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Teaching the Basics of Nanotechnology in School

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Abstract:Nanotechnology is a rapidly developing interdisciplinary field with significant potential in various sectors, including medicine, electronics, and energy. Its integration into education presents both opportunities and challenges. Despite growing recognition of nanotechnology's importance, its successful integration into curricula requires addressing challenges such as developing appropriate teaching strategies and knowledge dissemination. The key to overcoming these challenges is the need to develop innovative educational tools and global collaboration to ensure effective integration of nanotechnology education. The problem of promoting nanotechnology advancements as an innovative field of knowledge in educational environments, particularly among school students, is considered. The relevance of knowledge in the field of nanotechnology, including for school students, is dictated by our times and represents an important part of improving the quality of professional personnel training for the nano-industry, as well as a significant component of career guidance and motivation measures for talented youth in the educational system. The rapid development of innovative nanotechnology-based production requires that school students become familiar with the picture of the nanoworld, nano-objects, and related phenomena, which constitutes the essence of the nanotechnological approach to education.

Keywords: Nanotechnology, Educational technology, Cognitive interest

Introduction

In any era, the foundation of a society's technical culture has been energy, materials, and information. One of the primary indicators of a society's technical culture is the materials it uses. This has been reflected in the names of ages: “Stone Age", "Bronze Age", "Iron Age" and others. The 21st century is called the century of multifunctional nano- and biomaterials, as the end of the last century marked the beginning of a new scientific and technical revolution - the era of nanoscience and nanotechnology, which will fundamentally change the face of the world in the near future. Terms like nanophysics, nanochemistry, nanoelectronics, nanomedicine, nanomaterials, nanotechnologies are increasingly encountered not only in specialized scientific journals but also in mass media. Many countries around the world have adopted and continue to develop national research programs in nanothematic areas. Objects have emerged without which modern development of science and technology is now unimaginable - these are nanoparticles in all their varieties. Nanotechnologies, along with information-computer technologies and biotechnologies, form the foundation of the 21st century's scientific and technical revolution. Currently, there is no field where nanotechnologies do not exert their influence (Jones, 2013).

The relevance of knowledge in nanotechnology, including for school students, is dictated by our times. Nanotechnology represents one of the most important and interesting areas of knowledge in physics, chemistry, biology, and technical sciences. This constitutes a significant component of a series of measures to improve the quality of professional training for the nanoindustry, as well as the most important component of measures to popularize knowledge in the field of nanosystems, nanomaterials, and nanotechnologies, career guidance, and motivation of talented young people in the educational system (Hingant, 2010). A necessary condition for developing the knowledge popularization process is introducing nanotechnologies to students using the educational program method "I teach in advance": 1. A collection of information and knowledge that should be sought before starting any scientific or special training; 2. An introduction to a science presented in a brief and elementary form, a preliminary, introductory course. The rapid development of innovative production based on nanotechnology requires that school students become familiar with the picture of the nanoworld and methods of controlling nano-objects and related phenomena, which constitutes the essence of the nanotechnological approach to education.

Method

The rapid development of innovative production based on nanotechnology requires that school students become familiar with the picture of the nanoworld and methods of controlling nano-objects and related phenomena, which constitutes the essence of the nanotechnological approach to education. The organization of the modern educational teaching and upbringing process should always encourage children to actively demonstrate their strengths and capabilities, putting them in the position of active participants. Activity, as a characteristic quality of children, creates favorable conditions for educational influence on the child. Creating conditions for the manifestation of children's cognitive activity is a means of achieving this: using various forms and methods of organizing educational activities; creating an atmosphere of interest for each participant in the educational process; stimulating participants in the educational process; using various methods of completing tasks without fear of making mista-kes or receiving incorrect answers, etc. Using didactic materials in the classroom that allow children to choose the most suitable types and forms of educational content for them; evaluating the activities of participants in the educational process not only by the final result (correct-incorrect) but also by the process of achieving it; encouraging students to find their own means of solving problems, creating an environment for natural self-expression of school students, and more.

One of the promising teaching methods in school is the project method. The project method was introduced into educational practice by "pragmatic pedagogy", whose founder is considered to be the American idealist philosopher Dewey (1902). The idea of the necessity of "elevating" the student to the rank of an educational subject has become particularly relevant. The conceptual provisions of J. Dewey's theory and his followers have been revised from the perspectives of modern achievements in pedagogy and psychology.

Results and Discussion

The goal of propaedeutics of nanotechnology knowledge is its popularization among school students, both as motivation for interest in the development of nanotechnology and early orientation of children for further professional training in this field. It is very important that the lessons contribute to the development of school students' cognitive activity and positive motivation. Therefore, it is necessary to organize more creative tasks, search and partial research activities, and to introduce non-standard forms of conducting educational lessons.

The basis of school students' productive cognitive activity is cognitive interest - a person's selective orientation toward objects and phenomena of the surrounding reality, characterized by a constant striving for knowledge, new, more complete, and deeper understanding. Systematically strengthened and developing cognitive interest becomes the basis for a positive attitude toward learning. When being introduced to nanotechnologies, a school student's cognitive interest takes on an exploratory character. Under its influence, school students constantly have questions like "What is this"? and others, to which they actively and constantly seek answers in libraries and on the internet. At the same time, the student's search activity is activated; they experience emotional uplift and joy from success. Cognitive interest positively affects not only the process and result of activity but also the course of mental processes - thinking, imagination, memory, and attention develop.

Cognitive interest is one of the most important motives for school student learning. Its effect is very strong. Under its influence, even the academic work of weak students becomes more productive. This is one of the most important motives for school students' learning. Under its influence, educational activities become more productive even in weak students (Ratner, 2003). With proper pedagogical organization of students' activities, systematic and purposeful educational work, cognitive interest can and should become a stable feature of the school student's personality.

Introduction to the achievements of new technologies in school should be carried out in forms easily accessible to school students: through entertaining stories, games, and also through generally accessible public labor activities. For example, why are nanowires stronger than ordinary wires? As the size of nanoparticles decreases, not only their mechanical properties change, but also their thermodynamic characteristics - their melting temperature becomes much lower than that of a regular-sized sample. In the nanoworld, tehir electrical characteristics also change - the resistance of a nano-sized resistor cannot be calculated with the known formula but is determined by two physical constants. Their optical properties are no exception - the color of nanoparticles depends on their size. For this purpose, a course in nanotechnology can be developed, for example, "Unimaginably small scales and fantastically huge potential" - from the latest medicines to ultra-fast computer chips (Table 1). Students will learn when and how such a field of science as nanotechnology emerged. They will become familiar with nanomaterials and their classification. They will study various methods of nanomaterial synthesis and how nanoparticles combine with each other and what structures are obtained in the process. They will get acquainted with nanotechnology tools - modern nanotechnologist instruments and equipment. It is also possible to model and use one's own microscope to study the obtained structures. It is interesting to talk about the use of nanomaterials in life - in all spheres of human life where nanotechnology is encountered and about several nanomaterials that are already bringing benefits to humanity. Such courses will allow us to present a number of ideas that will help activate and develop school students' thinking for the expansion and deepening of knowledge, skills, and capabilities. These methodological ideas have the ability to transfer knowledge from one field to another, which allows us to draw conclusio-logical ideas have the ability to transfer knowledge from one field to another, which allows us to draw conclusions about their general nature, which contributes to the formation of general educational skills and methods of action (Tretter, 2020).

Table 1. Thematic planning of an elective course in nanotechnology

Topic	Objective	Main Content
Nanoworld	Will learn about the history of nanotechnology development, understand what nanotechnology is, where it is used, and what nanoparticles are.	Nanotechnology, history of development. Nanotechnology as a scientific-technical direction.
Nanomaterials	Will learn about methods of obtaining nanomaterials.	Classification of nanomaterials. Nanoparticles, nanotubes, nanocrystals.
Nanotechnology Instruments	Will learn about modern nanotechnology instruments and equipment.	Electron microscope. Scanning tunneling, force, and optical microscopes.
Nanotechnology Around Us: Reality and Perspectives	Will learn about areas of human life where nanotechnology is encountered: nanoelectronics, nanoenergetics, nanomedicine, food industry, etc.	Nanotechnology in electronics, energy, food industry. Nanoparticles in various fields of medicine.

The laboratory, which is part of the elective course, is aimed at developing the school student's cognitive interest, and students have the opportunity to conduct experimental work. For example, obtaining copper (Cu_2O) and silver (Ag) nanoparticles using various simple methods. Studying the optical properties of the nanoparticles. It is possible to perform a laboratory task: synthesis of Ag nanoparticles using the citrate method. This method allows us to obtain relatively large silver particles with a diameter of ~60-80 nm. The absorption maximum is at 420 nm. For this, we need to prepare a 0.005M (0.085%) $AgNO_3$ solution in water by dissolving 0.0425 g of the substance in 50 ml of distilled water. 25 ml of the prepared solution should be transferred to a flask and 100 ml of water added. Then we need to prepare a 1% sodium citrate solution by dissolving 0.5 g in 50 ml of water. The resulting 125 ml of silver nitrate solution should be heated until boiling. As soon as the solution begins to boil, add 5 ml of 1% sodium citrate solution. The resulting solution should be heated until the color becomes light yellow, which we then leave to cool to room temperature. The reduced volume of the solution due to boiling should be topped up with water to 125 ml. To evaluate the obtained nanoparticles, we should plot the absorption spectrum of the resulting solution. Absorption spectra can be plotted after one day and one week. We can compare the obtained spectra. Later, we can offer them both individual and collective projects, such as the electrochemical method of nanoparticle synthesis, which is a very attractive and interesting method because the process is simple and effective. Nanoparticle deposition is possible both in direct current (DC) mode and alternating current (AC), depending on conductor requirements, applications, and characteristics. In the first case, a constant current is supplied to the electrodes, while in the second case, the potential of the working electrode is controlled. During electrochemical deposition, ions from the solution are deposited on the surface of the cathode (working electrode). This process can occur alongside electrolysis, and depending on the depositing material used, nanoparticles as well as continuous layers, nanowires, or nanotubes can be obtained when using pre-structured matrices. The amount of deposited material, layer thickness, or nanowire length depends on the deposition time and matrix structure. Using the obtained nanoparticles, it is possible to create lighter and stronger materials with programmable characteristics, fundamentally new devices, as well as molecular and cluster objects. The main advantage of the method is experimental accessibility and the possibility of process control and management.

The relationship between the current passing through the solution and the reduced deposited substance on the electrodes is determined by Faraday's laws, which are known to students. According to the first law, the mass of substance deposited on the electrodes is proportional to the amount of current passing through the electrolyte - $m=kq=kIt$, where: m - mass of substance reduced on the electrode, k - electrochemical equivalent, q - charge, I – current, t - time. According to Faraday's second law, during the passage of the same charge, the mass of different substances deposited on the electrodes is proportional to its electrochemical equivalent - $m/q=(1/F)\times \times(M/n)$,-„-..„-..or $F=(q/m)(M/n)$. Where, F - is Faraday's constant (96,500 C), M - molar mass, n - number of electrons in the process.

It is desirable to record voltammetric curves for each deposition process. If two electrodes - cathode and anode, which usually have the form of plates, are placed in a specially selected electrolyte and are connected to the positive and negative terminals of the power source by metal conductors (Figure 1), then, when an external electric field is applied to the electrode, charged particles move from one electrode to the other and electrochemical reactions occur simultaneously on both electrodes. At the same time, anions give up electrons and are oxidized at the anode (positive electrode), at the cathode (negative electrode), cations accept electrons and are reduced.

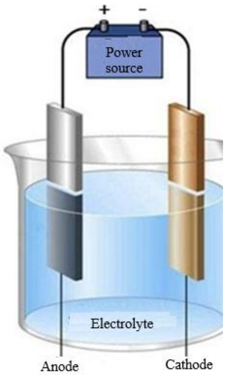

Figure 1. Simple sketch of electrochemical double electrode cell.

The relationship between the current strength in the solution and the amount of substance deposited on the electrodes is determined by Faraday's laws. Methods for synthesizing nanostructures require expensive equipment, but this method uses simple means. In particular, during each deposition process, we should construct voltammetric curves - the dependence of current strength in the electrolyte on electrode potential (Figure 2), which provide information about the deposition process on the electrodes, and we can discuss and evaluate the obtained nanostructures. In addition, such measurements provide additional qualitative and quantitative information about the composition of electrolytes and the chemical reactions occurring at the electrodes and in the electrolyte. Using these curves, the best deposition conditions can be determined for different potential values.

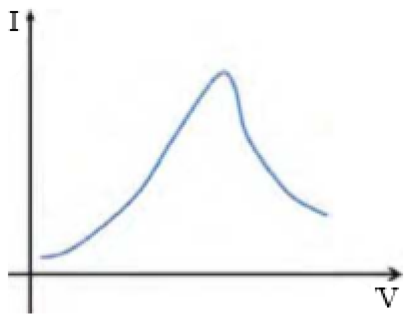

Figure 2. Typical voltamperomertic curve $I=f(V)$

The precipitate formed on the cathode can be a loose or dense layer of many microcrystallites. The texture of the precipitate is influenced by many factors such as the nature of the substance and solvent, the type and concentration of target product ions and impurities, properties of the particles to be deposited, ambient temperature, electrical potential, diffusion conditions, and others. The synthesis of nanoparticles is, on one hand, very interesting, but on the other hand, requires overcoming difficulties. It is necessary to maintain special purity to avoid various impurities and monitor all process parameters. The process of electrolysis is mainly influenced by geometric factors (shape and size of electrodes, their position relative to each other and the cell walls) and electrochemical factors (change in cathodic potential at different current values), electrical conductivity, composition, density, viscosity, electrolyte temperature, etc.). It requires selection of reagents that dissociate in the solvent. During the electrolysis process, an electrolytic reaction occurs at the anode and cathode, and a precipitate is released at the cathode. It is necessary to periodically remove the precipitate from the cathode, which is essential for obtaining a nanostructure of uniform size and composition. Because the composition of electrolytes near the electrodes constantly changes, forced circulation of the electrolyte is necessary during the process.

Conclusion

The main result of working with school students should not be the sum of transmitted knowledge (or information), but the formation of students' interest in nanotechnology problems, the development of their thinking, assistance in formulating ideas about the fundamental unity of natural sciences, the incompleteness of knowledge in the field of natural science, the possibility of its further development, and the role of nanotechnology in realizing humanity's needs. At the same time, the most important didactic principles must be strictly observed: the dialectical unity of scientific rigor and accessibility, systematicity and consistency, the implementation of interdisciplinary connections, and more.

Thus, the preparation of future specialists in the field of nanotechnology should begin from early childhood and become an actual educational task, as nanotechnology is a key direction in the development of 21st-century technologies. And the use of the project method in pedagogical practice is possible not only at the student level but also at the teacher level. Pedagogical design can be a function of any teacher, no less important than organizational, gnostic, or communicative functions. Thanks to design, the educational process becomes "technological." Mastering project-based teaching methods is currently one of the indicators of subject teachers' professionalism. In addition, the project method involves not only studying complex processes and objects through their modeling and construction, not only allows creating something new, achieving set goals in the most effective way, but by its nature, it can also be a technological means to develop a person's creative self-realization by implementing project activities.

Recommendations

Research will continue in the direction of introducing and teaching nanotechnology at various educational levels, using the method mentioned in the article as well as other methods.

Scientific Ethics Declaration

* The scientific ethical and legal responsibility of this article belongs to the author.

Conflict of Interest

* The author declares that he has no conflict of interest

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