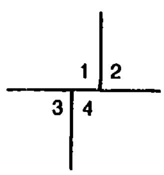
Innovations in Science and Mathematics Education in Schools in the Soviet Union



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Innovations in Science and Mathematics Education in Schools in the Soviet Union

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Preface

The present volume is an addendum to *Science and Mathematics Education in the General Secondary School in the Soviet Union*[1]. As mentioned in the Preface to that document, school science and mathematics are undergoing constant revision, which is the reason for the publication of this update.

Unesco wishes to thank the authors and the USSR Commission for Unesco for having prepared this addendum. The views expressed in the text are those of the authors and not necessarily those of Unesco.

1 'Science and Mathematics Education in the General Secondary Scool in the Soviet Union', Paris, Unesco, 1986. 211 pp. (Science and technology education, 21.)

Contents

Background

The reform of general secondary school education and vocational training in the USSR aims at further improving quality and bringing them into line with social demands. The reform raises the scientific level of school subjects to meet the demands of accelerating scientific and technological progress, strengthens the role of school subjects in shaping scientific world outlook, radically improves students' knowledge, improves polytechnical education and equips students with necessary practical abilities and skills.

Achieving the first aim has involved reworking curricula to make them reflect present-day issues by paying more attention to the role of methodology in science and by structuring the contents of general subjects on the basis of scientific theory, as well as through the introduction of a new subject, *Fundamentals of informatics and computing*, compulsory for all students in grades IX and X.

Achieving the second involved demonstrating the dialectical links between theory and experience, acquainting schoolchildren with the stages of scientific epistemology (i.e. to proceed from summarizing facts to framing a hypothesis and from theoretical conclusions to their experimental verification and practical application) and summarizing knowledge in the shape of a present-day picture of the world. Considerable effort is made to show the increasing role played by science in technology, technique, production and in the acceleration of scientific and technological progress.

In order to imbue students with a deeper and more enduring knowledge, unnecessarily complicated study material has been eliminated from school programmes and the structure has been made less detailed. School syllabuses indicate the basic knowledge and skills to be acquired and the standards to be met; they indicate useful interdisciplinary links and recommend lists of methodological literature as well as learning aids.

The polytechnical education of students is improved while the importance of theory as the scientific basis of modern industry is demonstrated, using examples of the application of science to the national economy. In addition, the following methods are utilized:

The introduction of generalizing themes showing the scientific basis of major trends in scientific and technological advances; students' acquaintance with some professions.

Equipping students with practical skills in preparation for working life.

Acquainting students with labour protection measures, industrial safety provisions, ecology and the protection of the natural environment.

Encouraging students' inventiveness, research ability and design talent through laboratory exercises and workshop activities.

Certain revisions in the structure and content of school mathematics, physics, chemistry and biology programmes are due to changes in the curriculum, the lower primary school enrolment age from (7 to 6), new general subjects, vocational training and socially-useful labour, and eleven rather than ten years of schooling, giving the following structure:

primary school: grades I to IV
incomplete secondary school: grades V to VIII
secondary school: grades IX to XI

The school reform provides for a single unified level of general education and new syllabuses in which a minimal level of knowledge in various subjects is specified. Another aspect that has been developed concerns schools and classes with extended programmes in some subjects, optional courses and out-of-school assignments, in order to cope with schoolchildren's individual interests and inclinations. Time is set aside in the school timetable for all kinds of additional classes: two hours a week in grades VIII and IX and four hours a week in grades X and XI.

Soviet schools offer three types of optional courses.

Advanced level courses co-ordinated with the main programmes, giving deeper knowledge in all subjects and;

Special courses of an applied character aimed at acquainting students with the ways and methods of practical applications of scientific knowledge.

Special courses in certain specific scientific and technological subjects or trends of scientific and technological progress.

The necessary conditions are created to arouse students' interest and inclinations and to bring their optional studies into line with the vocational training introduced in secondary school.

All these changes are directed towards benefiting the national economy and at the same time satisfying the demands of both students and their parents.

Mathematics

The reform's main underlying motivation is the qualitative improvement of the educational process, in every subject. Today, with the integration of general and vocational schools, mathematics has become one of the most important elements in students' vocational training. A thorough grasp of the basics of the school mathematics course is essential for success not only in those fields where mathematics is widely used but also in those where more elementary knowledge and skills are required. In the latter, mathematics contributes to the students' general culture.

Today when each general school student must orient himself as a function of his future occupation, the role of school subjects in general and professional education is changing radically. Prior to the reform, all school subjects were viewed as the necessary sum of the knowledge and skills which, being acquired by the student, benefit his or her intellectual, emotional and psychological development. Good knowledge of all school subjects ensured admission into an institution of higher education. Should the school leavers fail their entry exams or have no wish to continue their education, they could choose any job. Their work choice, however, might not be the right one, since at the time of leaving school, they were not in a position to evaluate their own abilities and to recognize their interests. It took young people a long time to become successful, fully-developed social participants in their society. The general school reform includes measures directed towards overcoming this shortcoming; it introduces young people to socially-useful productive labour; it introduces occupational counselling; it creates opportunities for initial vocational training; and it introduces new courses such as *Fundamentals of informatics and computing* and *Ethics and psychology of family life*. The above explains in part the reasons behind the modernization of traditional subjects, first of all mathematics, which is concerned with both practical and polytechnical applications. Fortunately the mathematics course for grades I to X, adopted shortly before the reform, has remained virtually unchanged.

Under the reform, children begin school at the age of 6 instead of 7, which means that primary school gains one year from below and comprises therefore four years. This extra school year makes it possible to redistribute the same study load more evenly in primary school and to ensure a thorough grounding in the relevant mathematical skills. Those children who now begin school at age 6 will by grade V have the same age as those who started school at 7 and had only three years of primary school. One result has been avoiding the need to review the contents of mathematics courses in grades V to XI in order to bring them into line with age level. Certain shifts in the study material among mathematics courses have been made in order to avoid repetitions and overly complicated topics (unnecessary propaedeutics of algebraic and geometric formulae in trigonometry, etc.). This made it possible to provide some time for review at the end of each grade as well as each stage (grades V and VI, grades VII to IX and grades X and XI).

Thus arithmetic today is studied in grades V and VI. Exponential function and logarithms are no longer treated on two levels; they are now part of the grade X course. This measure freed extra hours in the grade IX mathematics course for part of the trigonometry material (calculations and transformations). The need to make the mathematics course more compact and to provide geometry and physics with the necessary trigonometic apparatus lay behind this redistribution of study material. The topic *Trigonometric expressions and their transformations* falls naturally within the algebra syllabus, a main concern of which is indentity transformations. While studying this topic, students are given an opportunity to apply previously-acquired rules of identity transformations to new expressions. The trigonometry course aims at familiarizing students with the basic formulae and teaching them to use these formulae in simple transformations of expressions.

Trigonometric expressions and their transformations consists of three parts: trigonometric functions of an angle, basic trigonometric formulae and addition formulae and their corollaries. Thus in the grade IX geometry course less time is now spent on trigonometry when the Pythagorean proposition is studied. Attention is concentrated on developing the ability to use sine, cosine and tangent of a sharp angle for resolution of right triangles. The following basic trigonometrical identities are supposed to be examined since they are used in sine and tangent theorems.

$$sin^2\alpha + cos^2\alpha = 1$$

$$tg\alpha = \frac{sin\,\alpha}{cos\,\alpha}$$

Because the new syllabus enlarges topics while reducing their numbers, the manner in which material is set forth gains in consistency and method, important for its scientific background. This is also important from the practical point of view: experience showns that whenever similar material is split up (e.g. logarithms in the present syllabus), teaching in each case must be started anew and requires many hours. The new syllabus saves these hours for developing students' basic skills and abilities.

The new grade XI geometry syllabus does not consider questions related to vectors in space; they are covered at the end of solid geometry.

The topic of approximate calculations is distributed throughout the algebra course in grades VII, VIII and IX. In grade VII, the notions of absolute error and the accuracy of approximations are introduced; in grade VIII, students learn to evaluate expressions by the method of limits and are introduced to notions of relative error, standard number and recording approximate values of numbers; and in grade IX, they learn practical methods of approximate calculations.

When the question of the polytechnical orientation of the mathematics course was considered, it was thought advisable that students should come to understand the wide possibilities of mathematics application in various spheres of human activity. This is only possible when they learn to apply their mathematics as well as other skills to practical ends. Prior to the reform, the mathematics syllabus had been modernized; in particular, vector methods in proving theorems and solving problems, and notions of the definite integral of a function and its derivative had been introduced. This gave students better insight into the spheres where mathematics is used.

The polytechnical orientation of the mathematics syllabus requires electronic calculators, i. e. industrialization of calculations at school and improvement in problem-solving. The new mathematics syllabus acquaints students in grades V and VI with the use of calculators, with their history and with performing arithmetical operations with whole numbers and fractions.

Students in grade VIII will learn to do operations with approximate values on electronic calculators. In the grade IX algebra course, electronic calculators of a more advanced level will be mastered and students will develop their techniques further, learning to find the values of functions and to use the memory of electronic calculators; a rational order of computation becomes a special topic for discussion; and problems involving exact and approximate data are offered for solving.

With the introduction of a new topic, *Fundamentals of informatics and computing*, the school mathematics syllabus has acquired a more applied and polytechnical character. Shoots of logical thinking culture of a future mature adult can be recognized in this course; with the help of it, workers engaged in different fields of production will be able to unite their efforts for the solution of complex tasks; they will be able to communicate with each other and with the electronic computer in a common language of algorithms.

School informatics is based on three fundamental notions: information/algorithm/electronic computer. Their common feature is the modern technique of automatic information processing. It is precisely that system of notions that fixes the compulsory level of theoretical knowledge for schoolchildren.

In order to prepare students in grades X and XI for *Fundementals of informatics and computing*, the notion of algorithm appears in grade IX. In fact, the whole algebra course provides a solid basis for it. The rules of operations with polynomials and algebraic fractions, and of solving problems, inequalities and systems, mastered step by step within the algebra course, present layouts of algorithms. At the end of grade IX, the term 'algorithm' is explained and simple block diagrams are charted. In this way, students are prepared for the grade X informatics and computing course.

The school mathematics programme is by no means rigid, immutable and fixed. It reflects the content of mathematical education which is directed towards solving the tasks faced by our schools at the present stage of social development. A characteristic of present-day Soviet society is a new appoach, discernible in all spheres, to the acceleration of scientific and technological progress based on the application of electronic computers. That is why the mathematics education of school leavers and their psychological development must enable them to meet successfully the challenges that will arise in their working life. In the future, too, one of the main problems of school mathematics will be that of evaluating the practical significance of mathematics methodologies. The polytechnical orientation of the mathematics programme can be enhanced only when obsolete methods are replaced by modern methods. In this case, mathematical education can be brought closer to the practices of modern Soviet society.

The modernized mathematics syllabus is based on the previous syllabus, which has been in use since the 1981-1982 academic year. While preserving the characteristic features of the latter, the modernized syllabus comprises new sections, *Inter-subject links* and *Recommendations on correct estimations of pupils' knowledge and skills*. Two main sections, *Requirements to the mathematical education* and *The content of education* lay down the content obligatory for all students. The section *Thematic planning of the study material* is addressed to the authors of prospective textbooks.

Requirements to the mathematical education provides a list of skills and abilities obligatory to each stage of the mathematics course. These skills are of primary importance since they form the core of mathematical knowledge necessary both for further studying of the subject and related disciplines, and for general and vocational education.

Aspects of the latter section are considered in greater detail in the section *The compulsory results of education*; a system of problems for each stage is also provided.

Problems have been carefully chosen after a thorough examination of the syllabus itself, of interrelated topics and of educational experience to bring them into line with the level of mathematical education established by the new syllabus. The problems mainly concern alogorithms, methods and fact, and their simple standard combinations. In other words, they set the minimum level of mathematical education below which students are regarded as being mathematically ignorant.

The obligatory level of education implies that students must attain a clearly-indicated minimum standard. At the same time, conditions for a better mastering of the subject, for the maximum development of mathematics capabilities should be created.

With this aim in view, the school provides optional lessons in grades VII to XI. For grades VII to IX, we have a new mathematics curriculum today subdivided into two stages, *Beyond the pages of a textbook* and *Mathematics mosaic*. Themes of optional courses for grades X and XI have also been elaborated.

Physics

The physics course in the eleven-year school consists, as previously, of two levels. Roughly speaking, the first level deals with kinds of matter, physical phenomena, fundamental notions and certain laws (the structure of matter and mechanical motion in grade VII; thermal phenomena, electromagnetic and luminous effects in grade VIII). Second level students study mechanics, molecular physics, fundamentals of thermodynamics, electrodynamics and quantum physics.

The scientific background of the physics course has improved as a result of structural changes, a fuller generalization of study material on the basis of fundamental theories, introducing certain important scientific concepts earlier and including some topics, which, though not covered by the present programme, are valuable for scientific and technological progress.

Fundamental theories have assumed a more general character and the quantity of study material has been reduced, as well as the number of topics (from twenty-four to sixteen). The major structural change involves shifting material from the second to the first level, for example, the laws of geometrical optics from grade XI to grade VIII. This will improve inter-subject links (optical instruments occur in many school courses), make the first-level physics course more interesting and help to shape a scientific way of thinking. At the same time, other topics must somehow be cut back. Reductions will be mainly made at the expense of electromagnetic induction, which will in the future be dealt with in detail in grade XI.

The shifting of mechanical oscillation and waves from grade XI to grade IX, and its incorporation into the mechanics course, is made possible by transferring statics to the first level.

Generalization of study material on the basis of fundamental theories has a number of methodological advantages: it provides schoolchildren with better insight into the role of experience as a source of knowledge and the criterion of its truthfulness, into the correlation between theory and practice; it reveals a field of physical reality described by a theory and the limits of practical application of the latter; and it enables students to construct a scientific picture of the world.

A significant role in the new physics programme is played by questions of methodology, particularly those of correlation between theory and practice. Fundamental experiments (for example, Ioffe-Millikan, Rutherford and Lebedev), notions (for example, irreversibility of thermal processes, n-type conduction, coherence, corpuscle wave dichotomy, Einsteinian relativity, etc.), laws (for example, relating to mass and energy, to conservation, etc.), and practical applications of theoretical conclusions (for example, the lift of an aircraft wing, the efficiency of heat engines, the magnetohydrodynamic generator, quantum-mechanical oscillators, nuclear reactor, etc.). A high theoretical standard of the school physics course adds to students' scientific world outlook and their communist education.

The school programme also acquaints students with the role played by physics in the acceleration of scientific and technological progress: Soviet achievements in exploring outer space, the significance of heat engines for the national economy, heat engines and protection of the natural environment, the role of V. I. Lenin's ideas in the electrification of the USSR, the role of Soviet science in the creation of quantum-mechanical oscillators, advances and prospects for nuclear power in the USSR, and physics and the scientific and technological revolution.

The polytechnical orientation of the physics course is realized along the following lines.

The significance of theory as the scientific basis of modern industry is demonstrated.

Examples of the application of physics in the national economy are given (some thirty modern technological devices have been added for consideration in the new syllabus).

Fundamentals of major trends of scientific and technological progress are elucidated.

Students are equipped with practical skills for working life.

Students' creative abilities are developed.

When learning such notions as weight, mass, density, elastic force, etc. in grade VII, students familiarize themselves with the properties of widely-used substances and materials, for example, steel, pig iron, aluminium, concrete, glass, plastics, water, air and combustible gases. Their properties can be learned both theoretically and practically, during laboratory exercises, with the help of such simple measuring instruments as a ruler, scales and balances, a dynameter, a measuring glass, etc. (Some information concerning processing technology is transmitted to children receive in the next grade when they study melting, solidification and crystallization. In grade X, they will acquire a more thorough knowledge of the properties of solids, liquids and gases while studying methods of liquefaction, wetting, surface tension, elasticity, strength and plasticity.) Students in grade X will learn more about hydraulic presses, jacks, pipelines, pumps, locks, pontoons, levers, blocks and other mechanisms and devices.

The grade VIII physics course acquaints students with the use of internal and electric energy (heat and electrical engines), means of heat transfer, heating (hot-water heating) and refrigeration, and the use of electric current (electric appliances and electric equipment, electromagnets, and so on) as well as with the properties of light and optical instruments (the eye, spectacles, the photographic camera and the projector).

The grade IX mechanics course which considers various models of motion (straight-line, curvilinear, rotatory, reciprocate, uniform, irregular, uniformly accelerated and oscillatory) as well as bodies' regular inter-action and changes in their movement is very important for polytechnical education. The programme covers important practical elements of mechanics, such as satellite orbits, circular velocity and jet propulsion. Laboratory exercises and problem-solving acquaint students with numerous examples of mechanization, both domestic and industrialized: means of transportation, agricultural technology, rockets and missiles, household machines and automatic equipment. All this material is generalized in *Mechanics and mechanisms of production.*

In grade X, students study the principles of operation and efficiency of heat engines; they begin a course on electrodynamics (which continues in grade XI) which has a broad practical application. In grades X and XI, they examine electrical measuring instruments, capacitors, loud-speakers, magnetic recordings of sound, temperature-sensitive resistors, diodes, transistors, cathode-ray tubes, electrolysis, magnetohydrodynamic generators, transformers, transmission and application of electric power, electric resonance, modulation and detection of electromagnetic modes, radiolocation, radio communication and television.

This applied material is studied in lessons dedicated to the fundamental laws of electrodynamics and their practical application and to means of communication and to advances and prospects for power engineering in the Soviet Union.

Quantum physics, which is in the vanguard of technology, concludes the syllabus. The course covers: vacuum and semi-conductor photocells, spectrum analysis, lasers, detection methods of radio-active radiation, nuclear reaction, radio-isotopes, chain reaction, nuclear reactors and thermonuclear fusion.

Lessons dealing with advances and prospects for nuclear power in the Soviet Union provide overall material on nuclear physics. In the final lesson, the practical application of physics and its role in scientific and technological progress are reviewed and summarized.

In the new physics programme, considerable attention is devoted to students' practical training. The programme incorporates forty-one teacher-performed laboratory exercises and thirty practical laboratory assignments. Students learn to use more than twenty different instruments and devices. They perform experiments independently, from preparing a plan for an experiment, through assembling a technical set-up, reading instruments, carrying out observations, drawing tables and plotting graphs, to evaluating and interpreting errors in measurement.

It is well-known that invention and rationalization are vital for the acceleration of scientific and technological progress. Young people should therefore be prepared in this direction at school, which involves equipping them with both practical skills and research methods. Laboratory exercises with various assignments can be of help: graduation of instruments (dynamometers, spectroscope, etc.), study of the characteristics of devices such as semi-conductor diodes and transistors, determination of certain physical constants (free-fall acceleration, the rigidity of a spring, the coefficient, friction and specific resistance of glass), and the assembly of very simple devices and parts of engineering instruments (electromagnet, relay, models of an electric motor, a transformer and a radio receiver, as well as some parts of automatic devices and computers).

There is a wide range of opportunities to develop students' creative abilities as they master research methods. This is possible because it is the teacher himself who choses laboratory exercises and assignments as well as their number. It is recommended that preference be given to those involving students' carrying out a research project on their own or designing devices to achieve a specific effect.

As is the case in other disciplines, there are new physics programmes for optional courses: physics for advanced learners, the Earth and the Universe (grades VII to XI), fundamentals of cosmonautics (grades IX and X) and physical and technical modelling (grades IX to XI). The latter aims specifically at developing creativity, for example, modelling and testing. The course comprises such topics as engines, transmissions and working machine parts, elements of automatic devices, automated production, advances of physics and technological progress, and invention and rationalization in the USSR.

New physics programmes for the eleven-year school provide advantages and have considerable potential for the further improvement of education.

Chemistry

The new curriculum, which has been described elsewhere[2], stipulates that chemistry be taught in the final four grades: three hours per week in grade VIII, two-and-a-half in grade IX and two in grades X and XI. The number of hours has been reduced from ten to nine-and-a-half and the general level of the course raised to meet the demands of changing conditions. How was this achieved?

The previous syllabus was organized so that inorganic chemistry (with the general concepts of chemistry at the beginning of the course) and organic chemistry which followed it, had to be studied at different theoretical levels. Inorganic chemistry was taught in the middle grades and thus complicated material on atomic structure and regularities of chemical reactions could not be taught owing to the students' relatively low level of knowledge. Organic chemistry, especially the structure of substances, was studied at a higher level. In grade XI, twenty school hours were alloted to the generalization of the studied material, but these lessons were in fact more a general review of the completed course preparing for the final examinations and, as a result, students' knowledge therefore remained incomplete as far as theory was concerned: inorganic and organic chemistry were largely disconnected in their minds, each having its own laws and theories. Notions of the material unity of substances in nature and of the general regularities of a chemical form of motion of matter were not sufficiently developed.

The new syllabus includes inorganic chemistry within the framework of lower secondary school, that is, in grades VIII and IX. Students will receive a comparatively full set of knowledge on the main concepts and laws of chemistry and the most important substances, which will allow them to continue their chemical education in higher grades or other secondary-level establishments of education such as vocational or technical schools. Since the number of hours allocated to chemistry has been reduced, secondary material and even some theoretical questions are being eliminated or dealt with less fully: the examination of electron sublevels (*s* and *p* electrons) and the atomic structure of the large period elements has been excluded; the interpretation of the concept 'hydrolysis' and of the theory of reaction rates has been simplified; peculiarities of the reactions of oxygen acids with different materials are not discussed; problems of stoichiometry are distributed to different topics; and so on. At first sight, the above seems to be in direct contradiction to the aim of raising the scientific level of education. However, one should bear in mind two circumstances. First, the exclusion of comparatively difficult secondary material makes the course more understandable and allows the teacher to concentrate on the principal, necessary elements. Second, the main extension of knowledge will take place in the final stage of chemistry, grade XI, where students' ages and abilities facilitate successful teaching.

For this purpose, a forty-three hour course of general chemistry is introduced for a graduating class which involves extending theoretical knowledge in chemistry, and using this as a basis for generalizing previously studied inorganic and organic chemistry material. For instance, electron structure of atoms, formation and properties of different kinds of chemical bonds and molecular geometry are studied more fully; peculiarities of atomic structure of the large period elements are discussed; and substance properties are correlated not only with an atomic structure and character of bonding but also with a type of crystal lattice. The regularities selected in the periodic table of chemical elements may be seen more clearly. The new syllabus also covers the theory of reaction rates, catalysis, and chemical equilibrium and its shifts, as well as information on the substances of constant and variable composition, compounds, colloid systems and elemento-organics.

[2] 'Science and Mathematics Education in the General Secondary School in the Soviet Union', Paris, Unesco, 1986. (Science and technology education, 21.)

The analysis of new questions as an extension of the earlier-learned concepts, laws and theories, in combination with the factual material in inorganic and organic chemistry known to the students, guarantees systematic chemical knowledge of a sufficiently high scientific level.

Generalization in the final year entailed shifting organic chemistry forward, to the grade X and early grade XI syllabus. This also provided an opportunity to overcome serious weaknesses in terms of existing relations among various subjects such as the situation in which the functions of carbohydrates, fats and proteins in organisms were studied in general biology before the students encountered the structure and properties of these substances in chemistry classes. Post-reform organic chemistry covers the above-mentioned substances within the chemistry syllabus before the chemical organization of a cell and the processes which take place in it on a molecular level are considered in biology. Furthermore, for the first time, the chemistry syllabus includes information on nucleic acids, without which it is difficult for the students to understand the process of synthesis of proteins in an organism and mechanisms of transmitting hereditary characteristics. The general tendency of linking of chemistry and biology syllabuses and the striving to elucidate the material foundation of life phenomena permit us to shape more successfully a modern scientific picture of the world in the students' consciousness, which is, as mentioned above, one of the demands placed on contemporary school science and mathematics education.

The inclusion of nucleic acids (their composition, nucleotide structure, RNA and DNA, complementary principle) required, in turn, more material on monosaccharides (the structure of ribose and desoxyribose) as well as data concerning heterocyclic compounds (pyridine and pyrrole as representatives of heterocyclic nitrates, pyrimidine and purine bases). The study of the above improves students' grasp of the main concepts of organic chemistry and, at the same time, explains the diversity of natural organic compounds.

Under the new requirements, further development of the polytechnic principle of education is important. Previously, polytechnically-oriented chemical education mainly involved familiarizing students with the most important chemical industries and major related tendencies of the national economy. This aspect of polytechnization, carefully elaborated methodologically at one time, now requires deeper and more detailed interpretation of production processes. Other aspects of the polytechnization of the chemistry syllabus also require development. While studying various chemical industries (the list of which in the school curriculum remains basically the same), special stress will be laid on their scientific foundations. The descriptive study which often existed before should be replaced by an analysis of industries concentrating on the technological application of scientific knowledge. This means that the approach partially used earlier when the scientific foundations were considered before discussion of a technological process, should now become a generally applied principle. For example, the construction of an ammonia synthesis column and a general technical chart of its production may be analysed only after the given reaction has been discussed on the basis of the regularities of chemical equilibrium shift and the optimal conditions of its industrial implementation determined; when studying the cracking of petroleum products, the conditions and mechanisms of rupture of chemical bonds, the significance of catalysis and conditions of an uninterrupted process will be cleared up, and only on this basis will the construction and operation of a setup for catalysis cracking be considered.

The principle of the study of chemical industries *from the laws of science to their technological implementation* helps students to understand the role of science as society's immediate productive force and to obtain information about industries, not in the form of separate and uncoordinated bits of data, but as general scientific principles, so that they will be learned better and more permanently.

Besides the scientific foundations, other aspects of modern production need to be discussed in chemistry. The study of chemistry, similar to that of other school subjects, was always closely linked in the Soviet school system with the life of the country. The Soviet Union today pursues a course of accelerating scientific and technological progress, intensifying production and upgrading it qualitatively. Under these conditions, while solving production problems, the questions of the complex use of raw materials, economics, environment control and creation of new technologies acquire new significance. Students must be properly oriented in production development trends and be inclined in the future to participate actively in scientific and technological progress. In the current pedagogical process, these aspects of production are analysed not as supplements to the main content but integrated into it, as a means of an object's study. For instance, while studying sulphuric acid production, students compare the economic aspects of obtaining the product from pyrite, natural sulphur, and metallurgy and oil processing wastes; they discuss the main stages of the technological process and ways of refining waste gas from harmful effluents and consider the possibilities for improving production. When oil-refining is studied, stress is laid on decreasing the role of oil in the country's fuel and energy balance, and its increasing use as a raw material for chemistry. Students are also introduced to new oil syntheses based on no-waste limited-stage technologies.

The analysis of chemical industries from different sides taking into account the prospects for their development, is, like the study of developing scientific notions, a manifestation of the dialectical approach to the solution of the methodological problems of teaching chemistry.

Production processes are an important component of the polytechnical content of the chemistry syllabus, but not the only one. The familiarizing of students, more circumstantial than before, with the scientific foundations of creation and the practical application of technology materials, is a new aspect of their polytechnical training. It is relevant in this respect that, in the world of work, students will come across substances and materials more often than chemical processes. In order to be able to use them successfully, correctly and rationally, they must learn and understand the structural principles of the typical materials and the influence of structure on properties.

The significance of materials in modern production grows swiftly. Electronics, electrical engineering, cosmonautics, laser technology, and modern mechanical and instrument engineering, all branches of the national economy, continually demand new materials of high quality. There are now, for example, ceramic materials which combine high strength and hardness with sufficient elasticity, which allows their use for manufacturing components of the most complex constructions and devices. The successful development of organic synthesis permits the creation of various plastics, technical fibres and rubbers with a wide variety of properties. Great successes have been achieved in inorganic and organic-based composite materials.

In organic chemistry, therefore, special emphasis is placed on construction materials, ceramics and alloys. A special subject, *High-molecular substances and polymer materials based on them*, was introduced at the end of the course replacing the uncoordinated material on the individual polymers. To single out information about polymers thus follows the principle long-established in the methodology of chemistry: polytechnical data are given not only along with the basic material but also as separate themes, permitting detailed consideration of solutions to major economic problems by means of chemistry. Now polymer materials rank with other school topics, such as mineral fertilizers, metallurgy or refining combustible fossil fuels.

Treating this topic at the end of the organic chemistry course, after students have mastered the main theoretical scientific questions, especially in the field of the structure of substances, and have become acquainted with the most important classes of organic compounds, allows polymers to be considered within their own system, on a sufficiently high level. First, general problems of high-molecular chemistry are discussed, that is, the concepts of 'polymer', 'monomer', 'structural link', 'polymerization degree', peculiarities of the molecular mass of polymers and geometric structure (linear, ramified, spatial, crystal and amorphous structure), then peculiar properties of polymers, conditioned by their structure. Here the students also learn about the main methods of synthesizing high-molecular substances: the processes of polymerization (free radical mechanism) and polycondensation.

Furthermore, the most important group of polymers is studied on the basis of this general theoretical knowledge. Among plastics, polyethylene (of high and low pressure), polypropylene, polystyrene, polyvinyl chloride and phenolformaldehyde plastics are studied, and among synthetic fibres, polymid and polyester; synthetic rubbers are represented by stereoregular isoprene and divinyl rubbers.

Polytechnical knowledge about technological processes and materials, acquired by students in inorganic and organic chemistry is generalized in the grade XI general chemistry course. This course is organized on the basis of a consistent awareness of the need to apply the principle of relating theory and practice. The aforementioned extension and generalization of scientific chemical knowledge contained therein leads students to important conclusions which help them to recognize chemistry's place among other natural sciences, to understand its contribution to shaping a contemporary picture of the world and our scientific materialistic world outlook. The generalization of polytechnical knowledge allows a clear understanding of the role of chemistry in the development of the national economy in the solution of tasks set by the Party for accelerating the county's social and economic development, an important contribution to the ideological education of schoolchildren. The following list is given by way of illustration.

Scientific foundations and general technological principles of chemical production.

Trends of scientific and technological progress: complex use of raw materials, co-operation of production, organization of uninterrupted wasteless technologies with a limited number of stages, increases in unit capacity of devices, economy of material, raw material, energy and labour resources.

Creation of new materials for modern technology.

Environmental control against production waste pollution.

Characteristics of major chemical professions.

The generalization is carried out also to reveal the tasks set before chemistry by the Energy and Food Programme of the USSR.

In conclusion, let us give a brief outline of the characteristics of the optional chemistry courses and the content of education in those classes and schools with an emphasis on chemistry. Both optional chemistry lessons and classes and schools with an emphasis on chemistry have been further developed. They are intended for students with special interest in chemistry who wish to extend their knowledge and to be better prepared for practical activities connected with chemistry. Optional courses are offered in schools in general as a supplement to the compulsory general chemistry course. The classes and schools with special emphasis on chemistry tend to be located close to large-scale chemistry industries, chemical establishments of higher education, etc. They are very important in preparing future specialists of a scientific and practical profile.

The corresponding school syllabuses have been worked out for optional courses and classes and schools with an emphasis on the subject.

There are three types of optional school courses.

1. High-level optional courses (grades VIII to XI). Their aim is to extend the knowledge acquired by students in the general chemistry course, and so they follow the latter in the content of their work.
2. Applied optional courses of which aim to prepare the students for work in agriculture, industry and chemical laboratories: *Chemistry in agriculture* (Grades IX and X); *The fundamentals of chemical analysis* (Grades IX and X); and *Chemistry in industry* (Grades X and XI).
3. Optional special courses, which are meant for the extension of theoretical and experimental capabilities of students in different spheres of chemistry: *Chemistry of metals* (Grade IX); *Chemistry of polymers* (Grade XI); *Elements of bioorganic chemistry* (Grade XI); *The fundamentals of basic chemistry* (Grade XI); and *The theory of disperse systems* (Grades IX and XI).

For the classes and schools with an emphasis on chemistry, Table 1 shows that part of the curriculum which includes chemical disciplines.

Table 1

Subjects	Classes and number of hours per week			
	VIII	IX	X	XI
Inorganic chemistry	5	3.5	-	-
The fundamentals of chemical analysis	-	1	3	-
Organic chemistry	-	-	2	3
Chemistry in industry (or Chemistry in agriculture)	-	-	1	2
The generalizing chemistry course	-	-	-	1
Total	5	4.5	6	6

Naturally, the standard chemistry course is not studied in such classes and schools. It is also obvious that, having significantly more hours for chemistry than do their counterparts in ordinary schools (twenty-one-and-a-half instead of nine-and-a-half), students are well-prepared for further education and future practical activities.

Biology

The tasks advanced by the school reform, of raising an ideological-theoretical level of education and the quality of students' knowledge and improving their preparedness for future work, as well as changes in the curriculum, required further improvement of the content of general secondary school education and elaboration of its aims and tasks.

One of the main trends of the modernization of secondary school biology education is the singling out of the leading ideas and major notions, which takes form in the creation of a unified, integrated biology course, in which the traditional division into four isolated courses (botany, zoology, human anatomy, physiology and hygiene, and general biology) has been abandoned. 'Biology' is now studied at school as a single subject consisting of several interrelated sections.

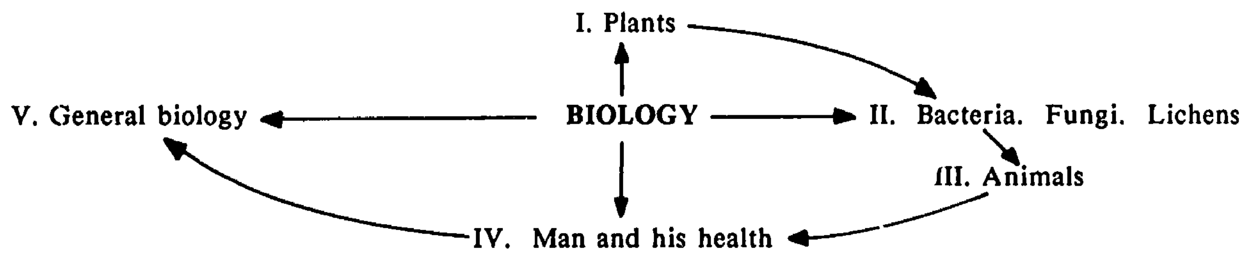

Fig. 1. The structure of the school subject 'Biology'

The abolition of the old courses and the singling out of new sections allowed the content of secondary school biology education to be brought into line with the modern level of development of the science of living nature. According to data presented by the leading specialist in systematics (A. L. Takhtajan), bacteria and fungi are the independent kingdoms of animate nature, parallel to plants and animals, and should not be reckoned part of the plant kingdon. In the new programme, therefore, fungi and bacteria are dealt with in an independent section.

The reflection in the former programme of botany, zoology and other courses required the completeness of each course and sufficiently full presentation in them of the fundamentals of those spheres of science. The inclusion of agricultural plants and animals in these courses was highly contested as agricultural forms are not studied either in botany or zoology courses.

At the same time, the solution to the task of preparing students for future life, for work in agricultural production, requires including in the school biology course the scientific fundamentals of production in which biological systems are used, that is, modern technology of growing plants and breeding animals, selection and biotechnology. The creation of a single biology course permitted the inclusion of 'agricultural plants' in the section *Plants*, which present the scientific fundamentals and technology of growing the most important cultured plants, with due regard to ecological factors. In *Bacteria. Fungi. Lichens*, the problem of bio-technology is considered, specifically the use of bacteria and fungi for producing vitamins, medicines and fodder yeast. *Animals* covers agricultural animal breeding and includes the prospect of an excursion to a cattle-breeding complex in order to familiarize the students with different branches of animal husbandry. *General biology* includes material on microbiological synthesis, genetic and cellular engineering, scientific foundations, and successes and prospects of the development of biotechnology.

The syllabus was drawn up according to new requirements. All its sections must be closely interrelated to ensure the subject's integrity. To meet this need, leading ideas were singled out and used for the integration of various fields of knowledge and the establishment of successive links among the sections. The following are the most significant for biology: evolution, multi-level organization of living nature, intercommunication of a structure and its functions, interlinks in biological systems as a basis of their integrity, interdependence between biological systems and their natural environment, and the relationship between theory and practice.

The concepts of evolution and multi-level organization are particularly important in establishing the logic of development of the major concepts. They determine the sequence of sections and the order of themes within the sections: first the organismic level of life is studied, then supraorganismic systems, first more simple, then more complex ones.

The idea of intercommunication of structure and functions is most completely understood through studying the organismic forms of life. The structure of cells, tissues, organs and systems of organs is analysed in terms of functions. The ideas of interlinks within biological systems, and between the latter with the environment, allow us to lead students to the concept of the integrity of these systems (cell, organism, species and eco-systems), to bring out destabilizing factors and to shape careful attitudes towards nature and humane consideration for every living thing. The interconnectedness of theory and practice is taught by showing the utilization of biological knowledge in the national economy, in production and in everyday life; this in turn helps to solve problems concerning occupational counselling for students, preparing them properly for the world of work.

Singling out the main concepts and their logical development in all the sections also guarantees the unity of *Biology* as a subject. The evolutionary, ecological and morphological-functional concepts should be called the main concepts. These complex notions include more simple ones, singled out in each theme, which the students must learn.

Improving the content of biology education is directed at a more consistent development of general biological notions in all sections of the course, their use as a basis for the formulation of philosophical conclusions, the formation of the scientific view of nature and conviction of the necessity to shape human activities with all due regard to the laws of ecology.

The teaching of evolutionary notions has been substantially improved in the new programme; knowledge of these notions is very important for shaping the students' scientific world outlook, their belief that the organic world develops in conformity with natural law. By familiarizing students as early as possible with the theory of evolution, explaining changes in the animal and plant world from a scientific position is facilitated. A definite step has been taken in that direction in the new syllabus. Where previously, while studying the diversity of plants, students were simply told about the historical development of the organic world, now they are introduced to the proofs of evolution, supported with examples from palaeontological findings and stages of development in the plant world. The development of the concept of evolution is supported by the arrangement of material about different types of plants in order of complication of the plant world from algae to angiosperms, and by excluding from this complicated world bacteria and fungi which, from the point of view of evolution, are not directly connected with plants.

The links between the sections *Plants* and *Animals* are established on the basis of evolutionary concepts. Since students have mastered questions of the historical development of the plant world, material in the section on animals can be arranged in the order of complication of the animal world; this material can be enriched by proof about evolution as a result of palaeontological and comparative-anatomical and embryological evidence of evolution. It also allows students to become familiar with Darwin's theory of the evolution of the organic world, to consider the main stages of the historical development of animals in the light of theory and to receive a scientific explanation.

The links with the section *Man and his health* are also established on the basis of evolutionary notions. The new syllabus directs one towards finding similarities in the systemic structure of organs of man and other mammals and establishing their kinship. At the same time, the syllabus brings out the difference between man and animals, conditioned by man's labour activities and the social character of human life, and substantiates conclusions about his biosocial nature.

In *General biology*, evolutionary concepts dominate; they serve as a basis for close links with all the previous sections, leading to their unity. In the concluding section of the course, evolutionary concepts are expanded and deepened: Darwin's theory of evolution is analysed more profoundly. It is used to explain biological phenomena such as the appearance of adaptation and the formation of species, and fpr criticism of anti-scientific views of the origins of plants, animals and man. The development of the organic world is considered in the light of the main evolutionary theory, which helps to relieve the course of the detailed description of pictures of the development of life on Earth and free time for the students to master the main knowledge and skills. The origin of man is analysed in the light of Darwin's theory of evolution and Engel's theory of labour; racism and social-Darwinism are criticised. The course concludes with an exposition of contemporary views of the theory of evolution.

The integrity of the course is achieved through a more consistent development of cytological notions which are part of morpho-functional concepts. When the students study the section *Plants*, they first learn about a cell, its structure and vital activities, and about the cellular structure of plants. The concept of cell and the cellular structure of organisms is developed while studying bacteria and fungi. Previously in the zoology syllabus, the formation of cytological concepts was interrupted. With the new syllabus, this inaccuracy is eliminated and in the section *Animals* students learn about the structural peculiarities of uni-cellular animals and a cell of a multi-cellular organism, as well as the cellular structure of animals. The link of the section *Man and his health* with the preceding sections is established on the basis of the study of the structure and vital activities of man's cells, of the structure and functions of different tissues. Knowledge of a cell and the cellular structure of organisms is extended and generalized in the concluding section *General biology*. Here students learn about the chemical organization of a cell, the structure and functions of its organoids, plastic and energy metabolism and transformation of energy in a cell, the role of a cell and DNA molecules in the reproduction of all living things, in supporting successive links between generations and in the manifestation of inherited regularities. Knowledge of the cellular structure of a plant, animal or human organism, as well as fungi and bacteria, takes the shape of the cellular theory at the final stage of biology. On the basis of cytological knowledge, students are led to conclusions concerning the material unity of animate and inanimate nature, the unity of the organic world.

The new course has an improved system of ecological notions by means of which closer links are established between the sections, and the students' careful, solicitous attitude towards nature is cultivated. The main ecological notions are introduced as early as the first year of biology, which ends with the theme *Plants and the environment*. In this section, questions are considered concerning the interrelationship of a plant organism and the environment, the concept of ecological factors is introduced and the connection is shown between plants and factors of animate and inanimate nature, as well plants' degree of adaptability to their life together with other organisms.

Furthermore, the ecological approach is used in studying the diversity of plant, animal and fungus species and more attention is paid to showing the place and role of species in nature and measures for their protection. The section *Animals* ends with the theme 'Natural communities', in which the concept of food chains is introduced and knowledge is generalized on the role of plants, bacteria, fungi and animals in the communities and on the influence of man's activities upon this system. When man is studied, they particularly stress the importance of his environment for his life and health, for normal functioning of his organ systems. In this section, ecological knowledge serves as a basis for the hygenic education of students. Ecological knowledge is developed and generalized in *General biology*; the complex influence of ecological factors, organisms' adaptability to nature's seasonal changes, ecosystems and their characteristic regularities, agrocoenoses and their increased productivity, the biosphere, circulation of substances and the role of an organic substance therein and the noosphere are introduced.

Thus the unified syllabus results in the students' acquiring an integrated structure of biological knowledge, a structure which develops with each school year and serves as a basis for shaping a scientific picture of the world, ecological and hygienic education, preparation for the future work and occupational counselling, and creative development.

Biology, however, is meant for the average student and does not provide the depth needed by those who wish to continue their biological education or go on to work in the branches of production in which biological systems are used. For this purpose, syllabuses are worked out for schools and classes with an emphasis on biology in which evolution, ecology, molecular biolgy, genetics, biotechnology and so on are delved into more thoroughly and more attention is paid to practical work. The time allotted to the study of biology in such classes is twice that allotted normally in grades VII and VIII and three to four times that in grades IX to XI.

Interest in the subject may also be satisfied by means of optional courses. At present, there are over ten optional courses, which have both a theoretical and an applied character and are expected to be covered in thirty-four or sixty-eight hours, while the basic course allots to similiar problems several hours only. Optional courses are introduced from grade VII classes with a emphasis from grade VIII.

Table 2. Biology in the general secondary school

Grades	General course	Classes with an emphasis	Optional courses
VI	1. Plants	-	-
VII	1. Plants 2. Bacteria. Fungi. Lichens 3. Animals	-	Plant life
VIII	3. Animals	Animals Plant life	Animal Life
IX	6. Man and his health	Man and his health	Physiology of agricultural animals and zootechnics. Physiology of man. The fundamentals of hygiene and sanitation. The fundamentals of ecology and environmental protection
X	5. General biology	General biology	The fundamentals of ecology and environmental protection. Physiology of agricultural plants and plant-growing. Physiology of higher nervous activity.
XI	5. General biology	General biology	Evolution of the organic world. Molecular biology. The fundamentals of genetics and selection. The fundamentals of biotechnology.

Thus, the solution to the problems of a school reform was aimed at the modernization of both the general biology course and the classes with a special emphasis on biology as well as optional courses. In other words, it was carried out in many aspects and affected the whole system of general secondary school biology education.