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# Basic Training and Methodological Problems of the Modern Chemical Education in Secondary School

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**Abstract**—The article deals with basic problems of modernization of the education system in our country and the ways of their ra-tional solution. It is shown that among the main objectives are the mass training of highly qualified teachers, and increase of their prestige in society. The authors discuss the content of secon-dary school courses in physics, chemistry and biology, and rele-vant textbooks. Particular attention is drawn to the scientific and methodological support to the chemical education, as well as general standards.

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Basic problems of modernization of the education system in Russia and the ways of their rational solution were discussed. It was shown that among the main objectives are the mass training of highly qualified teachers and increase of their prestige in society. The content of secondary school courses in physics, chemistry, and biology, as well as relevant textbooks were considered. Particular attention was given to the scientific and methodological support to the chemical education, as well as to educational standards.

High quality of natural-sciences education at the secondary school level is essential for development of a civilized society. Clearly, without urgent steps to be taken, the school education quality in Russia will be increasingly deteriorating.

The policy of modernizing the education system, pursued now in Russia, calls for improved approaches and methods. To achieve compliance with the new education requirements (which concerns, above all, the competence-based approach to learning), it is essential to solve a number of training and methodological problems. All the components of the educational process need serious reforms.

Here, we discussed these basic problems and suggested rational ways to their solution.

## Teacher: A Key Figure in the Educational Process

The overall objective pursued by improving education at the secondary school level is the mass training of well-educated teachers, loving toward children and enjoying the subject matter they teach. The quality of secondary school education depends primarily on teachers' professionalism and competence. Teacher is a key figure in the educational process, and as long as there is no effective national system of training highly qualified teachers, any education reform is doomed to failure. Unfortunately, today, secondary school in Russia suffers from deficiency of good, particularly young, teachers.

What steps should be taken in order to achieve the above-mentioned objective?

First of all, there is a need to raise prestige of the teaching profession. This is a challenging task, which is not reduced (as it might seem) to providing higher salaries, which measure is certainly necessary but insufficient.[1]

Certainly, the level of teachers' financial security should be sharply increased: The young teachers' earning 4000 rubles a month is a disgrace to the country. Considering the salaries currently paid for the hard teachers' labor, raising the teachers' prestige in society hardly can be discussed. Not surprisingly, only a small proportion of graduates from pedagogic higher

[1] Indeed, the Moscow Government has very significantly raised the teachers' salaries (25 thousand rubles as of December 2009, on the average). As a result, those willing to teach in secondary school have immediately increased in number. However, this has not led to significant improvement of teaching quality.

education institutions choose secondary schools as their job places (according to the RF Ministry of Education).

The teachers' prestige is primarily determined by professionalism, high intellectual level, and excellent knowledge of the subject taught, as well as by the ability and capacity to share this knowledge with schoolchildren and get them interested in the subject. These were specifically the distinguishing qualities of teachers in Tsarist Russia, whose prestige, especially in rural areas, is known to be very high. It should be recognized, however, that the teaching corps in those days was about 10 thousand people, most of which were university graduates who enjoyed extremely high prestige against the background of uneducated masses of the population.

Today the situation is different: The teaching corps amounts to one million, and secondary school teacher (typically, a female teacher) is a mass profession. At the same time, a fundamental, fairly obvious for professionals, problem with Russian education system at the secondary school level consists in deficiency of good teachers. Pedagogic higher education institutions are significantly superseded in training quality by technical and classical universities. The teachers' prestige in our society is typically not very high.

Increasing prestige of the teaching profession is a challenging task, but its accomplishing is critical for actually reforming the secondary school education system in Russia. This is by no means new challenge. A direct relationship between self-esteem and attentiveness to other people was mentioned in [1], together with the fact that teachers with low self-esteem are less loving toward children. As emphasized in [2], teacher's profession should be made attractive in order that there could be more kindly hearted school teachers; strong competition for school teaching job could provide an opportunity to refuse hiring those who do not love children.

It is no secret that today's teacher is no longer the primary "source of information" for schoolchildren who are often more active Internet-users, and have a better command of information technologies, than do teachers, even those who teach natural sciences. At the same time, teachers need to know much more than what they teach in a classroom, and this is not only because he/she must be prepared to answer an unexpected schoolchildren' question. Teachers should have a solid stock of knowledge acquired at higher education institutions and possess better, compared to schoolchildren's, information searching skills (including the Internet resources).

Thus, the top priority should be assigned to significant improvement of teachers' training quality. This will require, above all, reforming the system of pedagogic higher education, i.e., in the first place, of the teachers' training system at pedagogic universities, rather than the education management system. There is a need in training subject teachers having an excellent knowledge of their subject and certain understanding of the subject matter of related sciences. Training such a teacher within the four years of study under a bachelor's degree program is an unfeasible task. Like in the case with technical universities, pedagogic higher education institutions should draw the prospective teachers into research project activities. To this end, it is essential that these institutions be equipped with modern instrumentation, and students, mandatorily undertake research work on their subject profile. Professional training holds more importance for prospective teachers than their methodological instruction! The diploma thesis topics to be chosen by students who are going to teach natural sciences should belong to the scope of natural sciences.

To improve the teaching quality, pedagogic higher educational institutions need to attract professors and associate professors from classical (traditional) universities and to establish the pedagogic higher educational institution – secondary school – research institute complexes, as suggested in 1966–1984 by M.A. Prokof'ev, Dr. Sci. (Chem.), the then USSR Minister of Education. Today, an example of such complex can be found in the Chemical Lyceum – Higher Chemical College – chemical institutes of Russian Academy of Sciences complex, established by RAS Academician O.M. Nefedov.

In this context, we suggest the following major steps:

(1) Increase the funds allocated to pedagogic higher education institutions and spend this finance for equipping them with modern instrumentation and for attracting highly qualified teachers.

(2) Leave unchanged the five-year study period for pedagogic higher education institutions: Secondary school does not need teachers with bachelor's degree.

(3) Expand the secondary school teachers' training program at classical universities.

(4) Establish, on the basis of pedagogical universities (similarly to medical higher education institutions), complexes including pre-school institutions, secondary schools, and after-school child care institutions, where pedagogy students, guided by experienced teachers, could master the teaching profession in practice [2]. Students should constantly communicate with secondary school and be aware of its problems and also have contacts with schoolchildren. This will provide school graduates with higher motivation for entering pedagogic higher education institutions.

Certainly, the topic of increasing teachers' prestige should be covered in all the media (television in the first place).

In this context, of much interest is the experience with the Department of Pedagogic Training at the Lomonosov Moscow State University (MSU). Students enrolled at MSU on a budgetary basis are offered free study at this department (in the evening time). The Department of Pedagogic Training, MSU, undertakes different activities, in particular: training secondary school teachers; training pedagogic staff to be engaged in skills identification and development in talented young people, their vocational guidance, and in-depth general education activities to prepare them for entry into higher education institutions; carrying out research work, preparation of scientific and methodological, as well as training and methodological materials for educational activities; development of methodological, as well as of training and methodological principles of pre-university education. The Department of Pedagogic Training provides the graduates with state diplomas of further (additional to higher) education in "teacher" or "high school teacher" specialty. Every year, tens of graduates receive such diplomas, and over one hundred, certificates of graduation. It is reasonable that all classical universities have such departments.

Further, there is a need to cancel the military service for male teachers who, after graduation from pedagogic higher education institutions, have been engaged in teaching activities at rural secondary schools (especially considering the fact that such persons are very few in number in Russia). Unfortunately, the currently acting Federal Law "On Military Service Obligation and Military Service" does not contain provisions according to which rural school teachers could be deferred from military service (this determent was cancelled on January 1, 2008). The RF Minister of Education and Science A.A. Fursenko holds a different opinion: He believes that, in the process of creating a professional army, "... it would be more appropriate to completely cancel any occupational determents". According to the Minister, the determent for rural school teachers does not provide a solution to the problem of the lack of male teachers among the teaching staff: "Over the period of operation of the determent, this opportunity was taken by several hundreds of persons only."

This brings up the question, what was the situation with rural teachers in Soviet times.

In Soviet times, teachers of rural general education school enjoyed a number of statutory benefits. "If a teacher is the head of a family, the family is fully exempted from agricultural taxes. This benefit is preserved when a teacher reaches the retirement age. Some benefits are provided not only to teachers but also to other educational workers of general education schools located in rural areas. Teachers, principals, head teachers, youth workers, pioneer leaders, and other educational workers, as well as their family members living together in the family have a right for free accommodation which heating and electricity supply services to be provided according to the locally established norms. If an educational worker lives in his/her own house, he/she is also granted heating and electricity supply privileges. The right for free accommodation provided with heating and electricity supply services is preserved for the educational workers after they reach the retirement age, regardless of whether they are further engaged in teaching or any other activity." [3].

The right for free accommodation provided with heating and electricity supply services was also secured for those educational workers of schools in urban settlements (but not in cities) who had at least ten years of working experience at rural schools. Teachers and other educational workers of rural general education schools enjoyed additional benefits when obtaining loans for purchasing items of economic equipment and constructing a new residential house. For example, young specialists who graduated from higher and secondary pedagogic education institutions and had a job placement at rural schools could obtain a loan of up to one thousand Soviet rubles for purchasing items of economic equipment, to be repaid within five years starting in the third year after the date of the loan. Teachers, and

other educational workers, who were higher and secondary education teaching professionals could obtain a loan of up to two thousand Soviet rubles (this amount typically exceeded the annual salary of a teacher) for constructing a new residential house, to be repaid within ten years.

Male higher education teaching professionals were deferred from active military service throughout the period of their work at a rural school. The Central Committee of the Communist Party of the Soviet Union and the USSR Council of Ministers suggested that the All-Union Central Council of Trade Unions, the Ministry of Health, trade unions, and public health and public education institutions take measures to improve the health, health resort, and recreation organization services to be rendered to rural teachers and provide more teachers with vouchers to health facilities in the school holiday period, allocate tourist and excursion vouchers at discount prices, and organize excursion tours for rural teachers on favorable terms. The attention of the party and government bodies was drawn to the necessity to provide constant care about educational workers, to carefully consider the needs and demands of teachers, to exercise strict control over provision of statutory privileges and benefits for teachers and other educational workers of rural schools.

Even if these measures were not fully implemented, these were indications of a serious concern at the national level about the rural teachers' situation and of understanding of the important role played by rural teachers in upbringing of children in rural areas. Naturally, a question arises, why, today, the attitude to rural teachers is so different?

Getting back to the point, it should be noted that the currently acting (largely formal) teachers' inspection and certification system needs to be modified. Specifically, these functions should be delegated to the best teachers from other than inspected schools, rather than to officials on the part of education. Teachers' recertification should consider not only the courses which were learned by teachers at educational institutions (and whose assimilation was not checked) but also, above all, the courses mastered by teachers themselves. Thus, teacher's training is again in the foreground.

Another challenging task consists in selection of applicants having pedagogic inclinations. To this end, it would be advisable for school psychologists to organize senior schoolchildren testing process and undertake vocational guidance activities with respect to teaching profession. It is reasonable that "schools of future applicants" be established at pedagogic higher education institutions on a permanent basis so that the admission of a new corps of teaching profession-oriented first-year students be ensured [4].

Thus, solution of all the above-mentioned problems lies in providing more funding to pedagogic higher education institutions and allocating finance for equipping them with modern instrumentation and attracting highly qualified teachers. This is the only productive strategy of modernizing the Russian secondary school.

## Textbook

The issue of the content of secondary school courses in physics, chemistry, and biology and relevant textbooks is anything but simple.

In the Soviet Union, there were no variative textbooks for secondary school: All school disciplines were taught on the basis of a single textbook. Textbooks were prepared very carefully by the best pedagogues, and their validity was tested and proven by tens of years of using them by tens, if not hundreds of millions of schoolchildren.

The present system of variative textbooks, on the one hand, beneficially affects the education process: In theory, a teacher can choose from among several textbooks that which, from his/her viewpoint, is best suited to this/her specific region, school, class. On the other hand, this system has some negative aspects, the most important of which will be discussed below.

Today, many individuals whose competence and pedagogic skills seem doubtful undertake textbook writing on a mass scale. The textbooks they develop are written in poor, difficult to understand, language and contain methodological and (which is worse) factual errors. Also, there are a lot of quick-fix alternative education programs today. All this leads to violated continuity between the secondary and higher education systems and deteriorated overall academic background of schoolchildren.

Under competition conditions (not always fair), publishers tend to publish study materials in a haste, with the result being under-reviewed and under-edited textbooks and tutorials.

Cases of corruption in distribution of textbooks and forced choice of the "proper," rather than the best,

textbook (unprecedented phenomenon!) occurred in several Russia's regions, and even in some municipalities.

The situation with too many textbooks on the same subject inevitably leads to restrictions with respect to their circulation. Even good books written by well-known specialists are published in very small runs, so that a teacher who does not live in a big city often cannot not only provide these textbooks to the whole class but also learn about the latest publications. As a result, with a typical textbook circulation of 5000, a teacher residing in a small town or in a rural area cannot always use in his/her teaching activities the textbook that he/she considers the best. Finding a good textbook published in small runs is a hard to accomplish task.

Some authors tend to "adjust" their textbooks to the Unified State Examination system which is mandatory today, to which end they undertake rigid formalization of the material, with all the treated themes "arranged in orderly pigeonholes."

Attempts have been made to bring into secondary school biology course creationist concepts (passed off as beliefs "parallel" to the scientific worldview).

The textbook problem can be illustrated by the following example. All domestic secondary school chemistry textbooks, without exception (including those published in recent year) are organized in essentially the same manner: They provide a more or less successful presentation of a systematic course of chemistry by the German classical scheme adopted before the World War II. The differences consist in the depth of coverage of selected topics, in the order in which the sections are arranged, and in some other, basically special, aspects. Russian chemistry textbooks provide all the interested schoolchildren with basic ideas of the chemistry science and are suitable as a good-quality foundation for their future learning activities.

At the same time, a drawback suffered by virtually all chemistry textbooks consists in that their content is inadequate to the needs of the majority of schoolchildren having real contacts with the "chemical aspect" of the surrounding world. Indeed, what is the use of the knowledge how to balance redox reactions by future accountants, forwarders, journalists, or governesses? This is a kind of activity that is very rarely undertaken even by chemists, for which reason, in 1997, even a moratorium was declared "on manuscripts about how to balance equations" in the Editorial of the Journal of Chemical Education (US) [5]. For those schoolchildren who do not plan to get chemical education it will be sufficient to have an idea of stoichiometry in chemistry, i.e., actually, of the law of conservation and indestructibility of the atom. At the same time, it would be very useful for them (as well as for senior schoolchildren) to get to know what to do if a mercury thermometer breaks and how to collect up the spilled mercury. At the sight of Allan Chumak (a popular faith healer in the Soviet Union) while he is demonstrating the "elimination of the mercury atoms" under the action of passes in a television program, these schoolchildren should just laugh and be able to explain their family why this is not possible. Also, it would be a good thing for schoolchildren and school graduates to know the basic properties of fertilizers and pesticides, the so-called "household chemicals" sold in hardware stores.

At the same time, the vast majority of Russian secondary school textbooks are distinguished by excessive theorizing; they are overwhelmed by the material which, for the bulk of schoolchildren, is not only difficult to grasp but also hardly needful. The gap separating the information contained in a textbook and real life is excessively wide. Maybe, this is specifically the reason for low motivation to study chemistry, exhibited by many senior schoolchildren?

It is no way our intention to call to turn a school textbook into a manual on household chemicals. Clearly, formation of a system of knowledge, even if presented at the very basic level, requires that a sound fundamental approach be applied.

In this connection, of considerable interest is the "Chemistry in the Community" textbook [6], which gives much food for thought. It was prepared by the American Chemical Society with participation of tens of scientists (including several Nobel Prize laureates), methodologists, and teachers. The underlying principle of this textbook is completely different from those described above. Initially, the textbook describes a mysterious ecological event (mass fish die-off in a local river), and this is followed by discussion of the possible reasons for this situation (which, as it turns out, can be many) on the remaining pages of the textbook. While solving the puzzle together with the local school teachers of physics, chemistry, and biology, as well as with external experts, school-

children learn a lot of new, starting from the way of measuring the concentration of a substance in solution and ending with information from the fields of medicine, electrochemistry, nuclear power generation, etc. All these pieces of information are somehow related to the original problem. The textbook has numerous interesting colored illustrations. It is important that local residents are involved in finding solution to this problem: they establish committees, decide which experts are to be invited, how much and in which way to spend finance, etc. Thus, in parallel, schoolchildren can get to know how self-government operates, which is essential for any citizen who can (and should) participate in solving local problems.

However, this textbook is not suitable for our mass school. First, it is based on American reality; second, it does not correspond to the Russian traditions of teaching chemistry in secondary school, as it does not provide systemic treatment of the material; and third, the training system practiced by Russian pedagogic higher education institutions does not allow most of teachers to use this book. Thus, a chemistry textbook for the mass general education school still remains to be written. We believe that it will be a kind of "hybrid" of a book like [6] with a traditional Russian textbook.

There is a need in a scientifically rigorous chemistry course, free from scholasticism and formalism, such that could be developed through the cooperative efforts by Russian scientists, methodologists, and secondary and high school teachers [7]. For example, students do not need to memorize the rules of distribution of electrons in the atoms of transition elements: There are many exceptions which cannot be understood by them (by teachers either), and the practical significance of these rules for, e.g., chemistry, is totally unclear to them.

The secondary school chemistry course should, above all, provide schoolchildren with an idea of the world structure and, in more detail, of the science of chemistry (for those who will be seriously interested in it), specifically: what chemists are doing at laboratories and production facilities; what are the existing substances and their properties and why they possess these properties; and what are the adverse and beneficial effects produced by the development of chemistry on the mankind and which of the effects is more powerful ("would you like to live in a world without chemical industry?"), etc.

To answer these questions, schoolchildren need chemical knowledge, which in turn creates the need for a new generation of textbooks that will combine basic information with the competence-based approach. This task can be accomplished via well-coordinated work of an authors' team consisting of the best teachers and active scientists engaged at universities and academic institutions.

## Laboratory Course

Effective learning of the secondary school course of chemistry, like those of physics and biology, is impossible without carrying out a minimum of laboratory course work by learners. In this respect, of much help can be the manual [8] written by an authors' team led by distinguished American scholars and teachers Glenn Theodore Seaborg and James Arthur Campbell. This manual describes a number of interesting classroom experiments and optional additional studies.

Also, there are various, in particular very successful, practical courses for secondary school, prepared by Russian methodologists. A problem resides in rigorous implementation of the practical course, which activity is prevented by the lack of chemistry classrooms in thousands of Russian schools and the collapse of the system of supply of secondary school with chemicals, materials, and labware.

It would make perfect sense to saturate the practical course works and demonstration experiments with household chemicals, substances that people regularly contact in everyday life. Schoolchildren should be trained to read carefully (and follow strictly!) the instructions to household chemicals and medicines.

Each school should provide special physics, chemistry, and biology classrooms to all their senior schoolchildren so that they could do (mandatorily) laboratory works on these subjects. This especially concerns chemistry, which is an experimental science whose learning (and teaching) without demonstration of experiments is a great challenge. If the author of a textbook or a methodologist has never in his/her life done a chemical laboratory work (except for during his/her study at a pedagogic higher education institution), the textbook will contains erroneous definitions and distorted facts.

## Scientific and Methodological Support to Chemical Education

The development of chemistry teaching methods in Russia is the scope of activity undertaken by tens of research groups at pedagogic and chemistry-oriented

higher education institutions, as well as at institutes of the Russian Academy of Education. Also involved are enthusiastic teachers who are engaged in practical improvement of the study process. The results of methodological studies are typically formalized as numerous Candidate of Sciences (chemistry, 13.00.02 specialty) dissertations. Every year, one or two Doctoral dissertation theses in this specialty are defended.

Certainly, the relevance and effectiveness of some of the methodological studies are arguable, which concerns, in particular, studies in which hypotheses are advanced that are obvious, and in fact are not hypotheses at all. Nothing but incredulous attitude can be displayed toward the constant and continuing success of some pedagogic experiments; the artificiality of the themes chosen for some Candidate of Sciences and Doctoral dissertations causes nothing but distress. Comprehensive analysis of the array of methodological studies conducted over the last 10–15 years is a separate issue which is beyond the scope of this study. Here, we will only note that, in our opinion, there exists a set of important problems that escaped the attention of Russian methodologists.

The "terra incognita" for our methodological science is the knowledge retained 2–3, or 5–10 years after secondary school graduation by those graduates (they constitute the majority) who are not chemistry students and do not apply to natural sciences-oriented, engineering, or medical higher education institutions. Clearly, secondary school education pursues specifically the goal of formation of an array of retained knowledge such that will "be effective" for a long time, preferably during the entire active life of school graduates.

What is the actual level of retained knowledge? How does it change over time? What pieces of knowledge derived from the secondary school chemistry course are the first to "disappears" and what are most strongly fixed in the memory? To what extent is the knowledge, acquired at the secondary school, demanded? How is the retained knowledge connected with the chemical aspect of the real activity of an individual? And, most importantly, what is the optimal content and volume of retained knowledge to be strived for? All these important questions are, unfortunately, beyond the interests' sphere of Russian methodologists.

In order to get fairly adequate answers to these, and many other questions, it might be well to conduct surveys of representative groups of respondents. Naturally, drafting a competent questionnaire, developing a survey methodology, and processing the survey results should be the focus of collaborative activities of methodologist with social scientists, which will require certain organizational efforts on the methodologists' part. However, these efforts will be certainly "reimbursed," because the results to be provided by such a survey will be undoubtedly demanded and will constitute the basis for scientifically sound correction of the chemistry course program. The leading role in this surveying activity should belong specifically to methodologists, while social scientists will contribute with consultancy.

In the future, this activity could be extended to cover school graduates who studied chemistry after graduation from secondary school, though as an additional discipline, e.g., at medical higher education institutions. The results to be provided by such surveys will be useful for substantiating the content of the profile-based teaching of the chemistry course at the secondary school level.

It would be reasonable that identification and analysis of the retained knowledge possessed by ordinary school graduates be carried out for all the major school subjects, not only chemistry. This is of much significance, because the focus of secondary school course programs and the content of relevant textbooks should be specifically on strengthening and improving the content of retained knowledge.

An issue closely adjoining that of retained knowledge is the development of a science-based method for selecting the content of the basic minimum of knowledge [9]. What are the optimal content and volume of knowledge? Clearly, the knowledge to be possessed by future applicants to a chemistry-oriented (or, e.g., a medical) high education institution will be a wrong choice. Unfortunately, specifically this knowledge of chemistry is chosen today by many ordinary secondary schools (and not only in the case of chemistry). At the same time, teaching the general chemistry course intended for nonchemical higher education institutions should not be provided to all schoolchildren (although this is specifically the approach that is practiced today by some specialized schools).

Also, methodologists still have to examine the relationship between the secondary school course of chemistry and the chemical (and environmental)

concepts and terms used in the media. This is an essential task, because both schoolchildren and graduates constantly obtain chemistry-related information from outside and often are not able to adequately respond thereto. It is desirable that the first phase of such examination consist in compiling a thesaurus of chemical terms and concepts occurring in newspapers, television and radio programs, and nonchemical websites on the Internet. In the second phase, the frequency of occurrence of specific chemical terms could be examined, and a kind of a frequency dictionary could be compiled. It is difficult to predict in advance what will be the result of this examination, but at least the terms most commonly used in the media would be incorporated into the secondary school chemistry course.

Another problem lies in the fact that the introduction of Unified State Examination (USE) has not received any prior methodological substantiation. The very applicability of USE, in its current format, to natural sciences causes profound doubts. At the same time, the experience with USE has already shown that, despite its shortcomings, its results could provide a lot of information about how chemistry is taught and, moreover, how various sections of the chemistry course are perceived by schoolchildren in a specific region. The advantage of this opportunity still remains to be taken.

In this context, it is important to estimate the efficiency of USE and to elucidate what kind of performance is demonstrated by students admitted to higher education institutions on the basis of their USE scores. There is a need in statistically reliable comparison of their academic background with that of the students admitted on the basis of the traditional competitive system.

Studies dedicated to the scientific and methodological aspects of selection of materials for the regional component of the secondary school course of chemistry are very scarce (see, e.g., [10]). The problem with the content of regional education is far from being solved. At the moment, no common understanding exists, and no single approach is taken with respect to definition of the very notions of "national-regional component" and "regional educational system." Many scientists, teachers, and officials of different levels treat these notions in very different ways, which situation is responsible for spontaneous process of regionalization of education.

Approaches to formation of specific subject programs within the regional component still remain to be theoretically substantiated. The basic principles and selection criteria for study materials to be incorporated into such programs are poorly understood. No duly substantiated ways and means of integrating the regional and federal study courses were suggested. Solving this problem requires, above all, algorithms for developing programs to address at least two cases of the regional component of the secondary school program: a region with developed chemical industry (or related industries) and a "nonchemical" region.

The last few years have seen a large increase in the degree of computerization of chemical education. Many different computer-based manuals on chemistry are available on the market, most of which, however, do not stand up to scrutiny. A computer-based teaching aid can be really effective only if it is a result of collaborative efforts undertaken by chemists, methodologists, and programmers. In this respect, development of a computer-based tutorial is a more difficult task compared to a printed-on-paper tutorial.

Features distinguishing computer-based tutorials from other on-screen teaching aids (training films, videos, and slide shows) include interactivity and possibility of widespread use of hyperlinks. Virtually any educational chemical experiment can be demonstrated using the computer possibilities. However, some fundamental questions arise in this connection, like, e.g., what is the right proportion of virtual and real chemical experiments? Can real experiment be replaced by a virtual one? Is it possible to develop "a sense of substance" using virtual experiments? In any case, it is necessary to develop optimal schemes of using computer-based aids for chemistry teaching purposes, because computer has a function which is only supplementary to that of a teacher. The development of a methodology for implementation of this supplementary function specifically constitutes the major methodological task in this context.

Certain problems exist in providing the scientific and methodological support to schoolchildren's chemistry Olympiads. The national system of schoolchildren's science Olympiads has existed in our country for over 40 years. However, the problems of methodologically sound development of sets of Olympiad problems to be suggested to competitions of various (from school to Republican) levels still remain

to be solved. There are no methodological guidelines on how to organize and conduct the experimental round in an optimal manner. No methodological support is provided to evaluation of completed Olympiad assignments, to solving the Olympiad problems, etc. The development of methods of schoolchildren's training for top-level chemistry Olympiads is now undertaken by postgraduate chemistry students, teaching staff (typically very young) of higher educational institutions, and even students.

This situation has come about for objective reasons. The development of Olympiad problems and the very organization of chemistry Olympiads require in-depth knowledge of the subject, especially in the case of top-level competitions. At the same time, the bulk of methodologists have not received serious training in chemistry and especially have no experience of scientific work in the field of chemistry, essential for fulfillment of the tasks discussed. This fact prevents methodologists from involvement in the Olympiad movement, and chemists have to address the emerging methodological issues "by intuition," which situation often leads to different complications.

Since recently, the Internet resources have been actively attracted to holding schoolchildren's science Olympiads. Internet-based Olympiads have their intrinsic features and give abundant scope for methodological activities.

However, the main problem with the system of schoolchildren's Olympiads in different subjects, including chemistry, consists rather in the lack of reliable statistically significant data on the scientific fate of winners, prize-winners, and participants of Olympiads. How does the success of senior schoolchildren in science Olympiads correlate with the success of their subsequent academic career? Single observations show that, often, the first prize-winners of chemistry Olympiads subsequently could not keep up with the ordinary participants. A possible reason is deformation of the personal qualities of the first prize-winners [11].

It should be remembered that, to become a winner, top-level Olympiad participants need to possess a number of qualities, e.g., the abilities for quickly focusing on the problem, for speedy thinking processes, and for a violent, though short-term mental exertion. Science Olympiads are, essentially, a kind of sport in which sprinters are winners, while long-distance runners, phlegmatic slow thinkers, have little chances to become winners. However, a sprint-type style is by no means necessary for conducting an effective research activity.

The raised issues need to be seriously examined and comprehended, which task can well be accomplished by domestic methodologists: There exist extensive archives of chemical Olympiads of various levels, arrays of information about the academic career of former Olympiad participants, and, certainly, data arrays for comparison (see, e.g., [12]).

As regards the environmental aspect of the chemical education, the situation is the opposite: This is a fashion trend which sets off a huge flow of methodological publications. The only disappointing thing is that some methodologist authors, including chemists sometimes, recklessly represent hypotheses as proven theories and use invalidated, sometimes wrong concepts. For example, statements about expected implementation of waste-free processes and development in the near future of clean energy (e.g., hydrogen, solar, etc.), which goals are unattainable in principle, wander from one dissertation to another and from one teaching aid to another [13]. Regretfully, the development of industrial civilization objectively entails inevitable anthropogenic pressure on the nature. The mission of scientists and engineers is to minimize this pressure which, unfortunately, cannot be entirely eliminated.

Hypotheses of destruction of the ozone layer in the upper atmosphere by Freons and of man-made enhancement of greenhouse effect are passed off as validated theories [14]. Many authors do not consider the fact that ecology in its environmental aspect is a young, still unconsolidated science which lacks accurate methods of investigation. Therefore, its concepts are to be used with great caution, and recommendation to make ecology an individual subject in the secondary school curriculum is ridiculous. Secondary school greening should contribute to green thinking development in schoolchildren and in such a capacity largely belongs to the scope of moral education.

Lastly, we will mention a problem from a domain intermediate between the chemistry teaching methodology and educational psychology, specifically, that of chemical abilities. This interesting aspect deserves thorough scientific examination, in which respect little progress has been achieved so far [15, 16]. Do chemical abilities exist or are there only

abilities in natural sciences in general? Is it possible for any individual, or only for an individual with a special structure of personality, to become a chemist? If the abilities for chemistry do exist, how can they be detected? Are these abilities identifiable in the stage of early child development? Is it possible to develop chemical abilities and which is the best way to this end? What age period is the most effective for chemists? Such questions are numerous. Clearly, conducting research in this area requires collaborative efforts to be undertaken by methodologists in chemistry and professional psychologists, because neither of them alone will be able to solve these problems.

We are fully aware of the fact that, in choosing the above-mentioned scientific and methodological problems, we gave preference to those closest to our activity sphere. Probably, time has come to analyze the achievements and shortcomings of Russian methodologists' activities in the field of chemistry and to discuss future strategies. In any case, we consider it useful to take the methodologists' opinion of the problems raised here and, more importantly, to reveal some other, maybe, more relevant lines of future activities.

## Development of Educational Standards

Educational standards should be developed for each subject and take the form of a thorough and detailed list of knowledge and skills to be possessed by learners, with examples of problems and exercises (including interdisciplinary ones) provided. There should be no brief declaration like those in the much-critiqued recent draft educational standard. The development of such standard for each school subject is an activity of critical importance, into which both teachers and scientists are to be involved. A sad example of deviation from this approach can be found in the recent Federal State Educational Standard for high school, rightly subjected to tough public criticism. The draft Standard was developed by the Institute for Strategic Studies on a noncompetitive basis without broad public discussion, which facts had most negative implications for its quality.

There should be two types of standards. One type is a basic standard applicable to all secondary schools, whose underlying principle is that of providing each school graduate with a basic, minimal knowledge needed by a cultured person. In particular, this will help him/her resist the misleading advertising of "miraculous" medical devices, food additives, etc., not to mention the belief in horoscopes, telekinesis, sorcerers, and witches. The other type is a standard containing a wealth of knowledge needed by school-children who are interested in some subject and may twist their fortune therewith. The latter type can serve as a guide for teachers of special schools and classes.

Educational standards should not contain "trivialities" which do not bear any content, like, e.g., "the formation of ability to explain the relationships in chemical reactions, to predict the possibility of their proceeding." To be serious, criteria such as "predict the possibility of chemical reactions" cannot be satisfied even by some Doctors of Sciences! And "the formation of ability to predict, analyze, and assess the environmental impacts from household and industrial human activities associated with materials processing" is a task to be accomplished by entire specialized research institute, rather than by schoolchildren...

## Church and School

In an attempt to fill the ideological vacuum left after the "Moral Code of the Builder of Communism" was rejected in Russia, the authorities resorted to the Church (which preaches religious morals) in an attempt to compensate, at least partially, for the decline of morality, especially among young people.

Despite the fact that, according to the Constitution, the Russian Federation is a secular state where school is separated from the Church, in the post-Soviet period the Church, especially the Russian Orthodox Church and Islam, tend to exert ever increasing influence on many government institutions, including secondary schools. In television programs we can see worships attended by national leaders and consecrated nuclear missile submarines. It was suggested that theology be listed among the scientific disciplines controlled by the Higher Attestation Commission, etc. Apparently, religion in Russia enjoys resurgence: The pendulum of the authorities' attitude toward the Church swung from severe persecution (1918–1970s) to the opposite direction, with the result being the today' "excesses."

What kind of harm is inflicted by penetration of religion into schoolchildren's consciousness? Considering the fact that all natural sciences are underlain by materialistic worldview and do not tolerate any compromise with idealism, the penetration of religion into the thinking apparatus (immature in school-age children) leads to an irresolvable internal conflict.

Religious thinking is dogmatic; it is totally incompatible with the scientific thinking whose capabilities are to be developed in children during their secondary school study. The penetration of religion into school must be stopped. As shown by historic experience, highly moral individuals can be brought up on the atheistic basis as well.

To conclude, the goals of the currently pursued Russia's modernization policy can be achieved only with scientists and engineers not just competent in their sphere but proactive, being able to set and accomplish nonconventional tasks.

Of critical importance for these goals is implementation of a competence-based approach to learning. The issue of key competencies is currently the subject of much discussion all over the world. Of particular significance for modernization of the Russian education system is the development of competences, including knowledge and skills, needed by learners for their productive activities. The competence-based education implies the learner's mastery of sets, rather than of individual items, of knowledge and skills. Accordingly, the training methods need to be modified, or more precisely, defined in a different way.

The above-said suggests that it is essential that effective measures be taken in the educational sphere in order that Russia's positions of a strong and an independent state can be secured. Implementation of these measures should not be postponed, but there should be no hurry. A program for the next five, and ten, years should be developed, whose objectives, tools, and methods of implementation could be clearly defined on the basis of results of a mandatory preliminary referendum.

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