lovell, "Apollo 13" captain. Naturally, different schools have different possibilities, but an ordinary good school can achieve this goal" [16].

Ignored by the RF Ministry of Education and Science, the PISA results have not been subjected to broad public discussion and have not been responded to by far-reaching actions.

What is Meant by Modernization and Who are Modernizers of Secondary School Education?

The development of the ideology of reformation or, as we now say, modernization of education in Russia is undertaken by the "guiding center," the State University – Higher School of Economics, rather than the RF Ministry of Education and Science and the Academy of Education. A brochure [17] prepared by the State University – Higher School of Economics experts presents its high officials' vision of all the main directions of modernization of education.

A question naturally arises: why economists, rather than experts in the field of education, are charged with development of an education development program? The only possible answer is that the state authorities are interested primarily in the sole aspect of the problem: how to make the education system maximally inexpensive and how to transform education into "educational services" to be provided preferably on a paid basis.

This sad conclusion is supported by the reformers' plans that are being actively promoted now: introduction of Governmental Individual Financial Obligations (which will inevitably lead to closure of all small schools which are tens of thousands in number in Russia); extended paid education; and a two-level higher education system (by contrast to most foreign countries, in Russia a person with a bachelor's degree, who is essentially an understudied specialist, is treated as a higher education professional, and obtaining a master's degree is regarded as a kind of getting the second higher education which is to be provided on a paid basis according to the existing Russian laws).

Following the Western models, the Russian education reformers introduced the notorious USE system; the focus of their current activities is on providing specialized (profile) training in secondary school, starting from 9th grade, with physics, chemistry, and biology courses to be replaced by one subject, natural sciences.

Below, we discuss the above-mentioned "innovations" in more detail.

The Concept of Profile Training

The administratively approved concept of profile training in senior grades of general school (from here on, the Concept) [18] implies introduction of specialized (profile) training at secondary schools in Russia in the coming years. At least two arguments in favor of this system are provided: satisfying the demands of those schoolchildren who show high interest in selected subjects and overcoming the infantilism of adolescents who must assume the responsibility in the choices and decisions they make (in other words, ensuring earlier socialization of young people, which issue is highly topical in the present economic situation of Russia).

At the same time, certain counterarguments cast doubt on the concept of profile training. For successful implementation of the planned school profilization it would be very useful to study and summarize the experience of schools that have been practicing this form of training for a fairly long time and, therefore, can tell those who will enter this path what can lie ahead.

In the 1960s, the concept of "differentiated training" was considered to be nearly an attribute of bourgeois society, for which reason organization of profile training in schools and individual classes was stiffly opposed by local education authorities; there was a need in getting permission from Ministry of Education officials for establishment of schools providing intensive study of selected subjects. For example, specialized chemical classes at Moscow secondary school no. 171 were established in 1974 on the initiative of Academician of the Academy of Sciences of the USSR I.V. Berezin, Dean of Department of Chemistry, MSU, and due to the personal assistance provided by M.A. Prokof'ev, the then Minister of Education of the USSR, Corresponding Member of the USSR Academy of Sciences, Head of Chair, Chemistry Department, MSU.

In the late 1960s, several boarding schools providing the natural-sciences training were founded in the USSR, in particular, that at AESC MSU by Academician Kolmogorov's initiative. This institution has existed till today; it provides multiple-profile training: in physics and mathematics, chemistry, and biology.

Currently, in Moscow there are several schools offering intensive study of natural sciences, including chemistry: secondary school no. 1543, gymnasium no. 1567, lyceum no. 1303, secondary school no. 171, and some others. Thus, profile training is not a new phenomenon to our country; profile training programs, in particular, those in chemistry, are offered by many schools.

The first problem faced by organizers of profile training is that of staffing, i.e., of recruitment of teachers able of teaching profile subjects effectively. Clearly, profile training can be successfully delivered only if profile subjects are taught by highly qualified teachers. In this connection, a question arises, whether every mathematics, physics, chemistry, or biology teacher is able today to solve problems suggested to schoolchildren at competitions and Olympiads or to demonstrate them how academic knowledge can be transformed into practice?

In gymnasium no. 1567, the teaching staff (which has been formed over decades) include now seven Candidates of Sciences, 6 Honored Teachers of Russian Federation, 22 Exemplary Workers of Public Education and Honorary General Education Workers of the Russian Federation, 14 Soros Teachers, and 5 winners of the RF Presidential Award. Out of 67 gymnasium teachers, 29 are teachers in the highest qualification category. Over 200 works were published by gymnasium's teachers in the last few years. Nearly one-third of the teaching staff are male teachers; a significant proportion of teachers are graduates of gymnasium no. 1567.

At school no. 171 and AESC MSU, profile training is provided by MSU staff, Candidates and Doctors of Sciences, who are actively engaged in research activities. In lyceum no. 1303 (Moscow Chemical Lyceum) the implementation of the profile training program in chemistry is undertaken primarily by staff-members of the Institute of Organic Chemistry, Russian Academy of Sciences.

The Concept developers show some degree of understanding of the importance of staffing issue: One of the Concept domains is dedicated to training, skills improving, and retraining of teachers for schools providing profile training. However, experience suggests that, with the skills improving system existing today in our country, it is largely impossible for an ordinary teacher to acquire the qualification satisfying the needs of profile training. The reason resides not so much in the drawbacks of the retraining system (which naturally has certain drawbacks) as in poor qualification of our "average" teacher. Teaching is a mass profession, which means that teaching staff cannot be entirely represented by "outstanding" teachers. There is no direct correlation between the success of a person in pedagogy and his/her being Candidate of Doctor of Sciences. It is an illusion to believe (like officials do) that a master's degree suggests a person's aptitude for profile training-based teaching activity. A teacher of a profile subject should have not only an in-depth knowledge of his/her subject but also a command of teaching methods and experimental techniques and a good grasp of pedagogic knowledge and psychology aspects. Due to a heavy academic workload placed on an ordinary, "average" teacher, he/she does not always have an opportunity (and sometime desire) to get serious retraining to satisfy the profile training criteria.

Another problem is associated with the choice of the training profile to be made by 9-graders. According to the Concept developers, 15-year-olds can make a well-informed choice of training profile: "Near the end of their 9th year of study, 70–75% of 9-graders make their vocational choice," and only a quarter of senior graders adhere to the traditional position and wish "to acquire maximally deep knowledge of all school subjects (chemistry, physics, literature, history, etc.)."

Any teacher is aware of the fact that there can be only few isolated cases of 9- and even 11-graders able of making a well-informed vocational choice. Certainly, mathematical abilities of children are often expressed at early age. Quite often, the vocational choice for children is made by their parents, or it can also be influenced by a teacher enthusiastic about his/her subject, as well as by relatives and friends, both of the same age and somewhat older. However, the vast majority of schoolchildren are unable of making well-informed decision at the age of 15.

This statement can be supported by the results of an opinion survey carried out among schoolchildren of 16 secondary schools in Moscow, who attend an inter-school training complex [19]. Their interests and

inclinations were distributed virtually evenly among five areas of activity (according to E.A. Klimov's classification, person–machine, person–symbol, person–person, etc.). However, when these same schoolchildren were asked to make a choice among the nine study profiles proposed, ~75% of the respondents chose the economics profession because of its high prestige, while low-status pedagogy and sewing completed the list of the profiles. Hence, the choices made by schoolchildren clearly contradicted their interests and inclinations.

No less convincing are the data on choices made by schoolchildren in chemistry-oriented schools, who have a significantly higher, compared to the average level, motivation to study the profile subject taught in such schools. Only 70–80% of graduates of the chemical classes of school no. 171 typically enter chemistry-oriented higher educational institutions. The preferences of the remaining graduates undergo significant modifications: They tend to choose the professions of physicians, mathematicians, physicists, builders, journalists, and even filmmakers.

The choices made by about a quarter of ASESC MSU graduates do not correspond to their study profile, despite the fact that, when entering the ASESC MSU near the end of the ninth grade, they seem to have made their vocational choice.

The Concept suggests that the problem of choosing the study profile can be solved by pre-profile training to be offered in the second stage of the general education system via introduction of elective courses. The modernizers of the national school are planning to organize 9-graders into several groups in which the necessary vocational guidance information will be provided to them. The experience with multiple-profile gymnasium no. 1567 suggests that such approach is reasonable on the whole, but the problem lies, again in acute deficiency of high-level teaching staff.

To prevent choosing a wrong profile by ordinary school learners, the curriculum of each profile should be designed in a way such that learners could change the profile without prejudice to themselves, if they get disappointed in their choices. Hence, the curricula for different profiles must contain the same invariant core component. Specifically this aspect is not provided by the Concept which states that "any form of profilization of study leads to reduction of the invariant component" [18]! In curricula for humanities, the individual physics, chemistry, and biology courses are replaced by an integrative and abridged course of natural sciences, which prevents learners from changing to a different study profile.

Profile training should be provided only to those schoolchildren who have made their vocational choice near the end of their 9th grade, and this should be done without compromising the teaching quality of general subjects. A secondary school graduation certificate issued to graduates of profile training programs should allow them to be admitted to any higher educational institution on a competitive basis.

The third problem of profilization of secondary education is that of providing profile-based training in rural areas and small towns. Clearly, small rural secondary schools cannot in principle offer multi-profile training programs. Even in small towns there is no possibility of creating a network of schools to cover all the profiles planned. The most that can be done in this regard is to establish two or three schools that will offer profile training programs in one town. In this connection, it should be reminded that rural schools and schools in small towns constitute nearly a half of all the schools in Russia.

Funding constitutes another important problem of profile-based education. In order not to remain "ink on paper," profilization of secondary school education will inevitable require attracting significant financial and material resources. The costs of teachers retraining and creation of the material base for profile schools, as well as payments for additional teaching load, including the teaching of vocational guidance and elective courses, will be very significant. Calculations carried out by the Moscow Engineering Physics Institute for the lyceum they patronize [20] showed that, compared to ordinary school learners, providing training to one learner of a specialized physics/mathematics class requires additional ~5 thousand rubles per annum.

Methodological problems faced by schools providing profile training deserve special consideration. No systematic scientific and pedagogic studies have been conducted to cover all the profilization aspects [21]; the administrative decisions were taken before appropriate methodical studies had been undertaken. Still, there are publications analyzing the experience at schools and classes offering intensive study of selected subjects. According to the existing methodological guidelines for biology/chemistry classes, the following prerequisites must be met when implementing this profile training:

(1) Supply. There is a need in appropriate items for conducting laboratory practical classes in full volume (laboratory equipment, glassware, chemicals).

(2) Special program. Experience suggests that there exist two polar options for profilization in chemistry: "deep diving" into one of special chemical disciplines and learners' participation in research work on the basis of a research institution and, alternatively, expanded scope of intensive study without learners' engagement in research work. Both options have been successfully implemented; each has its advantages and disadvantages, but their comparative analysis still remains to be carried out.

(3) Adequate textbooks. Profile training classes need specialized textbooks. As regards chemistry, this problem is largely solved; in any case, an enthusiastic teacher can find a combination of tutorials that will satisfy the profile training needs, e.g., "Inorganic Chemistry" by N.S. Akhmetov, "Organic Chemistry" by E.E. Nifant'ev, "Organic Chemistry" by V.M. Potapov, and "Elements of Chemistry" by N.E. Kuz'menko.

(4) Research project activities. Profile training must be combined with teaching elective courses and individual research project activities of learners. Elective courses can help them expand and enrich their knowledge of special subjects and also can fulfill a different (psychological, cultural, etc.) function. For example, various elective courses are very popular in gymnasium no. 1567 [22, 23].

Thus, the Concept clearly suffers from a number of defects. Above all, the universal, global character of profilization is objectionable. Considering the above-discussed problems, universal profilization seems unrealistic. Rural and small schools, as well as schools in small towns, essentially fall out of the profile training-based education project. In big cities profilization is limited by deficiency of highly qualified teachers. Naturally, there is a need in profile training-based education, but its forced introduction, without real support provided, is a blunder, which will inevitably lead to decline in the academic background of young people in Russia.

The reduction of the core component, envisaged by the Concept, is nonsense. Through introduction of the Concept, the Russian secondary school would lose fundamentality and look like an American school. The natural-sciences cycle disciplines (physics, chemistry, and biology) should be included in curricula of nearly all profiles, but textbooks on these subject need to be fundamentally revised [24].

According to the RF Ministry of Education and Science, in the coming years there will be at least 30% general education (non-profile) schools with integrative profile. In our opinion, this proportion must be much higher, since, today, no more than a quarter of schools can actually offer profile training programs.

Replacement of Physics, Chemistry, and Biology Courses by a Natural-Sciences Course

The planned elimination of individual courses of natural-sciences subjects in senior secondary school is unacceptable. Even today, due to minimization of the academic hours assigned to the physics, chemistry, and biology courses in the secondary school curriculum the academic background of secondary school graduates is at the critical level. In can be presumed that, five years after this "innovation" (the introduction of the natural-sciences course) will be implemented, secondary school graduates will believe that, in winter, the Earth is farther from the Sun than in summer, that agriculture should abandon chemical fertilizers, and that the skills developed during the life of an animal or a human are hereditary... The situation is aggravated by the fact that training the staff able of teaching the natural-sciences course, who are knowledgeable in physics, chemistry, and biology at least in the volume provided to students of today's pedagogic higher educational institutions, is an utopia (see, e.g., [25]).

The Concept treats physics, chemistry, and biology as non-profile subjects to be replaced by an integrative course of natural sciences. Below, we will attempt to analyze possible ways to implement this replacement and assess its implications.

What do the developers of the program read into the "natural sciences" and what is the content of this course [26]? According to the basic curriculum versions proposed in the Concept, a total of 210 academic hours is to be assigned to the natural-sciences cycle in the framework of humanitarian or socioeconomic profiles in 9th and 10th grades (which is equivalent to 70-hour courses of physics, chemistry, and biology, one hour in a week for each of these subjects). Because teaching one-hour courses is completely inappropriate from the didactic viewpoint, the Concept considers a two-hour version of the course, though during only one academic year.

The Concept presumes that, at first, the natural-sciences course will be taught by traditional subject teachers whose place will afterwards be taken by persons of wide reading with encyclopedic knowledge, who will teach the entire course of natural sciences. The implementation of the integrative learning process should be started with studying topics such as transformation of energy in living and nonliving nature, stochastic processes and probability patterns, evolution (at physical, chemical, and biological levels), global environmental problems, etc. [26].

The main learning objectives for the natural-sciences course are defined by the Concept as follows: "get at least superficial knowledge of natural sciences-related information (media reports, Internet resources, popular science articles) and, possibly, its critical analyzing skills; gain some insight into the natural sciences-based method as a knowledge gathering and justifying tool; and acquire the ability to apply the knowledge gained to solving practical problems (medicine, safety, energy saving, ecology)" [26].

Thus, the basic skills to be acquired by graduates can be formulated as the following requirements to their academic background: having grasp of current scientific notions, being able to handle natural-sciences information, having command of some elements of research method, and being able to practically use the knowledge acquired [26].

One cannot but agree with the goals declared. Education does not imply a certificate of graduation from an educational institution; this is a body of knowledge, skills, and competences to be acquired, possessed, and actively used by learners upon completion of their study. Today, the ability to apply the knowledge acquired in secondary school for critically evaluating the information flows (often false) coming from the media, especially, from the Internet, is of the utmost importance.

The country is literally flooded with mysticism. Every day newspapers and magazines, as well as radio and television programs, provide bulk false or intentionally misleading information in order to "attract readers, listeners, and viewers." "Sensations" such as, e.g., UFOs, "snowman," living dinosaurs, aliens, psychics, etc. alternatively slacken and grow warm. This is so much the case that, when one of the authors of this study suggested a problem on Foucault's pendulum to the participants of the Intellectual Marathon for Moscow Schoolchildren, their answers include the following: "the rotation of pendulum is due to a bioenergy pulse sent by the person who hung it." A question arises as to how many graduates do actually know what kind of pendulum is this and which phenomenon does it demonstrate?

Another example can be found in referring to Darwin's "mistakes" by supporters of creationism, who criticize the theory of evolution of life on the Earth, being unaware of the fact that the traditional Darwinism dates back to the middle of the XIX century and belongs to the history of biology. In those times the first attempts were made to explain the origin of species and there was not even a hint of modern genetics. The denial of Darwinism results, e.g., in a sort of "monkey trial" in St. Petersburg at the suit to the RF Ministry of Education and Science, filed by a schoolgirl who, together with her father, clamored about the teaching of evolution in secondary school. A recent opinion survey revealed an incredible fact: Not a few people in Russia believe that the Sun revolves around the Earth!

It must be acknowledged with a bitter feeling that, even today, when full courses of natural sciences are taught in secondary school, a very large proportion of Russia's population who graduated from secondary school in their time are unable to critically analyze the incoming information. It is not hard to guess that, after the physics, chemistry, and biology courses would be reduced, the degree of ignorance would increase dramatically.

The natural-sciences courses and the corresponding textbooks for ordinary secondary school undoubtedly have to be revised with a view to eliminating the excessive theoretical information needed by specialists only and to bringing the content closer to the real context [24]. However, all the three major natural sciences and mathematics should be studied seriously.

It is not infrequent that, in discussion of modernization of education, the need to reduce the natural-sciences courses in secondary school is explained by the fact that, in the USSR, these courses were supposedly excessive, as dictated by the demands of the hypertrophied military-industrial complex in those times. In this respect, a highly illustrative example can be found in the experience of Japan and of Japan-centered countries (Taiwan, South Korea, etc.), where the secondary school courses of physics, chemistry, and biology are studied more extensively and profoundly than in the USSR. Maybe, this is

specifically one of the reasons for technological progress achieved by Japan? Or Japanese secondary schools also experience the pressure from the military-industrial complex?

Another (quite obvious) argument in favor of an integrative natural-sciences course, provided by the modernizers, is that, due to artificially subdividing the one and undivided nature into weakly interconnected individual domains to be studied at the secondary school level, schoolchildren in their senior grades gain a false idea of the occurrence of sharp boundaries separating physics, chemistry, and biology. Indeed, nature is one and undivided; many teachers underemphasize the existing interdisciplinary connections, and secondary school programs certainly need to better coordinate individual natural-sciences courses (which regards particularly the order in which specific topics are to be studied). However, to overcome these shortcomings it is necessary to improve teachers' qualifications and revise natural-sciences programs, rather than reduce them to a single secondary school subject.

Clearly, widespread introduction of the new subject in secondary school will require adequate programs, textbooks, and teachers' qualification. Today there are no successful programs and especially no good textbooks on this subject, but this problem is solvable in principle, e.g., via revising and adapting for senior grades one of the textbooks used in teaching the "Concepts of Modern Natural Sciences" higher school course. Nearly twenty tutorials of this type, which strongly differ in quality and volume, were published in recent years; in our opinion, a decent tutorial still remains to, and can, be developed in the future.

A different situation arises with teachers' qualification. Today, schools cannot be staffed by teachers able of teaching an integrative natural-sciences course. Moreover, raising the question of their training in today's pedagogic higher educational institutions is unrealistic. Even graduates of the Physics Department or the Chemistry Department, MSU, who have a perfect knowledge of the program, only in rare cases are able of teaching the integrative course in secondary school. One can hardly imagine a teacher (or a common person) equally knowledgeable in physics, chemistry, and biology (certainly, not at the secondary school level).

The problem with today's teaching corps is that most of them teach everything they know (we will put aside those teachers who do not have the knowledge of the secondary school program in full measure). At the same time, there is an old wise pedagogic saying: Teaching is fully valid only when a teacher presents to learners no more than a third of what he/she knows himself/herself, while the rest remains in his/her head for reinforcement purposes. Do many subject teachers satisfy this criterion? According to our observations, they constitute a small proportion of the total mass of teachers. Only in rare cases can a chemistry teacher calculate the equilibrium constant for any reaction using the data from the table of thermodynamic quantities or carry out synthesis of an organic compound of medium complexity, if provided with all the necessary equipment and chemicals. Do teachers know how to use reference books or find relevant information on the Internet? Inadequate scientific qualification of our teachers can easily be seen through publications in scientific and methodological journals. For example, the majority of publications by chemistry teachers are dedicated to special issues of teaching methods and often contain factual errors, thereby indicating a low competence level of their authors.

This is not surprising. Most of our chemistry teachers are graduates of the biology/chemistry departments of pedagogic higher educational institutions, who have "learned" (mostly on paper) the entire chemistry and biology courses, but this is unrealistic: No productive training can be provided to students in two disciplines that are fairly distant from each other as are chemistry and biology. First, any serious knowledge of these two voluminous and multifaceted areas of knowledge cannot be achieved in five years of study. Second, the primacy of descriptive biology leads to presentation of predominantly descriptive part of chemistry, which does not match reality and distorts the students' idea of chemistry.

As to the physics course, its providing at pedagogic higher educational institutions in a volume sufficient for further teaching in secondary school seems even less realistic.

Thus, training of teachers possessing encyclopedic knowledge is a utopian idea. Consequently, teaching the natural-sciences course, planned by the Concept, will be divided among three subject teachers, and the introduction of the natural-sciences course will be reduced in reality to the fact that this name will be assigned to a mishmash of physics, chemistry, and biology. This course will be taught by teachers of these subjects, one after another. The program will be

greatly reduced in the volume, the teachers' responsibility for their corresponding subjects will decrease, and the course will turn into a haphazard conglomeration of different knowledge components.

One gets a painful impression that the reformers (Ya.I. Kuz'minov, V.A. Bolotov, and the former and current RF Ministers of Education and Science) are concerned exclusively with replacing the education system existent in the USSR and Russia by that of the US and Western Europe, rather than with strengthening and improving the education to be provided to Russian youth. Hence follow the USE, profilization, diluted courses of natural sciences, and individual learning trajectories through which "too hard to learn" basic disciplines can be replaced by something like the "history of sports."

Individual courses of chemistry, physics, and biology must be taught, as previously, at all general education secondary schools and at schools offering intensive study of physics and mathematics and natural sciences, as well as at those with agrotechnological, industrial and technological, and other profiles. The programs of the courses should be designed in such a way that physics, chemistry, and biology courses be mandatory, rather than elective for all learners (without exception), who will have to take graduation exams in these subjects (to prevent a decrease in their study motivation).

Unified State Examination

There has been much discussion about the negative aspects of the Unified State Examination. The major harmful effect of USE consists in that it focuses the secondary school teaching on couching the young generation for USE tests rather than on assimilation of basic science knowledge and potential development.

One of arguments in favor of introduction of USE is that it prevents corruption in admission to higher educational institutions. Some people believe that USE has already demonstrated its effectiveness in fighting this phenomenon and that it allows a more unbiased assessment of results and provides better opportunities to equate the rights of all applicants, which statement is questionable. Clearly, the scope for possible corruption in higher school is much narrower than that of (possible) corruption in all Russian secondary schools, if for no other reason than because, in Russia, there are over 50000 secondary schools and less than 700 state higher educational institutions of which only 150–200, according to the RF Minister of Science and Education, provide quality education and, therefore, could expect fairly strong competition for admission. Also, the prestige of higher education and the demographic situation in Russia are currently at a level such that not every higher educational institution may vaunt success in achieving high competition rates.

The reality is that schoolchildren taking USE exams have unequal chances for success, which is absolutely unacceptable! In particular, some schools strictly follow the rules and ensure that schoolchildren answer USE questions without prompting, while in other schools teachers openly help answer questions, or even fill in the test forms themselves and allow the use of mobile phones by examinees. In this respect, the USE campaign-2011 led to nearly unprecedented wave of scandalous stories: The USE questions could be found on the Internet prior to exams, and higher school students took exams instead of schoolchildren. The result was arising of a serious problem: A considerable number of schoolchildren gained the maximum (100) of USE points, while many university professors argue that they feel unequal to this task. For example, M.L. Kalenchuk, Deputy Director of Vinogradov Russian Language Institute, Russian Academy of Sciences, expressed her opinion of the situation as follows: "I strongly oppose the USE system. I am Doctor of Philological Sciences, Professor at Moscow State University, but when I attempted answering the Russian language USE test questions, the points I gained could be graded most probably as "satisfactory." Being a professional, I understand that many of USE questions can be answered correctly in several different ways, of which only one is stored in computer memory, and nothing can be done to prove the correctness of other ways in this situation. Some questions are formulated in a manner such that I (once again, as a professional) do not understand what is being asked. Naturally, this concerns not all the questions, but many of them."

Nevertheless, some schoolchildren manage to get close to the maximum possible points. It could be presumed that these are wunderkinds, but a simple "experiment" showed that this is not true. According to Prof. N.E. Kuz'menko, Deputy Dean of the Chemistry Department, MSU, a half of the students enrolled in 2010 at the Chemistry Department, MSU, could not be able to be admitted but for the opportunity to pass an additional entrance test (a written exam in chemistry) organized by the Chemistry Department. Otherwise,

the places of those actually enrolled had been taken by those who have 100 USE points! The additional examination showed that many of the applicants who submitted very high scores on USE exam in chemistry failed at the written exam at the Chemistry Department, MSU, and therefore were not enrolled. Thus, it makes sense to consider the possibility of conducting such additional entrance tests on the profile subject in other higher educational institutions in Russia, perhaps, at their requests.

The introduction of USE and its content deserve separate special analysis. Here, we will touch upon some of its shortcomings directly related to the content of the secondary school chemistry course and control of secondary school graduates' knowledge.

By contrast to mathematics, chemistry is a natural, but not exact, science. In mathematics, one can compose an infinite number of tasks on simplifying algebraic expressions, solving different types of equations, and finding one or more unknowns and the domain of functions, etc. In all cases, the answer will be unambiguous, which allows the problems to be easily formalized and computerized, and the necessary number of versions of test questions for each program item to be provided, and little wonder: Mathematics is an exact science.

In the case of chemistry (and even more so of biology) this algorithm does not work. Therefore, the development of a large number of test questions in chemistry, uniform in complexity and form, as required for USE in its present format, seems unrealistic. Moreover, the formalism in teaching chemistry and the desire to arrange everything "in orderly pigeonholes," similarly to the case of mathematics, lead to errors both in textbooks and in USE questions. This results in appearance of artificial and even erroneous questions inconsistent with reality, because in chemistry, by contrast to mathematics, it is only rarely possible to formulate rules that are valid for all cases without exception. The laws of chemistry are not unequivocal; there are many exceptions to the "rules." Even one of the so-called "basic laws of chemistry," the law of definite proportions, is strictly obeyed by inorganic compounds only in rare cases. The situation with organic chemistry is even more complicated: Reactions follow a single route and go to completion only rarely. At the same time, the compilers of "measurement and control materials" (simply put, USE questions) must invent tens of versions of answers for each program item, like in the case of a test in mathematics, and every year there is need in providing new versions, which task is basically impossible to accomplish.

As a result, for some questions a competent chemist can easily provide two, or three, or none answers, instead of the expected one "correct" answer! When taking an oral examination, an examinee still has an opportunity to prove something, to try to explain to examiner that, in one of the textbooks, he/she read this and that. By contrast, computers do not accept any "explanations": The examinees have to provide a single "correct" answer, and that is it!

It may well be that schoolchildren who acquired a very good knowledge of chemistry from higher school textbooks will get zero point for correct answers to some USE exam questions. According to Zagorskii, an AESC MSU teacher, "to accomplish some of the USE tasks, our learners need to deliberately grow stupid." In other words, AESC MSU teachers can well advise that, to pass a USE exam, very well-prepared learners forget everything they were taught at AESC MSU and everything they read in all the high-toned books on chemistry, because this is the only way for them to "correctly" answer USE questions. The results of the "experiment" with AESC MSU students, together with the conclusions derived therefrom, were published in "Khimiya v Shkole" journal. Amazingly, the developers of tasks for USE exam in chemistry responded to this publication by saying that they have to prepare tasks for ordinary, average, Russian schoolchildren, rather than for "wunderkinds" from the AESC MSU. So, for them "it will do as it is"?

What kind of professionals (and citizens!) can be trained by forcing them to "pretend" when responding to incorrect questions! Among other things, schoolchildren having an excellent knowledge of a subject will get a "duplicity lesson": When answering USE questions, they have to "play" to the situation, rather than provide an answer compliant with the laws of nature (as it can be done at an oral exam, while giving reasons for the answer). This means training conformists who will have to think about giving an answer that is considered to be correct by the task developer rather than about the fact of the matter. Perhaps, even greater conformism is required for "correctly" answering questions of USE exam on humanitarian and "social" sciences, e.g., history. One of the authors of this study, when acted in USE expert

capacity, was an unwitting witness of an argument of two scientists, engaged in preparation of new questions for USE exam on history, over the issue of when the development of capitalism began in Russia. Even they could not come to a consensus (and this is a norm for historical science, and not only for it), but then how could schoolchildren be required to answer this question!

Getting back to the point, it would be fair to say that most of the USE exam questions are not objectionable by professional chemists, except for one aspect: what is the good of knowing all this by an "ordinary person?" What is the use of his/her knowing "how many unpaired electrons are there in an unexcited atom of manganese?" (This is a real USE question). Do all secondary school graduates have to know the answers to the following USE questions:

– which of the Fe^{2+}, Cl^{-}, Cu^{2+}, or Fe^{2+} ions has the electronic configuration of an inert gas?

– do atomic radii increase in the Sb, As, P, N series?

– which of the nonmetallic N, S, F, Br does not exhibit the degree of oxidation, equal to the Group number?

– how many sigma bonds are there in a propionic acid molecule?

– is dimethylamine a liquid or a gas?

– what is the hybridization state (sp^2, sp^3, sp, or sp^3d) of the carbon atom in the functional group of propionic acid?...

Such knowledge items are not needed by vast majority of professional chemists, but methodologists believe that they are necessary for all secondary school graduates. What for: in order that disgust to this science will be developed in them, or in order that they will be shown that science is a solid scholasticism stuffed with worthless knowledge? In our opinion, the answer is simple: The methodologists do not know what real, relevant to real life, tasks can be developed for USE. And we also do not know how to come up every year with tens of really useful tasks for exams. This is specifically the problem to be solved above all by those who will (that is, if they will) develop future programs for secondary school.

Also, there are some factual errors in USE tasks that were offered in different years.

For example, the developers of USE tasks had to offer a number of tasks concerning reactions between acidic and basic oxides for the topic "Main classes of inorganic compounds and reactions between them." This situation sets thinking even a professional chemist (these are reactions in the absence of water) who, probably, will suggest a backward reaction to that of decomposition of calcium carbonate at high temperatures: $CaO + CO_2 = CaCO_3$. Calcium can be replaced by barium; and what else can be suggested without going beyond the secondary school program? Another example: A task offered to schoolchildren is to write the equation of the reaction between nitrogen pentoxide and magnesium oxide. It is implicitly presumed that schoolchildren are well aware (or rather, "should be well aware") of the fact that acidic oxide N_2O_5 reacts with basic oxide MgO to form the corresponding salt, and the "correct" answer is presumed to be the equation $N_2O_5 + MgO = Mg(NO_3)_2$. However, this "learning" equation does not make sense for a chemist, because nitrogen pentoxide is a solid, though extremely unstable substance, which decomposes slowly even at room temperature and explodes under slight heating. On the other hand, magnesium oxide is a high-melting substance (it melts above 2800°C!) and, consequently, can react with solids only at very high temperatures.

Some time ago, a USE question about the most appropriate labware for keeping a copper sulfate solution was subjected to criticism. Silver labware was considered to be the correct answer, which, of course, is not objectionable from the chemical viewpoint but looks absurd: It is impossible to imagine a silver vessel (and where it comes from?) in which copper sulfate is to be kept. In tasks of this type one can find typical examples of "paper chemistry", which looks smooth on the blackboard in a classroom or in a school exercise-book but has nothing to do with reality. Unfortunately, this is specifically the drawback suffered by some USE tasks which bear no relation to life outside special laboratories. The result is cramming, rote memorizing of a large volume of information which might be immediately forgotten for life after the exam. Moreover, negativism toward chemistry remains with many schoolchildren (certainly, not with those who enter higher educational institutions where chemistry is the profile subject).

Thus, at the very first chemistry lesson, a competent teacher should tell schoolchildren the following: "We will study two chemistries. One is

"artificial" chemistry which needs to be studied in order that you pass the USE exam, and the other is real chemistry, which is needed by any person to correctly perceive the world. And these are two chemistries that should not be mixed."

It follows from the above-said that, since it is impossible to develop many correct and simultaneously interesting and practically meaningful USE exam tasks for all items of the secondary school program in natural sciences, the USE exam in these subjects, probably, should either be cancelled or significantly modified via excluding tasks with multiple-choice answers. Alternatively, the secondary school program could be substantially revised via breaking into two blocks: one course will provide basic information about the world order and will be mandatory for everyone and the other, advanced course, will be intended for those who are interested in natural sciences and are planning to enter chemistry-, biology-, medicine-, or geology-oriented higher educational institutions.

Interestingly, there exist precedents to the current attempts to limit the number of academic hours assigned to natural science at secondary school. For example, as early as 1871 the Minister of Education of the Russian Empire, a famous reactionary Count D.A. Tolstoy carried out an education reform, according to which natural sciences were removed from the curricula of gymnasia under pretext that they promoted materialistic ideas, whereby teaching of ancient languages was enhanced [27]. The only difference from the actions undertaken by today's modernizers of Russian education system is that they propose "communicative competences" instead of Latin and Greek. By the end of the XIX century, the result of the Tolstoy's reform was the scientific and technological backwardness of Russia. Because of deficiency of engineers Russia could not catch up with advanced Western countries in highly technological industries, and this situation had tragic implications for the history of Russia (the defeat in the Russian-Japanese War, the Revolution of 1905, etc.).

Thus, there can be no doubt that the changes that are planned by modernizers, and are already currently underway, are leading to further decline in the academic background quality of secondary school graduates, particularly, in natural sciences. In this connection, it will be appropriate to cite the opinion of Academician V.A. Sadovnichii, Rector of the Moscow State University, Russian Rectors' Union Chairman, who is well aware of the education problems faced by Russia: "Serious blows, in particular, those of legislative nature, are descending upon the education system. In fact, we are witnessing the destruction of secondary and higher educational system with a view to its leveling with some mythical Western systems, while many achievements of the Russian education system are being negated. Even the schoolchildren Olympiad movement, which I am instructed to head in Russia, is meeting fierce resistance from officials" [28].

In this connection, another very important fact deserves mentioning: The modernizers constantly refer to the recommendations provided by the International Monetary Fund and the World Bank, which provide partial financial support to their activities. It should be noted that the title page of the brochure [17] contains a note that it was developed by the State University - Higher School of Economics with participation of those two organizations. It turns out that our well-wishers, the International Monetary Fund and the World Bank, want for some reason to raise our education, which will inevitably make Russia strong, defense-capable, and competitive. What do they want this for? Maybe, our well-wishers want the reverse [29]?

Sacramental "What is to be Done?"

The above discussion might create an impression that the authors of this study are mossy conservatives who tolerate no changes and strongly oppose any reforms, which opinion is not exactly correct. Specifically positive conservatism intrinsic to the Russian educational system, supported by the teaching elite, prevented the Russian secondary school from losing the best traditions of previous decades.

At the same time, it should be recognized that the Russian secondary school needs modernization. Moreover, if governed by a sense of proportion and common sense, many of the initiatives suggested by today's reformers could be used to good purpose. For example, it is extremely useful to systematically monitor the knowledge, skills, and competences of complete and incomplete secondary school graduates. However, one should not make a fetish of these monitoring activities and should not consider them as the only way to assess the graduate's knowledge and particularly not to attach to them the functions of entrance examinations at higher educational institutions.

Differentiated teaching is, certainly, necessary for senior grades. However, schools offering profile training should be relatively few in number and be distinguished from ordinary schools by a strong teachers' corpse and excellent supply system, rather than by the nameplate. Learners should be mandatorily provided with an opportunity to relatively smoothly change from one secondary school profile to another and from a school offering profile training to an ordinary school.

Integration of natural-sciences courses is an important line in development of secondary school education. An understanding of the fact that nature is one and undivided, with physics, chemistry, and biology being focused on its different aspects, should be developed in senior schoolchildren. However, this should be done via teaching a short synthesizing course rather than via rejecting those disciplines as individual school subjects.

Hopefully, the already mentioned positive conservatism intrinsic to the Russian educational system will prevent the RF Ministry of Education and Science from causing the Russian education system to significantly slacken.

To conclude, we will cite the words by S.V. Bagotskii, a biology teacher, Associate Professor at the Moscow Institute of Open Education: "The realities of our time contribute to development of a pessimistic opinion of the future of the Russian educational system. This opinion ... is understandable, but I can by no means embrace it, because it sends us into passivity similar to that displayed by sheep being led to slaughter. Sheep have no future. The future belongs to people who are ready to vigorously defend their own and their children's and grandchildren's interests" [30].

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