"Elements of STEM Nanoscience didactic for IBSE innovative teaching and learning"

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Abstract

Our society is immersed in a "Nanotech World" characterized by innovative products that are already present in all lives, even if we are not always aware of it. For years Nanosciences have in fact become a fully-fledged part of numerous areas of research, development and industrial production, from agriculture and health to the textile, environmental and energy sectors, all areas of study that are rapidly expanding. These are all multidisciplinary sectors that prove to be important resources for analysing in innovative multiyear projects with students the needs of new technology, but also the professional figures who will have to manage innovation and the responsible use of these applications. It is therefore of high educational value to carry out "*Integrated Nanoscience activities"* in scientific high schools as part of the curriculum and also aimed at promoting social elements of "*technological humanism"* in which it is increasingly important for everyone to reason in critical thinking about the usefulness, the safety and the limits of new scientific discoveries. In the *Nanoscience Blanded Learning* methodology of STEM disciplines were created STEM integrated learning activities and communication products with IBSE metodology in fully realizazion of soft and cognitive skills. Interdisciplinary and transdisciplinary didactic approaches are realized, structuring connections not only between different scientific disciplines (physics, chemistry, biology, engineering) but also with human and social sciences (historical analysis and scientific limits - social impact of nanoscience).

Introduction

The nanotech approach that proposes modern scientific topics by integrating content from different disciplines intrigues students, helping them to recover motivation to study and cultural interest even for those who show indifference to the usual curricular learning of chemistry and physics. It is interesting to capture the initial attention with the observation of the photographic reproductions of the Lycurgus Vases of the 4th century to understand how some ancient materials are characterized by particular optical (photonic) properties attributable to nanoparticles present: in this particular case the wonderful shades of glass of the vases characterized by a green or red color depending on the direction of the light that passes through the vessels illuminating them. an International Scientific Congress in 1959 presented innovative perspectives for a promising future development of the physical and chemical sciences. A singular lesson entitled "There is Plenty of Room at the Bottom", an incisive discourse on matter at the atomic level, launched a challenge to the young scientists of the time: the possibility of creating a very small engine and writing the information of a page of a book on a linear scale 25,000 times smaller. Over the years, Feynman's scientific challenge has led to a research and laboratory teaching challenge with the reading in the fourth and fifth high school classes of the original speech by R. Feynmann delivered during the Annual Meeting of the American Physical Society in 1959, "A new field of scientific adventure " from the first manifesto of nanotechnologies. It is interesting to reflect on some sentences of this speech in English. Groups of students, at different levels of study, have therefore participated over the years in the educational adventure of innovative "Teaching and STEM Learning Nanotech" courses in the full spirit of the visionary pioneer founder of a new sector of scientific research.

Materials And Methods

The promotion of the Nanotech STEM culture in schools is carried out effectively when the conditions are created for a non-passive acceptance of knowledge relating to the various technological achievements. Teachers become STEM actors in devising and activating broad and engaging educational paths with IBSE methodologies, beyond the usual curricular programs with prevalent references to textbooks in adoption, for a thorough understanding of the current applications of Nanosciences by integrating different strategies. With the IBSE didactic work modality, groups of students are guided to carry out work related to the historical development and evolution of some interdisciplinary areas of Nanosciences in cooperative working. STEM activities that can also be programmed in remote learning, inviting young people to formulate questions, to carry out guided research to make comparisons on some interesting international scientific studies currently underway. A comparative analysis of the scientific perplexities and the positive results obtained so far, from the elements of safety for the environment to the possible systemic effects on human health currently being investigated, especially in the neurobiology of the CNS in relation to any interferences of nanoparticles in neuronal synaptic plasticity derived from exposure to new generation nanostructured materials. Innovative ways of working that help "ignite young minds" to the scientific passion for an approach characterized by critical thinking in the analysis of modern application developments in science, educating on the interpretation of complexity in scientific knowledge. Paths that lead to a reasoned understanding of logical connections, developments and social consequences of modern discoveries in society, beyond any superficiality of communication and interpretation.

Results

The STEM Nanotech action-research activities in the context of laboratory method of teaching are in first phase carried out in observing some images of biological structures to discover the nanoproperties of the constituent materials, natural substances that have inspired the subsequent developments of the research of nanomaterials. Although nanotechnologies are directly linked to the laboratory environment, in reality they base their existence on the imitation of nanostructures already present in nature. The most emblematic example are the legs of the gecko, in fact, thanks to an electron microscope, the researchers observed that the legs and fingers of the gecko end with thin filaments, each of which branches into other even thinner filaments. Each filament in contact with a surface generates very small interactions similar to the Van der Waals forces and which allow the gecko to climb walls and ceilings quickly and easily. However, this is only one of the many examples that we could provide regarding the presence of nanotechnologies in nature and it is from them that the scientific community has been inspired to broaden its application horizons. Didactic operational strategies useful to intrigue young people who are the first users, even if little aware, of the Nanotech implications, of the current new nanoscience discoveries that are increasingly oriented towards the production of highly energy efficient electronic devices. An opportunity to reflect on the need to know the natural synthesis reactions of photonic crystals existing in nature to reproduce them by amplifying artificial syntheses; for example in the energy sector to produce solar cells in order to absorb light more efficiently or to produce portable devices capable of having a much higher autonomy of use than existing batteries. Researches and teaching activities carried out over the years with the methodology of the Teaching and Learning investigation IBSE (Inquiry Based Science Education) and of the Project Based Learning have been summarized by the author of this article in the contributions in different nanoscience international meeting.

Learning Debate About Graphene

Innovative debate learning and teaching about graphene was realized in different classes beginning from these questions: what is GRAPHENE and how was it discovered, which useful applications, which possible limits in different fields in research and technological transfer, which researches and results about safety of graphene? Graphene is a material made up of a monatomic layer of carbon atoms (i.e. having a thickness equivalent to the size of a single atom). As the name-ene ending suggests, the atoms are hybridized in the form sp^2, and thus arrange themselves to form hexagons with angles of 120 °. Thanks to the enormous theoretical background, consisting of numerous physical and mathematical models that described the properties of graphene, Andrej Gejm and Konstantin Novosëlov of the University of Manchester were able to isolate a single sheet of graphene by repeatedly tearing the various sheets that make up the graphite with some common "scotch". Subsequently, this layer was placed on a silicon support covered with an oxide layer and observed, for the first time, through a simple optical microscope. High school students were divided in little groups to realize a scientific debate about history and research of nanomaterials fullerene, graphene, nanotube also in virtual distance working activities after consulting international original papers and scientific articles. All students have realized oral terminal presentations sharing team reports of different groups: from discovery to modern STEM applications in different fields with considerations about possible limits of graphene’ researches and safety problems about transfer of technologies and results obtained.

Discussion

Nanotechnology is a science aimed at creating materials with completely new properties and for this to be possible exploit the extremely small size of atoms, molecules or their aggregates. These materials will be used above all for the production of solar energy through new photovoltaic cells or the production of sensors capable of detecting the presence of pollutants and toxic substances present in traces in the water up to ultrafiltrating nanostructured membranes to purify drinking water. a revolution in the methodological approach to research. In fact, prior to the birth of nanotechnologies, the science of matter had mainly followed a top-down evolutionary line, that is, an evolution in the creation of new materials that starts from macroscopic objects to arrive at the miniaturization of these systems in ever smaller parts. Unfortunately, the latter has some physical limits as the quantities cannot be further reduced in an infinitesimal way. With nanotechnologies, the application of the opposite procedure, the bottom up, was thus taken into consideration. This operational research approach starts from the use of small elementary units to arrive at the progressive construction of objects of macroscopic size. The historical foundations of the development of this science are therefore fundamental to create differentiated innovative teaching and learning paths in analyzing the first experimental phases of this innovative research sector: from the structure and history of materials such as graphite and diamond to fullerenes to move on to nanotubes and graphene after having treated the properties of carbon atoms and related allotropes. A positive promotion of the Nanotech culture in schools was achieved with non-passive acceptance of the knowledge, but with active role for teachers and students involving in interesting educational itineraries for the understanding of current applications and awareness in the orientation to future researches.

Conclusion

In this educational innovative STEM nanoscience path teacher - researcher create innovative didactic itineraries in which students are protagonists. It was possible to guide students with motivating strategies to work also analyzing biophysical and chemical innovative dates, relationship between different sciences, learning by doing also with interesting elements about history and evolution of nanoscience. For better learning Nanoscience was important to realize a modern STEM path with multidisciplinary approaches, analyzing also modern aspects of nanotech researches in energy and biomedicine fields, reflecting about importance of knowledge in impact of this new materials on human health and on environment, also for the sea and for the agricoluture. It was important for success of project to prepare flexibly actions and to programme active interdisciplinary lessons, to solidify learning with cooperative STEM class group-work. For the success of these set classes should be taught innovative elements of nanoscience with historical and interdisciplinary approaches integrating STEM enquire methods. From the basic concepts about carbon chemistry to understand evolution of physics-chemistry for nanomaterials, an interdisciplinary analyse of important applications in different scientific fields, from agriculture to biomedicine and to energy with photonics materials. All the applications implicated in modern sectors of systems science are important to analyze in critical thinking also some aspects of social impact and limits of nanoscience researches and discoveries for awareness, diffuse and deep knowledge for Society also involving local community for some topics in communication phase of didacic itineraries.

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