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The NANOLAB Project: Educational Nanoscience at High School

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ABSTRACT

The growing role of the nano-perspective in contemporary technologies naturally calls for the inclusion of Nanoscience in high school curricula. Reasons range from-the need to educate future responsible citizens to more exquisitely didactical ones. Nanosciences are-in fact a natural playground to introduce modern Physics in a hands-on interdisciplinary way, therefore opening the possibility to expose intrinsically quantum phenomena even in school laboratories. In some cases in fact the unusual properties of nanomaterials can be probed by simple experiments, including systematic data collection, in contrast to spectacular but qualitative-only demonstrations. In this paper-we will present NANOLAB, an open project by FIM Department of Modena and Reggio E. University in Italy, which aims at including nano-inspired hands-on activities in high schools. It consists of simple, cheap, robust and safe experimental protocols, currently covering four areas of nanoscience: smart metals, nanoparticles, conductive polymers, nanostructured surfaces, each linked to one of Nanoscience “big ideas”. The experimental activities range from manual to digital data collection and elaboration, including use of pupils’ own mobile devices (cell and smart phones, tablets) which turn out to be powerful, low-cost, sensitive multi-purpose lab tools, with an added impact on students’ motivation and active involvement in what we could rightly call a high-tech hands-on approach. All accompanying materials are published under Creative Commons license. In such a picture teachers’ role is crucial. To give them adequate support and provide solid background knowledge a coaching program has been running since 2011.

INTRODUCTION

The growing role of the nano-perspective in contemporary technologies naturally calls for the inclusion of Nanoscience in high school curricula. In addition to rising student consciousness about such a pervasive topic, and to the huge technological interest, which naturally appeals to students, Nanosciences are a natural playground to introduce modern Physics in a hands-on interdisciplinary way. Indeed, owing to the fact that nano-systems set themselves between the quantum scale of atoms and the classical macroscopic scale, they easily couple to several controllable external fields (temperature, pressure, visible light, electrostatic fields, etc.), but often respond to such fields in different, or even opposite ways with respect to 'classical' materials. This opens the possibility to expose intrinsically quantum phenomena even in school laboratories.

However Nano in formal education faces multiple challenges, including curriculum pressure, time constraints, need of appropriate resources and materials, funding drawbacks and, most important, teachers lacking confidence in managing new-and cross-disciplinary topics.

THE NANOLAB PROJECT

NANOLAB [1][2] is an open project by FIM Department of Modena and Reggio E. University in Italy, in collaboration with the nearby CNR NANO research center, which aims at including nano-inspired hands-on activities in high schools. It built from the start on a peculiar 'happy marriage' between Nanoscience researchers, daily working on the very same topics that are offered to the schools, and teachers driving their experience directly from class and therefore ready to tackle-K-12 nano-education specific issues. From the beginning the project counted among its priorities answering the specific needs expressed by teachers, such as more experimental activities and more quantitative ones.

In the existing panorama, most of the proposed nano-activities for young students are actually based on what we may call the *wow-effect*, consisting in high impact spectacular but strictly qualitative demonstrations, exploiting some of the peculiar properties and behavior of nano-systems to fascinate and stimulate discussion. NANOLAB project wants to be a contribution in showing that it is actually possible to go beyond this, exploiting *wow-effects* to capture student attention and give them the motivation for pursuing further, more quantitative investigations, and to interpret results within their own school labs.

Through the use of carefully chosen nano-materials, which are now available off-the-shelves-and relatively cheap, and parallely by exploiting pupils own consumer electronic devices as powerful lab instruments, jointly to other free educational resources, great effectiveness can be reached at very low cost, thus applying to a high-tech content what we may call a high-tech hands-on approach.

DISCUSSION

NANOLAB aims at bringing nano-education in the classroom, making its way in the standard curriculum. Therefore, tools and methods in NANOLAB specifically target teachers and their professional development, proposing a set of nano-inspired themes and related activities which the teachers may implement in their courses without the need of a specialized assistance.

Big ideas and thematic areas

In order to achieve this goal within the project four key-ideas [3] of Nanoscience and Nanotechnology, considered as the most significant for high-school context have been selected. Each of them has been linked to a relevant thematic area where cutting-edge research is being performed: nanoparticles, smart materials, conducting polymers, nanostructured surfaces. For each area, a small set of integrated experimental protocols have been developed which probe matter at the nanoscale highlighting the educational context in which they can be linked, with a special eye to the related applied fields.

- **Big idea #1**: Size matters → Thematic area: Nanoparticles

- **Big idea #2**: A new hierarchy in forces → Thematic area: Nanostructured surfaces and nanotribology
- **Big idea #3**: Structure and functionalities → Thematic area: Memory metals [4]
- **Big idea #4**: The leading role of quantum mechanics → Thematic area: Conductive polymers [5]

It is also possible to envisage cross thematic modules with a fusion of protocols coming from different areas, such as a didactic path on robotics and prosthetic hands involving two highly technological challenges: designing and manufacturing artificial muscles and supplying suitable tactile (e.g. pressure) sensors. Or-a module showcasing some of the most cutting edge Nanotechnology Health related topics. Finally "charge transport" may be approached treating classical materials along with the new and counterintuitive acting ones, such as Nitinol-or QTC©. In both materials Resistance exhibits peculiar aspects which can be linked to quantum behaviour.

The approach

To offer an idea of the general structure of each area-and-highlight a few typical aspects of NANOLAB approach, the "Nanostructured Surfaces and-Nanotribology" area (see Big idea #2 "a new hierarchy of forces") is described in detail.
Superhydrophobic surfaces exhibiting *lotus effect* are a must in all nanotechnology-demonstrations and never fail to capture attention and excite interest. In addition to the usual-classification of a collection of samples by contact angle (Exp 1), in NANOLAB students investigate the less known *petal effect* through the tilt angle (Exp 2). Video recording of the drops motion – students cells will easily do the job - and subsequent analysis with the free software-Tracker[1] brings to modeling the movement of-liquid on different substrates-with varying degrees of adhesion and friction. With similar modalities is proposed the study of a very recent technique in microfluidics: the so called "liquid marbles" (Exp 4). While through high speed videos (230 fps) students may study also the third parameter of-superhydrophobic surfaces, that is-restitution coefficient. (Exp 3). An alternative use for liquid marbles as gas sensors, which has been recently pursued by researchers, may be investigated too (Exp 5) providing-together with a spectacular demonstration an opportunity to introduce or revise the basic/ acids topic. Eventually, after studying the motion of liquid drops on both super-hydrophobic and conventional solid surfaces, also the motion of a super-hydrophobic surface within a liquid is dealt with. The aim is to test IBSE style whether in this case as well a decrease in friction takes place (Exp 6).

This last activity, along with many others of this module, are particularly suitable to implement a "*new life to old labs*" approach". That is, although based on nano-related topics some of the labs may be actually used to revisit well known mechanics laws and models, but in a new and-rather exciting and compelling modality. Just to cite a few: friction, down the incline motion, spheres falling within a fluid-motion and last but not least the bouncing ball .

Within the module students-make use of relatively low cost materials and equipment. Along with commercial nano materials such as textiles, aerogels, hydrophobic coatings, the only equipment needed are pipettes, food coloring plus a videocamera and a PC.-Fundamental-is the use of open source software together with the possibility to exploit students' own electronic

[1] *www.**cabrillo**.edu/~dbrown/**tracker/***

devices. These turn out to be powerful, low-cost, sensitive multi-purpose lab tools, with an added impact on student motivation and active involvement in what we could rightly call a hi-tech hands-on approach with a high level of motivation and involvement.
Finally The idea that through the nanostructuration of surfaces it's possible to-design and achieve new-tunable and predesigned properties is-further reinforced with the introduction of superadhesive surfaces exhibiting *gecko effect* (Exp 7. In progress)

In NANOLAB there are some specific aspects that deserve to be highlighted and which, in some cases, make the project differentiate itself in the panorama of nanoeducation within Europe and possibly-worldwide too. It may be rightly said that NANOLAB approach is complementary to other ones-and aims to fill-a few unfulfilled-needs..

- **Research brought to schools –** Although born and developed with the strict collaboration of researchers, one of the project ambitions is to bring cutting-edge research directly into school labs. This-challenges the idea that Nanoscience is just for undergraduates upward offering the opportunity of practicing it first hand, the earlier the better, therefore transmitting the working style in performing research.
- **A 'fil rouge' within the curricula –**Nanosciences and Nanotechnologies are introduced as a possible "fil rouge" across the curricula, since the very first years, rather than as a self-standing module, This approach might be successful also in partially tackling time constraints, namely saving time and finding an appropriate slot for the nano-activities in already crowded curricula.
- **Different levels of fruition are possible –** an effort is made to make protocols flexible enough as to be adapted to different grades of sophistication both conceptual and operational. Although originally thought as parts of a logically sequential module, the protocols may still be used as stand-alone labs.
- **Experimental approach with quantitative focus –** Great care has been taken to make the experimental activities easy to perform also in school labs: simple, safe and robust, short (1-2 lessons at most), low cost (employing relatively cheap materials and equipment), with a strong interdisciplinary approach, easy to tailor to suit different levels of both conceptual and operative complexity. The same activity can be in fact easily adapted for use with both younger and advanced pupils. In the existing panorama, most of the proposed nano-activities for young students are actually based on what we may call the "*wow-effect*", consisting in high impact spectacular but strictly qualitative demonstrations exploiting some of the peculiar properties and behavior of nanomaterials to fascinate and stimulate discussion. NANOLAB tries to go beyond this, exploiting-the wow-effects to capture student attention and give them the motivation for pursuing further, more quantitative investigations, to interpret results within their own school labs. This offers the double gain of supplementing traditional curricular topics with the new perspective of matter at the nanoscale and of introducing research own typical working style..

- **Inquiry Based Science Education (IBSE) approach –**The activities are designed as much as possible as the didactic counterparts of experiments performed daily in research laboratories; that is, students play with the real stuff, and explore the physics behind the phenomena in an inquiry based approach
- **Use of nanomaterials –** In NANOLAB students work with real nanomaterials. Students are excited to deal with the real "stuff "! Produced with specific and predesigned physical and chemical properties, nanomaterials are actually leading to many and appealing applications from energy harvesting to space flight and medicine.
- **Collaboration with firms, research centers and teachers association –**Firms and research centers provide samples which can't be bought off the shelf. The kit is distributed by the local association of Physics teachers. Therefore NANOLAB represents anyway a first attempt towards bringing together Education, Research & Enterprise.
- **High tech "bring your own device" approach –** It has also been made a massive use of new technology tools. Cells and smart phones, tablets, cameras all devices that our pupils daily bring along into the classroom, turn out to be powerful, low-cost, sensitive multi-purpose lab tools, with an added impact on student motivation and their active involvement, combining cheap solutions with effectiveness, and with the added positive effect to bring pupils to appreciate the potentialities of their electronic devices beyond the recreational or purely communicative use.
- **A focus on science basics and Physics:** NANOLAB is openly-more-Nanoscience-rather than Nanotechnology oriented. Similarly, however cross-disciplinary, the proposed activities have an added focus on Physics. These two are not preconceived positions, but rather an answer to an openly declared need. It's a fact that existing-nano-education initiatives are mostly Chemistry and Technology driven.
- **Extensive and free documentation –** A crucial point in supporting nanoeducation is the availability of appropriate extensive and high quality resources. In NANOLAB all the experimental protocols, including video and paper guides, student sheets, and a large sets of further supporting materials focused on the new Physics behind the phenomena, are published and distributed under Creative Commons license in the project website both in Italian and in English.

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Teachers training

Teachers professional development is widely recognized as the most crucial issue for-successful implementation of educational Nanoscience projects [6]. This is why NANOLAB focused strongly on teachers commitment and active involvement and implemented several actions to 'hit the classroom' from the start. A great effort has been spent in providing high quality and user friendly resources, networking possibilities and adequate professional development both on-line

(website and on-line community) and on-site (summer school 2011 and 2013) in order to have teachers independently implement the activities-in their courses, without the need of a specialized assistance.

CONCLUSIONS

NANOLAB implemented a bottom-up approach to the problem of introducing nano-education at high school in the attempt to answer Italian teachers specific needs. However-the resources produced and the approach developed may be of interest to a wider community and complement similar initiatives. All resources, both in Italian and English are distributed under Creative Commons license.

ACKNOWLEDGMENTS-

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