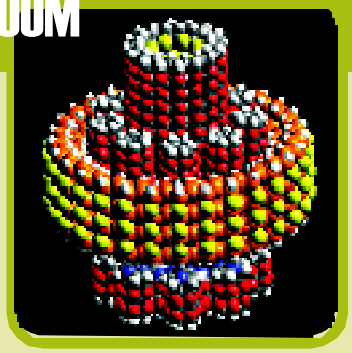
NANOSCIENCE CURRICULUM IN SCHOOL EDUCATION

INTEGRATING NANOSCIENCE INTO THE CLASSROOM



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Learning does not just mean studying for addition to qualifications or to improve job opportunities. It should be geared up to open up one's mental abilities to explore a wide range of activities that facilitate widening the horizon of understanding nature and natural phenomena besides expanding scope for and physical opportunities. NCERT is committed to building a world-class education and training framework. In order to accomplish its mandate for improving the quality of school education it strives continuously to develop, upgrade and modernise school curriculum, assessments and examinations. Main objective of these interventions is to provide a coherent and integrated curriculum and assessment framework for schools, which, in turn, may raise standard of achievement and widen educational opportunity.

Nanoscience and nanotechnology has led to an unprecedented excitement in the scientific and engineering communities, especially during the last decade. The recent revolutionary advances in nanoscale phenomena open exciting, new avenues for research and discovery. The potential contributions of advances in nanoscale phenomena to improve human health created even more excitement by envisioning new biomaterials, devices and techniques for biological detection and remediation. Thus, issues such as synthesis, fabrication and characterisation of functional nanomaterials and nanostructures for biomedical applications (molecular recognition, nanotubes, nanowires, nanoparticles, self-assembly, polymer-based nanomaterials, thin films, medical imaging, diagnosis and therapy, etc.) become very important. In recognition of this potential, we are proposing a new curriculum at senior secondary level school education. We also provide a lesson plan that would help teachers in dealing with this topic of interest.

Nanotechnology deals in the realm of the nearly invisible. The word comes from the Greek nanos, meaning "dwarf". But by most accounts, the technology's potential is anything but small. Scientists and engineers can now physically work

with materials at the atomic level to create stain-proof fabrics, scratch-resistant paints and longer-lasting tennis balls. And researchers say new medical diagnostic tools and smaller, more efficient fuel cells and batteries based on nanoscience are on the way.

According to Chad Mirkin, Director of the Institute for Nanotechnology at Northwestern University, "It has only been in recent times that we've had the tools that allow us to manipulate atoms and molecules. There is a big shift here in the way we approach science and the way we approach engineering and ultimately the way we approach medicine. And I think in many respects it is revolutionary."

From computer chips invisible to the naked eye to microscopic machines that seek out and destroy cancers inside the human body, many scientists contend that the potential of nanotechnology could be endless, but not without controversy. There are hundreds of nano-enhanced products already in the marketplace. But there are virtually no regulatory guidelines for their manufacture and distribution.

Nanotechnology Lesson Plan

This lesson plan has been prepared to serve as a model to help senior secondary school science teachers to develop their own plan for an introduction to nanotechnology in a classroom setting.

Introduction to the Concepts of Nanotechnology is the study and use of structures between 1 nanometre and 100 nanometres in size.

Ask the students : What is the smallest thing you can imagine? Answers might include a human hair, the head of a pin, or an atom.

Reading : Now have students read the following :

Introduction to Nanotechnology

Nanotechnology is defined as the study and use of structures between 1 nanometre and 100 nanometres in size. To give you an idea of how small that is, it would take eight hundred 100 nanometre particles side by side to match the width of a human hair.

Looking at Nanoparticle

Scientists have been studying and working with nanoparticles for centuries, but the effectiveness of their work has been hampered by their inability to see the structure of nanoparticles. In recent decades the development of microscopes capable of displaying particles as small as atoms has allowed scientists to see what they are working with.

Figure 1 provides a comparison of various objects to help you begin to envision exactly how small a nanometre is. The chart starts with objects that can be seen by the unaided eye, such as an ant, at the top of the chart, and progresses to objects about a nanometre or less in size, such as the ATP molecule that store energy from food in humans.

Now that you have an idea of how small a scale nanotechnologists work with, consider the challenge they face. Think about how difficult it is for many of us to insert thread through the eye of a needle. Such an image helps you imagine the problem scientists have while working with the

nanoparticles that can be as much as one millionth the size of the thread. Only through the use of powerful microscopes can they hope to 'see' and manipulate these nano-sized particles.

The Nanotechnology Debate

There are many different points of view about the nanotechnology. These differences starts with the definition of nanotechnology. Some define it as any activity that involves manipulating materials between one nanometre and 100 nanometres. However, the original definition of nanotechnology involved building machines at the molecular scale and involves the manipulation of materials on an atomic (about two-tenths of a nanometre) scale.

The debate continues with varying opinions about exactly what nanotechnology can achieve. Some researchers believe nanotechnology can be used to significantly extend the human lifespan or produce replicator-like devices that can create almost anything from simple raw materials. Others see nanotechnology only as a tool to help us do what we do now, but faster or better.

The third major area of debate concerns the timeframe of nanotechnology-related advances. Will nanotechnology have a significant impact on our day-to-day lives in a decade or two, or will many of these promised advances take considerably longer to become realities?

Finally, all the opinions about what nanotechnology can help us achieve echo with ethical challenges. If nanotechnology helps us to increase our lifespans or produce manufactured goods from inexpensive raw materials, what is the moral imperative about making such technology available to all? Is there sufficient understanding or regulation of nanotech based materials to minimise possible harm to us or our environment?

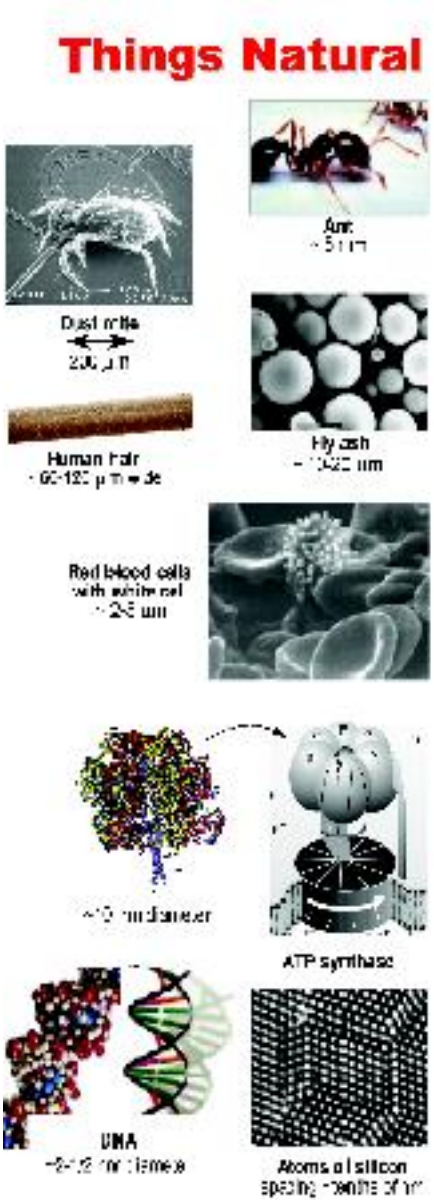
Only time will tell how nanotechnology will affect our lives, the following topics will help you understand the possibilities and anticipate the future. The following section is dedicated to provide clear and concise explanations of nanotechnology applications.

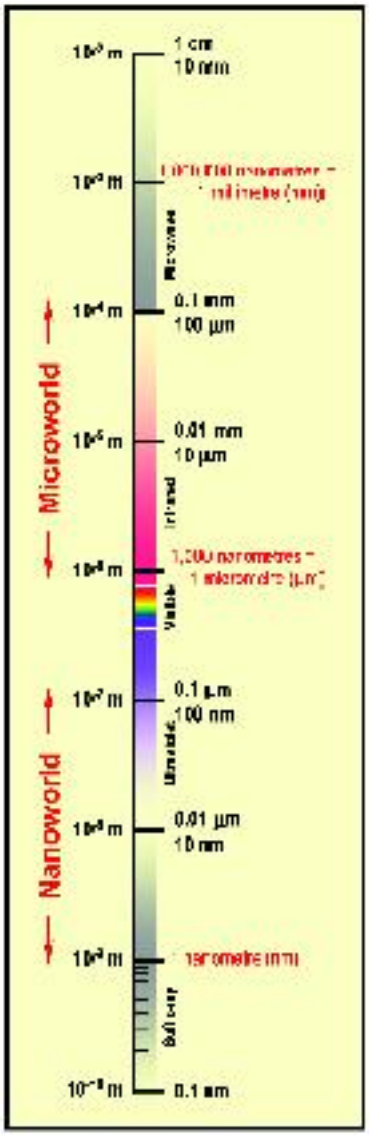
Nanotechnology Applications

The ability to manipulate nano-sized materials has opened up a world of possibilities in a variety of industries and scientific endeavors. Because nanotechnology is essentially a set of techniques that allow manipulation of properties at a very small scale, it can have many applications, such as:

Drug delivery: Today, most harmful side effects of treatments such as chemotherapy are a result of drug delivery methods that don't pinpoint their intended target cells accurately. Researchers at Harvard and MIT have been able to attach special RNA strands, measuring about 10 nanometres in diametre, to nanoparticles and fill the nanoparticles with a chemotherapy drug. These RNA strands are attracted to cancer cells. When the nanoparticle encounters a cancer cell it adheres to it and releases the drug into the cancer cell. This directed method of drug delivery has great potential for treating cancer patients while producing less side effects than those produced by conventional chemotherapy.

Fabrics : The properties of familiar materials are being changed by manufacturers who are adding nano-sized components to conventional materials


Things Natural
Dust mite
Human hair
Fly ash
Red blood cells
ATP synthase
DNA
Atoms of silicon


Microworld
Nanoworld
1 cm
10 mm
0.1 mm
100 µm
0.01 mm
10 µm
0.1 µm
100 nm
0.01 µm
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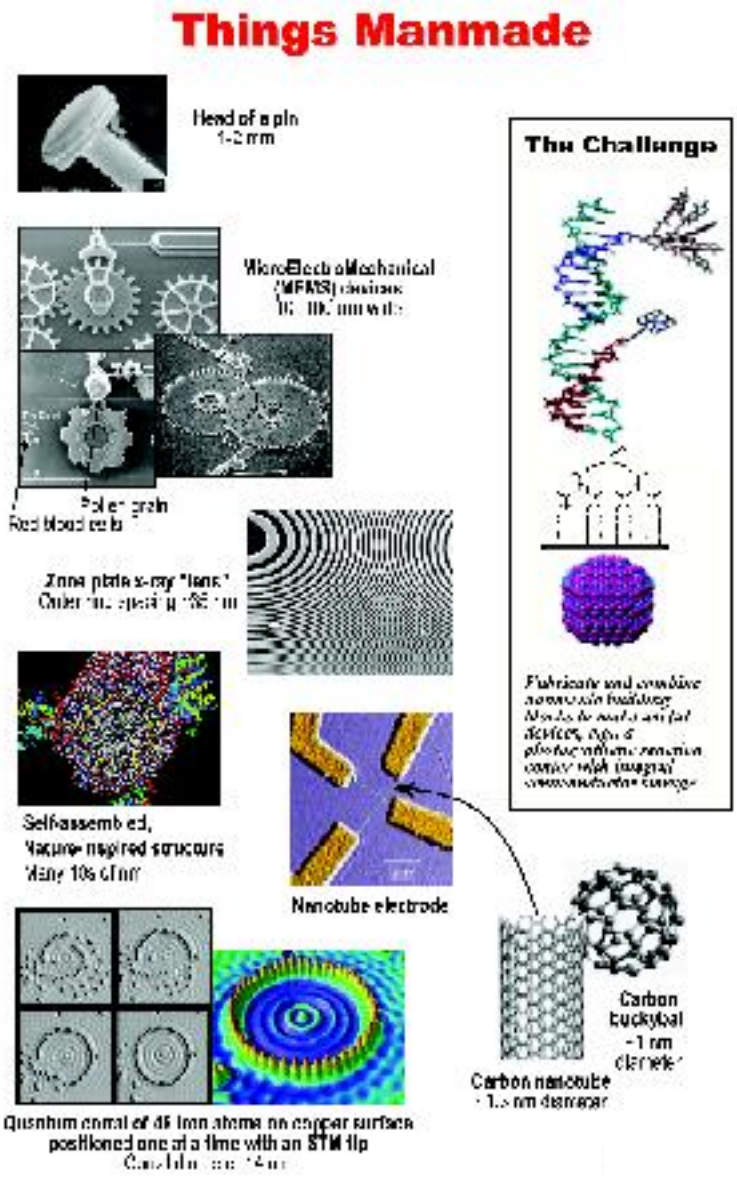

Fig. 1 The Scale of Things: Nanometres and more
(Source: www. highlight healt h. com/.../2009/10/telom ere.gif)

to improve performance. For example, some clothing manufacturers are making water and stain repellent clothing using nano-sized whiskers in the fabric that cause water to bead up on the surface.

Making composite fabric with nano-sized particles or fibres allows improvement of fabric properties without a significant increase in weight, thickness, or stiffness as might have been the case with previously used techniques.

Reactivity of materials : The properties of many conventional materials change when formed as nano-sized particles (nanoparticles). This is generally because nanoparticles have a greater surface area per weight than larger particles; they are therefore more reactive to some other molecules. For example, studies have shown that nanoparticles of iron can be effective in the cleanup of chemical in groundwater because they react more efficiently to those chemicals than larger iron particles.

Strength of Materials : Nano-sized particles of carbon, (for example nanotubes and bucky balls) are extremely strong. Nanotubes and bucky balls are composed of only carbon and their strength comes from special characteristics of the bonds between carbon atoms. One proposed application that illustrates the strength of nanosized particles of carbon, is the manufacture of bullet proof vests made out of carbon nanotubes which weigh as less as a T-shirt.

Micro/Nano Electro Mechanical Systems : The ability to create gears, mirrors, sensor elements, as well as electronic circuitry in silicon surfaces allows the manufacture of miniature sensors such as those used to activate the airbags in your car. This technique is called MEMS (Micro-Electro-Mechanical Systems). The MEMS technique results in the integration of the mechanical mechanism with the necessary electronic circuit on single silicon chip, similar to the method used to produce computer chips. Using MEMS to produce a device reduces both the cost and size of the product, compared to similar devices made with conventional methods. MEMS is a stepping stone to NEMS or NanoElectroMechanical Systems. NEMS products are being made by few companies, and will take over as the standard, once manufactures make the investment in the equipment needed to produce nano-sized features.

Molecule Manufacturing : If you're a Star Trek fan, you remember the replicator, a device that could produce anything from a space age guitar to a cup of Earl Grey tea. Your favourite character just programmed the replicator, and whatever he or she wanted appeared. Researchers are working on developing a method called molecular manufacturing that may someday make the Star Trek replicator a reality. The gadget these folks envision is called a molecular fabricator; this device would use tiny manipulators to position atoms and molecules to build an object as complex as a desktop computer. Researchers believe that raw materials can be used to almost any inanimate object using this method.

Medicine : Researchers are developing customised nanoparticle size of molecules that can deliver drugs directly to diseased cells in the body. When it's perfected, this method should greatly reduce the damage treatment such as chemotherapy, does to a patient's healthy cells. Nanomedicine refers to future developments in

medicine that will be based on the ability to build nanorobots. In the future these nanorobots could actually be programmed to repair specific diseased cells, functioning in a similar way to antibodies in our natural healing processes.

Electronics : Nanotechnology holds some answers for how we might increase the capabilities of electronic devices while we reduce their weight and power consumption.

Space : Nanotechnology may hold the key to making space-flight more practical. Advancement in nanomaterials make lightweight solar sails and a cable for the space elevator possible. By significantly reducing the amount of rocket fuel required, these advances could lower the cost of reaching orbit and travelling in space.

Food : Nanotechnology is having an impact on several aspects of food science, from how food is grown to how it is packaged. Companies are developing nanomaterials that will make a difference not only in the taste of food, but also in food safety, and the health benefits that food delivers.

Fuel Cells : Nanotechnology is being used to reduce the cost of catalysts used in fuel cells to produce hydrogen ions from fuel such as methanol and to improve the efficiency of membranes used in fuel cells to separate hydrogen ions from other gases as oxygen.

Solar Cells : Researchers have developed nanotech solar cells that can be manufactured at significantly lower cost than conventional solar cells.

Batteries : Work is currently being done for developing batteries using nanomaterials. One such battery will be as good as new even after remaining on the shelf for decades. Another battery can be recharged significantly faster than conventional batteries.

Fuels : Nanotechnology can address the shortage of fossil fuels such as diesel and gasoline by making the production of fuels from low grade raw materials economical, increasing the efficiency of engines, and making the production of fuels from normal raw materials more efficient.

Better Air Quality : Nanotechnology can improve the performance of catalysts used to transform fumes escaping from cars or industrial plants into harmless gases. That is because catalysts made from nanoparticles have a greater surface area to interact with the reacting chemicals than the same quantity of catalysts comprising larger particles. The larger surface area allows more chemicals to interact with the catalyst simultaneously, which makes the catalysts more effective.

Cleaner Water : Nanotechnology is being used to develop solutions to three very different problems in water quality. One challenge is the removal of industrial wastes, such as a cleaning solvent called TCE, from groundwater. Nanoparticles can be used to convert the contaminating chemical, through a chemical reaction into harmless material. Studies have shown that this method can be used successfully to reach contaminates dispersed in underground ponds and treat them at much lower cost than conventional methods which require pumping the water out of the ground for treatment.

Chemical Sensors : Nanotechnology can

enable sensors to detect very small amounts of chemical vapours. Various types of detecting elements, such as carbon nanotubes, zinc oxide nanowires or palladium nanoparticles can be used in nanotechnology-based sensors. Because of the small size of nanotubes, nanowires, or nanoparticles, a few gas molecules are sufficient to change the electrical properties of the sensing elements. This allows the detection of a very low concentration of chemical vapours.

Sports Goods : If you're a tennis or golf player, you'll be glad to hear that even sports goods has wandered into the nanotechnology applications in the sports arena include increasing the strength of tennis racquets, filling any imperfections in club shaft materials and reducing the rate at which air leaks from tennis balls.

Discussion : Hold a discussion in the class about the basic concepts of nanotechnology, which might include issues like :

- You learned in this introduction that scientists had to imagine the characteristics of nanoparticles for years before they developed special microscopes that allowed them to see them. What would it be like to work with a material you can't see? Are there other fields of science where you work with things you can't see? (Radio waves, gravity, etc.)
- Which is bigger : A nanoparticle, an atom, or a molecule? Discuss the fact that, depending on the composition and number of atoms in a molecule, it can vary from a nanometre in diametre to hundreds of nanometres in length. Similarly, different types of atoms may have diametres ranging from a tenth of nanometre to 5 tenths of a nanometre. Nanoparticles also vary in size, ranging up to 100 nanometres. All of these can be measured in nanometres, a measurement with a constant size of one billionth of a metre.

Explore an Application of Nanotechnology

Discussion : Some scientific fields focus on one type of material or process, such as biology that focuses on living organisms and metreeology that focuses on the weather. What does nanotechnology focus on? Remind the students of the definition of nanotech nanotechnology; this study of structures of small size can be applied in just about any field. Nanotechnology is currently being used in medicine, the environment, to add strength to materials such as fabrics, space flight, and so on.

Reading : Have students search over as many processes of information as possible including the internet and pick few pages to read. Encourage them to follow links on the site for additional information, if they find it interesting. Have them create a brief report about what they have read and present it to the class.

The Future of Nanotechnology

Explain that nanotechnology has the potential to be a disruptive technology, meaning that it could cause extreme change in our society that could have a wide range of consequences. An example of this would be the industrial revolution, which changed the economy of most of our cultures from agrarian to manufacturing based.

Discussion : Pick one of these topics:

- The molecular replicator, once developed, could allow people to simply produce many items they need themselves with no need for a company to manufacture those products. What would this do to our economy as we know it today? What if everybody could produce their own clothing, iPod, and shoes? Would it help poorer people or would it put people out of work? How would the world change?

- In the world of medicine nanotechnology could change the human lifespan. Repairs at the cellular level could stop and even reverse aging. If everybody could live hundreds of years, what would happen to our world? Would only an elite few get such treatment and what consequences would that have? If nobody ever died, would people have to stop having children to avoid overpopulation? What would that mean to our society?

One can hold a discussion with the entire class, or break up into smaller groups with some groups making an argument for the benefits of these changes, and the other groups arguing the case that such changes would bring more harm than good to our society.

Optional Activity : Hold debates between the groups on the above discussion topics.

Wrap up the lesson by pointing out that nanotechnology offers great potential for advancement, and that, as with any scientific breakthrough, it also raises ethical and societal questions.

The following is a model syllabus on nanotechnology that it can be most suitable for adoption at senior secondary level. The proposed syllabus is conceived for four semesters after class Xth. In semester format one can pursue issues more deeply and explore a wider variety of questions.

Nanoscience I

- Biology
- Algebra
- Computer Literacy
- Writing and Research
  - — Cell Structure
  - — DNA Extraction
  - — Gel Electrophoresis
  - — Enzyme and Protein Structures
  - — Tagging methods

Nanoscience II

- Chemistry
- Physics
- Mathematics
- Communication
  - — Periodic Table
  - — Molecules
  - — Compounds
  - — Physical properties
  - — Electrical properties
  - — Band structures
  - — Computer Simulation
  - — Basics of modelling programmes
  - — Input requirement
  - — Reliability
  - — Variations
- Observational Internship

Nanoscience III

- Nanoelectronics
  - — Serve as an introduction to electrical structures
  - — Processor and memory device design and fabrication
  - — Emerging technologies: quantum, photonics, nanowires, molecular
- Nanobiotechnology
  - — Serve as an introduction to the field
  - — Energy production and enzymatic processes
  - — Protein interactions
- Nanomaterials
  - — Introduction to material properties and manufacturing methodologies
  - — Adhesion, tension, friction, viscosity, etc.,
  - — Impact of manufacturing and operational environments

Nanoscience IV

- Advanced Fundamental Courses
- Micro and Nano Fabrication
- Thin Film Deposition
- Introduction to Materials Characterisation
- Principles and Applications of Nanobiotechnology
- Industry Internship

Picture on page 33 : Tiny nanogears may one day move microscopic machines through the human body in search of disease. (Source: www. highlighthealth.com/.../2009/10/telomere.gif)