ISSN 1070-3632, Russian Journal of General Chemistry, 2013, Vol. 83, No. 6, pp. 1282–1289. © Pleiades Publishing, Ltd., 2013.
Original Russian Text © V.V. Eremin, E.A. Gudilin, E.A. Eremina, Yu.D. Tret'yakov, 2011, published in Rossiiskii Khimicheskii Zhurnal, 2011, Vol. 55, Nos. 5–6, pp. 77–84.

The Science Olympiad "Nanotechnology: Breakthrough into the Future"

V. V. Eremin, E. A. Gudilin, E. A. Eremina, and Yu. D. Tret'yakov

Lomonosov State Moscow University, Leninskie Gory, Moscow, 119991 Russia
e-mail: vadim@educ.chem.msu.ru; goodilin@inorg.chem.msu.ru; eremina@inorg.chem.msu.ru; yudt@inorg.chem.msu.ru

Received April 24, 2011

Abstract—The science Olympiad "Nanotechnology: Breakthrough into the Future," a new educational program of the Moscow State University devoted to nanoscience, was described. The Olympiad combines the best traditions of Russian science Olympiads for schoolchildren with the new educational trends: research competitions for young scientists, creative contests for all participants, and a well-developed distant learning system. The Olympiad covers all the main branches of nanoscience and all the existing nanotechnologies. Examples of original problems on chemistry, physics, mathematics, and biology for schoolchildren were given. The new educational technologies used in the Olympiad, including distance learning techniques, were discussed. All the materials of the "Nanotechnology: Breakthrough into the Future" Olympiad are freely and openly available electronically.

DOI: 10.1134/S1070363213060480

INTRODUCTION

The Traditional Olympiad System and Its Role in Modern Education

One of the major Russia's achievements in the realm of education consists in establishment of a system of schoolchildren Olympiads in natural sciences. In the chemistry domain, this system has been operative since 1938 (in its present form, since the time of the first All-Union Schoolchildren Olympiad in chemistry in 1967). Every year, chemical Olympiads of different levels, starting from secondary school level, attract nearly half a million participants. This widespread system allows the following important educational tasks to be addressed:

– identify and develop learners' creative abilities and interest in scientific activities;

– establish conditions for supporting gifted children and encouraging their intellectual development;

– promote scientific knowledge; and

– enable realization of the creative potential of the best students and teachers.

However, this remarkable system is not ideal. First, though creative, this is still a competition, and it is not infrequent that participants sacrifice their scientific interests for competitive spirit, and the legitimate desire to gain extra points prevails over the pursuit of interesting solutions to Olympiad problems.

Second, though simulating the scientific activities, Olympiads in chemistry promote development of only one type of giftedness, specifically, the ability to quickly and correctly solve a clearly defined problem whose solution is known a priori. However, nature does not pose clearly defined problems: Problems are to be sought for and found, and it is unknown a priori whether solutions to them do exist. Traditional Olympiads do not teach their participants how to solve such problems. There is a big difference between the modern scientific and Olympiad activities.

Moreover, vigorous development of information technologies has affected people's way of thinking and has inevitable implications for the educational system. Media resources and Internet technologies have entered the educational process at all levels, from secondary school to postgraduate study; distance learning is becoming increasingly popular; and a growing number of learners get provided with free access to diverse sources of information and, thereby, to all human knowledge accumulated. In this connection, of much significance is systematization of the

available sources of information with a view to extracting therefrom only the scientific information that most closely meets the needs of particular learners' groups.

Major changes have taken place in science over the past 100, 50, and even 30 years. Certainly, the laws of nature remained unchanged, but the ways of delivering and processing of scientific information have fundamentally changed. In modern science, it is sometimes difficult to single out individual academic disciplines: chemistry, physics, mathematics, computer science, or biology. Physical research methods provide a tool for establishing the structure of ever increasing number of new substances and materials, and mathematical methods, for modeling chemical reactions and data analyzing and processing, as well as for statistical prediction of the properties of molecules that still remain to be discovered. Computer science creates optimal algorithms for all the computations, and biology provides chemistry scientists with very interesting objects of study, living systems.

The interdisciplinarity of modern science is seen most clearly in the example of nanotechnologies. Recall that meant by nanotechnologies are methods and techniques applied for studying, designing, producing, and using structures, devices, and systems that provide for targeted control and modification of the shape and size and integration and interaction of their nanoelements (1–100 nm) with the aim to obtain objects with novel chemical, physical, and biological properties [1].

Nanotechnologies and related physics, chemistry, and biology domains belong to the most important directions in contemporary science. This is evidenced, e.g., by the fact that, in the past five years, 90% of the most oft-cited papers in physical chemistry have been dedicated to nanoobjects and nanomaterials. New discoveries at nanoscale can lead to broad technological changes in the XXI century.

Teaching and learning in the nanoscience and nanotechnology field are fundamentally different from those in natural sciences as they were in the past 200 years. The main difference consists in that the entire nanoscience and its technological applications invariably rely on interdisciplinary approaches in which a balance is provided not only among chemistry, physics, biology, and computer science but also between the natural and social sciences.

To summarize the above-said, Internet and nanotechnologies are the two advanced ideas that will be of crucial importance for the development of mankind in the XXI century.

With the view of combining these ideas and the best achievements of the Russian system of science Olympiads, the Lomonosov Moscow State University (MSU) initiated in 2006 a new educational program based on the "Nanotechnology: Breakthrough into the Future" Internet Olympiad. This program involves virtually all sections of Russian society: middle- and senior-grade schoolchildren, students, post-graduate students, young scientists, and secondary and higher school teachers, as well as everyone interested in the achievements of modern science and its implications for people's life.

The educational program dedicated to nanoscience and nanotechnologies is characterized by:

– interdisciplinarity (the program integrates chemists, physicists, mathematicians, and biologists, as well as medicine and technology researchers);

– fundamentality (the program is underlain by basic fundamental natural-sciences education);

– continuity [the core educational projects of the program keep in view a transition from secondary to higher school and further to research work or practical activities (technology)]; and

– broad cooperation between educational and scientific institutions (including the Moscow State University and other higher educational institutions, secondary schools, and institutions of the Russian Academy of Sciences).

"Nanotechnology: Breakthrough into the Future" Olympiad: Goal, Objectives, and Thematic Scope

The organizer of the "Nanotechnology: Breakthrough into the Future" All-Russia Internet Olympiad is the Moscow State University. This project enjoys high popularity, as evidenced by rapid increase in the number of its participants, specifically, by a factor of 10 in 6 years, from 2007 till present time. The Sixth Olympiad which closed in late March, 2012, gathered over 10 thousand participants, including over 8 thousand 7–11-graders. The Olympiad organizing efforts are undertaken mainly by the Materials Sciences Department, MSU, as supported by the Chemistry, Physics, Biology, Mechanics and Mathematics, Fundamental Medicine, and Bioinformatics and Bioengineering Departments.

The goal pursued by the "Nanotechnology: Breakthrough into the Future" Olympiad is to improve the quality of training professionals for nanoindustry, as well as to popularize the knowledge of nanosystems, nanomaterials, and nanotechnologies via searching talented young people and providing them with support, vocational guidance, and motivation. The main objective is to establish a system of Internet Olympiads in the field of nanosystems, nanomaterials, and nanotechnologies, which will be steadily operative in the long run and accessible for a large number of different categories of participants. This system has emerged as one of the most important forms of enlightenment, distance learning, and self-education, essential for shaping public opinion and motivating schoolchildren and young scientists toward professional activities in the field of nanomaterials and nanotechnologies.

The Olympiad for schoolchildren involves competitions in a range of nanotechnology-related subjects (chemistry, physics, mathematics, and biology). The problems suggested at the on-site theoretical round have a difficulty level which is equal to, or slightly exceeds, that of the entrance examinations in higher educational institutions on the respective subject (set of subjects). The correspondence round problems are formulated in a way such that schoolchildren are motivated toward analysis of thematic information, which will allow them to solve problems by themselves via using approaches and techniques whose knowledge they possess. Original solutions are welcome which apply the heuristic techniques for disclosing the essence of the issues concerned and the specific features of nanosystems and nanomaterials.

The Olympiad problems suggested to students, post-graduate students, and young scientists cover a fairly broad thematic range; solving these problems requires making creative search of information, in particular, of original scientific publications available on the Internet (including those in English). Some problems have numerical solutions, and some constitute "self-educating" assignments (considering the specific features of the issues involved) which put the Olympiad participants on the right track in solving the problem. Solution is to be sought through using logical reasoning and approaches to be taken in addressing nanotechnology issues belonging to the scope of nanochemistry, nanosystem physics, nanomaterials, nanomedicine, etc. Virtually all assignments are interdisciplinary in nature, and their accomplishment requires extensive use of knowledge from several allied sciences.

The creative contest assignments provide the participants with an opportunity to demonstrate their personalized approaches and express their personal viewpoints on particular issues related to fundamental, engineering, or social aspects of nanotechnologies. Game elements can be used in formulating and accomplishing the assignments which deal with situations addressing the fundamentals of the science of nanosystems and nanomaterials. Participants may choose from a wide range of themes, whereby additional contingents, in particular, participants specializing in the humanities, can be attracted to this contest. The creative contest results should be defended orally at the on-site round.

With the registration period included, the major events of the Olympiad take place in the period from November till March, but some activities, e.g., those of the Olympiad Participants' Club, are performed on a permanent basis.

Currently, the "Nanotechnology: Breakthrough into the Future" Internet Olympiad ranks among first-level Olympiads in the official registry of schoolchildren's Olympiads. Its winners are admitted by many higher education institutions without taking entrance examination. The existing registry of chemistry competitions includes only one first-level Olympiad, the International Mendeleev Olympiad.

Fundamentality of the "Nanotechnology: Breakthrough into the Future" Olympiad

The fundamentality of the "Nanotechnology: Breakthrough into the Future" Olympiad lies, above all, in the fact that it covers virtually all aspects and all major branches of the science concerned with nanoobjects. Listed below are the main research and thematic areas of the Olympiad.

Nanochemistry: structure and methods for synthesis of carbon (nano)materials, chemistry of carbon nanotubes, nanodiamonds, and fullerenes; clusters, their structure and properties, physical chemistry of surface, self-assembling layers, heterogeneous catalysis, supramolecular chemistry, ultradisperse substances, and size effect.

Nanophysics: quantum-size effects, electronic structure and magnetic properties of nanomaterials, nanophotonics, and physical principles of advanced methods of analysis of nanosubstances.

Functional nanomaterials: classification of nanomaterials and their basic types, including magnetic, optical nanomaterials, hybrids, biomaterials, nanocomposites; the hierarchical structure of materials; micro- and nanostructured materials; one- and two-dimensional nanomaterials; membranes; sensor nanomaterials and nanoionics, chemical power sources and supercapacitors; crystal structure, microstructure, and micromorphology of nano-materials; self-assembly and self-organization, general and specific methods of preparation of nanomaterials; composition–structure–microstructure–property relationships; and methods of analysis and application of nanomaterials.

Biology and nanomedicine: elements of enzymology, molecular machines and their functioning, vector-mediated drug delivery, contrasting agents, and nanotoxicology.

Alternative energetics and ecology: nanomaterials in solar power generation, nanomaterials in hydrogen energetics, fuel cells, use of sorbents and nanomaterials in ecology, and photocatalysis.

Nanoelectronics: molecular electronics, quantum computers; development of basic elements of nanoelectronics, nanodevices; and information processing and storage, logical elements.

The accomplishment of assignments suggested to Olympiad participants at the experimental (practical) round involves the use of experimental methods: scanning probe microscopy, X-ray phase analysis, X-ray diffraction analysis, infrared spectroscopy, luminescence spectroscopy, Raman spectroscopy, dynamic light scattering, and electron microscopy, as well as by techniques based on analysis of local chemical composition, capillary condensation during nitrogen adsorption, and surface area and porosity determination.

An important feature of the "Nanotechnology: Breakthrough into the Future" Olympiad consists in that it includes not only traditional rounds, which rely on solving problems covered by the program for basic secondary school disciplines, but also creative contests and research competitions. Specifically this feature allows the "Nanotechnology: Breakthrough into the Future" to be treated as an Olympiad of the modern type. With wide thematic diversity of its assignments, this Olympiad can involve into productive activity a broad range of participants: schoolchildren, students, postgraduate students, young scientists, secondary and higher school teachers, and even participants specializing in the humanities. The main themes of the competitions at the "Nanotechnology: Breakthrough into the Future" Olympiad-2011 were as follows: "Light and Optics," "Green Chemistry, Ecology, and Medicine," "Alternative Power Sources," "Amazing Carbon," "Physics of the Nanoworld", "Nanomaterials around Us," and "Social Aspects of Nanotechnologies."

Interdisciplinarity of the "Nanotechnology: Breakthrough into the Future" Olympiad

As already mentioned, interdisciplinarity is one the most essential features of the "Nanotechnology: Breakthrough into the Future" educational program. The themes covered by the Olympiad assignments belong to the most important branches of nanoscience and nanotechnologies: fundamental physical and chemical characterization of nanosystems, preparation and analysis of functional and structural nanomaterials, nanomedicine, and nanoengineering.

The interdisciplinarity of the "Nanotechnology: Breakthrough into the Future" Olympiad is evident not only from its assignments suggested to schoolchildren but also from the themes offered at creative contests and research competitions for students, postgraduate students, young scientists, teachers, and other Olympiad participants.

Given below are examples of several simple problems from different knowledge areas, suggested at the "Nanotechnology: Breakthrough into the Future" Olympiad for schoolchildren.

Problems in Nanochemistry

Problem 1. "Aging" of gold nanoparticles

Organic compounds are often used to stabilize inorganic nanoparticles via formation of a surface protective layer which prevents aggregation and oxidation of nanoparticles and other undesirable chemical reactions. Substances containing a lone electron pair, e.g., thiols, amines, phosphines, phosphinoxides, etc., are typically used for this purpose. For example, reduction of $H[AuCl_4]$ with sodium borohydride in the presence of dodecane thiol gives gold nanoparticles 3.9 nm in diameter, coated with a thiol monolayer. During storage in air, the solution exhibits gradual "aging," with the average diameter of the gold nanoparticles increasing to 6.2 nm.

(1) What is the percentage of dodecane thiol molecules that pass into solution during aging? Name

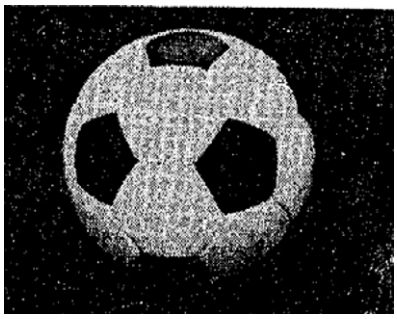


Fig. 1. An excerpt from the paper describing the discovery of fullerenes.

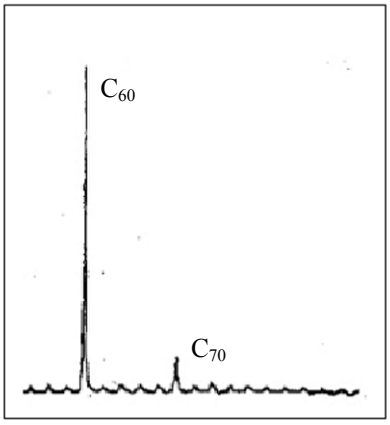


Fig. 2. Mass spectrum in the proof of formation of C_{60} and C_{70} molecules.

the compounds in whose form they will exist in solution.

An alternative method of preparation of gold nanoparticles consists in reduction of $Na[AuCl_4]$ with sodium citrate (trisodium salt of 3-hydroxy-3-carboxy-1,5-pentanedioic acid) in the presence of 12-aminododecane-1-thiol.

(2) Give the equations of the proceeding reactions. Calculate the volume of gas (standard conditions) released during formation of 1 g of gold nanoparticles.

Problem 2. Buckminsterfullerene C_{60}: a Legendary Publication

Figure 1 reproduces the picture from the "C_{60}: Buckminsterfullerene" paper (Nature, vol. 318, 1985), for which H. W. Kroto, R. F. Curl, and R. E. Smalley were awarded Nobel Prize in chemistry in 1996. Figure 2 shows the mass spectrum presented in that study, which proved the existence of individual C_{60} and C_{70} molecules.

This is a low-resolution mass spectrum.

(1) A high-resolution mass spectrum may contain signals from isotope-substituted molecules. How many lines should the mass spectrum of C_{60} contain in theory?

(2) The line intensity in the mass spectrum is proportional to the number of species with a given mass. Calculate the peak ratio for the two most intense lines in the mass spectrum of C_{60}. What is the intensity ratio between the lightest and the heaviest C_{60} molecules?

(3) Presume that football (soccer) in the nanoworld is played with buckminsterfullerene. What will be the distance between the penalty spot and the goal?

For reference: (1) carbon has two stable isotopes ^{12}C (98.9%) and ^{13}C (1.1%) and (2) the circumference of the football (soccerball) is 70 cm, and the diameter of the fullerene molecule, 0.7 nm.

Problem 3. Nanotubes for Hydrogen Energetics

Hydrogen is considered to be the most promising synthetic fuel: It is light, energy-rich, fairly easily accessible, and environmentally clean (its oxidation product is pure water).

(1) Compare the specific heat of combustion, kJ g^{-1}, of hydrogen, carbon, and hydrocarbons: methane and gasoline (C_8H_{18}). Consider carbon dioxide and liquid water to be combustion products. Find the necessary thermodynamic data by yourself. Which of these compounds represents the most energy-rich fuel?

(2) The maximum amount of work that can be performed as a result of the chemical reaction equals the Gibbs free energy of the reaction. Calculate the maximum amount of work that is done by a hydrogen fuel cell-powered electric motor as a result of combustion of 1 kg of hydrogen. What distance can be covered by a car weighing 1000 kg owing to this work done by the motor at the motor efficiency of 50%? Find the necessary thermodynamic data by yourself. Take the friction coefficient equal to 0.1.

Extensive application of hydrogen for power generation purposes requires solving a number of global technical problems, the main of which concerns compact and safe hydrogen storage.

An ideal device for hydrogen storage is that able of storing large quantities of hydrogen in a not very large volume and of easily giving it away as needed. One of the fundamentally different approaches suggested for solving the hydrogen storage problem is that based on the use of carbon materials, in particular nanotubes.

(3) Name the binary chemical compound containing hydrogen in the maximum weight proportion. What does it equal to (only the most common isotopes of elements are considered)?

(4) One of the mechanisms of hydrogen absorption by nanotubes is chemisorption, i.e., adsorption of hydrogen (H_2) on the tube surface, followed by dissociation and formation of C–H chemical bonds. What is the maximum possible weight proportion of hydrogen in nanotubes, obtainable by chemisorption? What is the proportion of carbon atoms bound to hydrogen atoms, if the weight fraction of hydrogen is 6.5%?

Problems in Mathematics

Problem 1. Nanofootball (Nanosoccer)

A fullerene C_{60} molecule is similar to a football (soccerball). Its faces are 12 regular pentagons and 20 hexagons. In the first half of the match, nanofootball player Maksim Grafitnyak shot wide three times. What is the probability for Maksim's boot to strike a pentagon in two out of three shots (the hexagons and pentagons have equal sides)?

Problem 2. A Short-Sighted Nanorobot

A graphene lattice having one of the atoms replaced by ^{13}C isotope is processed by nanorobot. In one step, it can reach one of the neighboring atoms, whereupon it discovers whether it approached the isotope. Also, the nanorobot is able to realize that it is processing the isotope. How can it reach the isotope in no larger than (a) 2000000 steps, (b) 1000015 steps, (c) 1000006 steps, if the isotope is initially separated from the robot by one million steps?

Problem 3. Interest in "Nano"

The public interest in new technologies typically varies from a short period of an explosion of interest via sharp decline to a long period of flat growth.

In the case of nanotechnologies, the time dependence of the public interest $f(t)$ is described by a function represented graphically in Fig. 3. This function at $t \le 2000$ is equal to nearly zero, and at $t \ge 2012$ (according to predictions) monotonically tends to 1/2. The maximum is close to the year 2007.

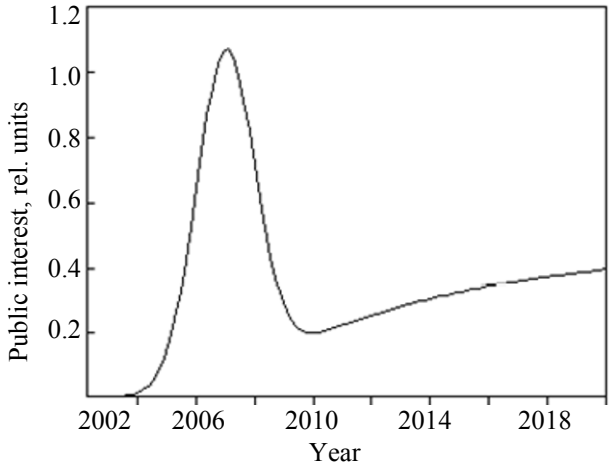


Fig. 3. Trends in variation of public interest in nanotechnologies.

Give the analytical expression for the function $f(t)$ that will qualitatively correspond to the graphical representation given above and satisfy the boundary conditions indicated.

Problems in Nanophysics

Problem 1. Piezoelectric Elements

One of the inkjet printing technologies is that based on ink squeezing out of the nozzle using a piezoelectric element. The printing resolution can be increased by reducing the ink droplet size.

Estimate the Young's modulus of the piezoelectric element in the print head of an inkjet printer, if the nozzle size is 50 nm. The relative elongation of the piezoelectric crystal is $\varepsilon = 0.01\%$, and the coefficient of surface tension of ink is 50×10^{-3} N m^{-1}. Consider that the nozzle surface is wetted by ink.

Problem 2. Graphane

Graphane is a two-dimensional system consisting of a single planar layer of fully saturated carbon atoms. Determine the empirical formula of graphane. Graphane is suggested for use as a hydrogen-storage medium. The essential characteristic of the storage technique is the weight ratio of "hydrogen stored" to "container:" The higher the ratio, the larger the quantity of hydrogen stored in graphane. Which of the "containers," graphane or a 30-l steel cylinder weighing 12 kg kept under the pressure of 100 bar at room temperature, is the preferred option for hydrogen storage?

Problems in Biology and Nanomedicine

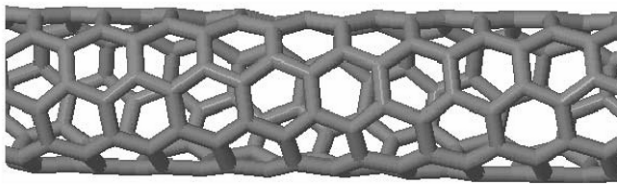
Problem 1. Brain, Brain ...

One of the promising lines in neurobiology is that based on the use of neural stem cells for treating various brain injuries and pathologies associated with neuron death. Experiments show that introduction of stem cells to the damaged area leads to partial replacement of dead neurons by new ones that have differentiated from stem cells. However, the latter do not easily penetrate into deeper layers of brain and remain mostly on the surface, thereby significantly reducing the range of possible applications of stem cells.

In which way can nanomaterials (specify which and why) promote penetration of stem cells into deeper layers of brain? How can the targeted delivery of stem cells to damaged areas be achieved? What makes the neural stem cells "creep" into the right place?

Problem 2. Nanoobjects in the Mirror-World

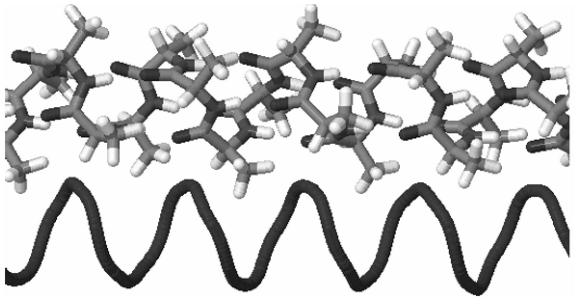
Chirality is a property of certain objects such that the object and its mirror image cannot be superimposed one on the other by any combination of rotations and translations in the three-dimensional space (e.g., the right and left hands). Such mirror images of a molecule are termed enantiomers.



In organic chemistry, chirality is typically associated with an asymmetric carbon atom (having four different substituents), but in the nanoworld there exist other types of chirality as well.

(1) What feature is the cause of chirality in carbon nanotubes?

(2) The figure below presents the a-helix of L-alanine. Describe its enantiomer. What will be answer will you give if L-alanine in such α-helix will be replaced by glycine (NH_2–CH_2–COOH)?



(3) Can the enantiomers described in items 1 and 2 differently affect biological objects and, if so, why?

(4) With which human body tissues, and how, will these objects interact above all in the case of oral, nasal, and dermal introduction?

Throughout the history of the Olympiad in nanotechnologies, several hundreds of original, previously unpublished, problems were developed for the theoretical and experimental rounds. Those materials are permanently free to access on the website of the Olympiad [2].

Use of New Edicational Technologies in the "Nanotechnology: Breakthrough into the Future" Olympiad

The "Nanotechnology: Breakthrough into the Future" Olympiad, whose subject and format (Internet-Olympiad) perfectly correspond to new learning forms, above all to distance learning, relies on many advanced educational technologies whose testing in the Russian educational system has just begun.

Extensive application of distance learning and other informational resources resulted in creation of a highly information-rich space of the Olympiad. In 2009, the Olympiad Participants' Club was established for the purpose of teaching nanotechnology fundamentals to everyone interested [3]. The Club activities are based on a discussion platform of the Olympiad website www.nanometer.ru; it contains video courses of lectures dedicated to development of nanotechnologies; all the educational materials useful for self-tuition (over 15 GB of information) are also available. Hence, the Olympiad not only performs the checking functions (typical for traditional Olympiads) but also creates its own learning environment which can provide new knowledge to the participants.

The Club was designed as a forum for discussing nanotechnology problems, promoting communications among the participants, and concentrating in one single place the study materials that will be available to any participant when needed. Previously, one of the frequently asked questions was "what is meant by nanotechnologies?", and today, this is "where are nanotechnologies taught?" The Club gave a start to making a collection of study materials, constantly replenished throughout the year. It is essential that the Club format implies free publication and free discussion of materials by all the participants and promotion of free contacts among the Club members.

The most essential component of the Olympiad is represented by the distance learning courses [4]. Distance learning is one of the most rapidly growing fields of additional education. The advantages offered by distance courses include easy accessibility, flexibility in learning trajectory building, and more efficient and prompter interaction with learners. Through distance learning courses, people with disabilities are provided with an opportunity to fully participate in the educational process. Creation of new open educational Internet resources of MSU is an important step toward popularization of science and fundamental education.

Considering major methodological irrelevance of the Russian educational system and sharp deficiency of teaching aids and educational materials in nanotechnologies, the distance learning courses provide the most important and relevant tool of professional training and retraining in this sphere. In 2011, flexible sets of courses were developed on the basis of educational and popular-scientific materials available from in-advance prepared "knowledge base." This allowed the existing materials to be adapted to the needs of participants from different social and age groups.

Engaged in providing methodological support to the courses and in their implementation are Professors and Associate Professors from the Lomonosov Moscow State University and Russian Academy of Sciences, having an experience of experimentation and teaching in the areas of interest.

All the Olympiad materials are available in the electronic form and can be used by secondary general and vocational education institutions, higher educational institutions, branch staff training and retraining centers, scientific institutions, research units of high-tech firms, and innovative enterprises, as well as by all members of the National Nanotechnology Network.

CONCLUSIONS

The "Nanotechnology: Breakthrough into the Future" All-Russia Intellectual Forum-Olympiad is a new educational program which was developed and introduced at the Department of Materials Science, Moscow State University. All strata of the Russian society have been involved in the Olympiad activities (over 20 thousand people of all ages and social groups in a 6-year period). Thereby, the Olympiad significantly contributes to attracting young people to scientific activities and to training professionals for nanoindustry.

This is an interdisciplinary Olympiad which covers all aspects of nanoscience and all the main world existing branches of nanotechnology.

The "Nanotechnology: Breakthrough into the Future" Olympiad combines the best traditions of Russian science Olympiads with new educational trends: creative contests, research competitions of schoolchildren and students, and a well-developed distance learning system.

The Olympiad offers a unique informational and educational environment for schools and universities throughout Russia to get actively involved. Through extensive use of distance learning and other information technologies, the "Nanotechnology: Breakthrough into the Future" Olympiad has created its own information space comprising the Olympiad Participants' Club, "knowledge bases" of educational and popular-science materials, and distance learning courses for all age and social groups.

REFERENCES

1. Eremin, V.V. and Plutenko, A.D., *Nanotekhnologicheskoe obrazovanie: problemy i perspektivy* (Education on Nanotechnologies: Problems and Prospects), in *Sovremennye tendentsii razvitiya khimicheskogo obrazovaniya: fundamental'nost' i kachestvo* (Modern Trends in Chemical Education: Fundamentality and Quality), Lunin, V.V., Ed., Mosk. Gos. Univ., 2009, pp. 141–153.
2. *www.nanometer.ru.*
3. *www.nanometer.ru/userc_stat_all_u3.html.*
4. *www.nanometer.ru/2011/10/09/13181416739526.html.*