Macro to the Micro

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Overview

Nanotechnology is the science of the extremely small. Nanotechnology, which is sometimes shortened "nanotech", refers to a field whose theme is the control of matter on an atomic and molecular scale, generally nanotechnology deals with structures the size of 100 nanometers or smaller developing materials or devices within that size (Wikipedia). One nanometer (nm) is one billionth or 10-9 of a meter or comparatively the size of a marble to the size of the earth. The study of these structures will provide unlimitless possibilities for modern technologies in areas of science, medicine and nature.

The first use of the concepts in 'nano-technology' (but predating use of that name) was in "There's Plenty of Room at the Bottom," a talk given by physicist Richard Feynman at an American Physical Society meeting at Caltech on December 29, 1959. Feynman described a process by which the ability to manipulate individual atoms and molecules might be developed, using one set, of precise tools to build and operate another proportionally smaller set, so on down to the needed scale. In the course of this, he noted, scaling issues would arise from the changing magnitude of various physical phenomena: gravity would become less important, etc. This basic idea appears plausible, and exponential assembly; enhances it with parallelism to produce a useful quantity of end products. The term "nanotechnoloy" was defined by Tokyo Science University Professor Norio Taniguchi in a 1974 paper as follows:

"*Nano-technology" mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule."* (Wikipedia/N.Tangiuchi)

The term reached greater public awareness in the 1986 with the publication of <u>Engines of Creation: The Coming Era of Nanotechnology</u> by Eric Drexler.

Nanotechnology and nano-engineering are still in the very early stages of development and possibilities. The major approaches to create nanostructures used in nanotechnology is “bottom-up” in which materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. In the “top-down” approach, nano objects are constructed from larger entities without atomic level control. (Rodgers)

Nanotechnology is concerned with the world of invisible miniscule particles that are dominated by forces of physics and chemistry that cannot be applied at the macro-or human -scale level. The classic laws of science are different at the nanoscale. Nanoparticles possess large surface areas and essentially no inner mass, that is their surface -to-mass ratio is extremely high. This new "science" is based on the knowledge that particles in the nanometer range, and nanostructures or nanomachines that are developed from these nanoparticles, possess special properties and exhibit unique behavior. These special properties, in conjunction with their unique behavior, can significantly impact physical, chemical, electrical, biological, mechanical and functional qualities.   A diverse array of ultra-small materials, including metal oxides, ceramics and polymeric materials, and wide-ranging processing methods including techniques that employ 'self-assembly'on a molecular scale, are either in use today or are being groomed for commerical-scale use. (Theodore/Kunz)

Examples of nanotechnology in actual commercial use, under serious investigation, or on the verge of commercialization include:

* Semiconductor chips and other microelectronics application
* High surface-to -volume catalysts, which promote chemical reaction more efficiently and selectively
* Ceramics, lighter-weight alloys, metal oxides, and other metallic compounds
* Coatings, paints, plastics, fillers, and food-packaging applications
* Polymer-composite materials, including tires, with improved mechanical properties
* Transparent composite materials, such as sunscreens containing nanosize titanium dioxide and zinc oxide particles
* Use in fuel cells, battery electrodes, communications applications, photographic film developing, and gas sensors
* Nanobarcodes
* Tips for scanning probe microscopes
* Purification of pharmaceuticals and enzymes

Many promising medical applications are being developed, but because of the lengthy approval procedures by the Food and Drug Administration (FDA) in the United States, may require some time before these items are put on the market for public use. Other examples , in various stages of development, focused on pollution prevention and treatment are listed below:

* Sensing of pollutants. pH, and chemical warfare agents
* Ultraviolet light (UV)-activated catalysts for treatment of environmental contaminants

* Removal of environmental contaminants from various media, including *in situ* remediation of pesticides, polychlorinated biphenyls (PCBs), and chlorinated organic solvents, such as trichloroethylene (TCE)
* Posttreatment of contaminated soils, sediments, and solid waste
* Sorption of contaminants for air and water pollution control, in a manner said to be vastly superior to activated carbon
* Chelating agents for polymer-supported ultrafiltration
* Oil-water separation
* Destruction of bacteria (including anthrax)
* Purification of drinking water, without the need for chlorination

(Theodore/Kunz)

The purpose of this unit is to expose the students to the current trends in science and technology, and the limitless possibilities for improving the quality of human life.

Rationale

Beeber Middle School is the site where this unit will be taught to middle years students in grades 6,7,and 8. It is located in the Wynnefield section of Philadelphia where students of moderate economic levels reside. There are approximately 460 to 520 students enrolled, with some of the graduating eighth graders going onto some of the magnet schools, and the majority of the students going to Overbrook High School.

The title of this unit "Macro to Micro" is intended to help the students both visualize and conceptualize the concept of nanotechnology. Objects that can be classified as having something to do with nanotechnology are larger than atoms but much smaller than we can perceive directly with our senses. One way to look at this size scale is that one nanometre is about 100,000 times smaller than the diameter of a single human hair.

The following figure may also help to put this size scale in context.

Mountain	Child	Ant	Bacterium	Sugar Molecule
l	l	l	l	l
1 Kilometre (1000m)	1 metre (1 m)	1 millimetre (0.001 m)	1 micrometre (0.000001 m)	1 nanometre (0.000000001 m)

*Objects of approximate size from 10 *3m to 10-9m (Hunt/Mehta*)

The surface-area-to-volume ratio is the amount of surface area per unit of an object. This ratio is measured in units of inverse directions. For most shapes the surface area to volume ratio decreases linearly with an increase in size. The surface area to volume ratio is calculated by dividing the surface area by the volume of an object.

The main focus of this unit is to use surface area to volume ratio to help the students understand nanoscience. Interestingly, the properties of materials change due to an increase in their surface area to volume ratios.

Relationship Between Particle Size and Surface Area

There is an inverse relationship between particle size and surface area, and one of the hallmarks of nanotechnology is the desire to produce and use nanometer-sized particles of various materials in order to take advantage of the remarkable characteristics and performance attributes that many materials exhibit at these infinitesimally small particle sizes.

To illustrate the relationship between shrinking particle size and increasing susrface area, envision a child's alphabet block that starts out being just the right size to fit into the chubby hand of a curious toddler. Now run an imaginary knife through the block, along its horizontal, vertical, and lateral axes, to divide the original playing piece into eight smaller blocks of equal size.

While the original block had just enough surface area to hold 6 colorful pictures, three quick swipes of the imaginary knife produces 8 smaller blocks, which now have additional--previously unavailable--surface area for picture display. With each of the 8 smaller blocks now having 6 sides of its own, the newly size-reduced blocks can now display 48 little pictures of circus animals, letters, or numbers -- much to the delight of the appreciative child.

Continue to divide each of these smaller blocks with three quick swipes of the imaginary knife, and you can see the exponential relationship between particle size and surface area. This inverse relationship between particle size and surface area is key underpinning of the field on nanotechnology.

"Reactions take place at the surface of a chemical or material; the greater the surface area to volume, the greater the reactivity." (Theodore / Kunz)

The link to nanotechnology is that as particles get smaller; their surface area to volume ratio increases dramatically. Nanoparticles are special and interesting because their chemical and physical properties are different from their macro counterparts. One prime example of surface area to volume ratio at the nanoscale is gold as a nanoparticle. At the macroscale, gold is an inert element, meaning it does not react with many chemicals, whereas at the nanoscale, gold nanoparticles become extremely reactive and can be used as catalysts to speed up reactions. "
(www.nanoed.org/lessons/Apples_to_Atoms/AtoAch5.pdf)

"Nanostructures intersect the macro world through surfaces and interfaces the novel properties of nanoscopic materials are determined to a large extent by their large surface/interface to volume ratio." (www.nsos.at/frame_home.htm)

The lessons in this unit will be used to teach the students the concept of surface to volume ratio as it relates to nanoscience.

"*Nanotechnology has given us the tools.....to play with the ultimate toy box of nature – atoms and molecules...The possibilities to create new things appear limitless"*

Horst Stomer, Physics Nobel Laureate

Objectives

The main focus of this unit is to help the students to conceptualize and then understand that scale matters. Nanotechnology deals with miniscule particles that are not applied at the macro-or human-scale level but with nanoparticles that have large surface area to mass ratios with unique properties that will revolutionize science and technology. It is my goal to lead the students to explore nanoscience and its related fields and possibilities.

Strategies

Natural and many important functions of living organisms occur at the nanoscale.

This will be an inquiry-based lab:

*to introduce the students to the innovative enhancements in the properties and performance of structures, materials and devices that have controllable features on a nanometer scale.

* to expose the students to the possible affordability of manufacturing structures and the nanometer scale to improve electronic, optical and mechanical devices.

* to show the possible synthesis of new compounds and designing new materials.

* to apply the process skills of observing, inferring, predicting, measuring, computing; also estimating, formulating, hypotheses, experimenting and problem solving.

Classroom Activities

The lessons in this unit will be used to describe and explain how to compare the surface to volume ratio of nanoparticles, cells etc. The surface area to volume ratio is very important in living things. The very small size of the cell is extremely important for it's survival. The students will compute the surface to volume ratio of several shapes.

Lessons

A) How to find Surface Area an Volume Ratio

Aim: To understand how nanoparticles may be used by investigating surface area to volume ratio as its shape changes.

Background Information

Surface area to volume ratio can be easily found in many shapes like spheres or cubes.

The surface area for a cube is S=6 *L*L where L is the length of a side and the volume

of a cube is V=L*L*L so the ratio of surface area to volume is given this equation

S/V=6/L.

The surface area for a sphere is S=4*Pi*R*R where R is the radius of the sphere and Pi is 3.14.

The volume of a sphere is V=4*Pi*R*R*R/3 so the ratio of surface area to volume is given by:

S/V=3/R

Surface area and volume of other shapes:

Volume of a box = LxWxH

Volume of a ball = 1.33Pi (radius)*3

Volume of a cylinder = Pi * H* (radius)*2

Surface area of a box =
(4*L*W) front face plus (2*L*W) side face

Surface area of a ball = 4Pi *(radius)*2

Surface area of cylinder =
(2Pi (radius)*2 plus (2Pi (radius)* H

Students will calculate the surface to volume area of cubes of different sizes.

side of cube	side*2	area of side	6*side*2	area of cube surface	side*3	volume	Ratio S/V
2	2*2	4	6*2*2	24	2*2*2		3:1
4							
6							
8							
10							
12							
16							

Procedure:

1. Have the students complete the table and divide surface by the volume to figure out the ratio.

2. Discuss how the surface area to volume ratio is inversely proportional to the size of the object.
(the smaller the size the larger the surface area to volume ratio)

3. This activity should take about 30 minutes. It can be extended by figuring out the surface to volume ratio of other shapes.

B) *One in a Billion* (NSTA press)

Goal: To get students to understand a number as small as one-billionth.

Background Information

One billionth is significant because a nanometer is one-billionth of a meter and nanotechnology involves the building of materials at this tiny scale.

The students will investigate a series of dilutions, each larger by a power of 10.

Materials:

Each group will need:

* White paper
* 1 ml dropper
* food coloring
* 200 ml of water
* rinse cup of water
* 9 small cups (clear) or beakers
* 2 graduated cylinders (10ml)

Procedure:

1. Number the cups or beakers 1-9

2. Place white paper under the nine cups or beakers.

3. Using a graduated cylinder, put 1 ml of food coloring and 9 ml of water in cup 1. Be sure to rinse the graduated cylinder with water each time. Swirl cup or beaker gently to mix solution.

4. In the results chart, describe the color of the solution in cup 1 and write 0.1 under concentration to represent a 10% solution.

5. In cup 2 add 1 ml of solution from cup 1 and 9 ml of water. Again, describe the color and calculate the concentration of the solution. Record results in the results Chart.

6. In cup 3 add 1 ml of solution from cup 2 and 9 ml of water. Record results in chart.

7. Continue the dilution process as done above for cups 4-9. Record all results in chart.

Results

Cup	Color	Concentration
1		
2		
3		
4		
5		
6		

Cup	Color	Concentration
7		
8		
9		

Questions:

1. In which Cup did the solution first appear colorless?

2. What is the concentration of food coloring in this cup?

3. Do you think there is any food coloring present in this cup of diluted solution even though you cannot see it? Explain.

Cup 1 Cup 2 Cup 3 Cup 4 Cup 5 Cup 6 Cup7 Cup 8 Cup 9

1/10 1/100 1/1000 -- 1/1,000,000,000

Explain and write on the board that cup 1 has a 10% solution or 1/10 solution. If they add 1 ml of a 1/10 solution to 9 ml of water the solution will now be 1/10, which equals 1/100 (a 1% solution) or 1 part per hundred. Have them calculate the concentration of cups 2 to 9.

C) *How Surface Area/Volume Ratio Affects The Rate Of Diffusion In Substrates And How This Relates to The Size and Shape of Living Organisms*
(www.neiljohan.com/projects/bioloby/sa--col.htm)

Goal: this is an experiment to examine how the Surface Area/Volume Ratio affects the rate of diffusion in substrates and how this relates to the size and shape of living organisms.

Background Information

The surface area to volume ratio in living organisms is very important. Nutrients and oxygen need to diffuse through the cell membrane and into the cells. Most cells are no longer than 1mm in diameter because small cells enable nutrients and oxygen to diffuse into the cell quickly and allow waste to diffuse out of the cell quickly. If the cells were any bigger than this then it would take too long for the nutrients and oxygen to diffuse into the cell so the cell would probably not survive.

Apparatus Needed for the Experiments:

1. Beakers
2. Gelatin blocks containg cresol red dye
3. 0.1M Hydrochloric acid
4. Stop Watch
5. Scalpel
6. Tile
7. Safety glasses

Method:

1. A block of gelatin which has been dyed with cresol red dye should be cut into blocks of the
following sizes(mm).

5 x 5 x 5
10 x 10 x 10
15 x 15 x 15
20 x 20 x20
10 x 10 x 2
10 x 10 x 10 (Triangle)
10 x 15 x 5
20 x 5 x 5

The rest of the blocks are just plain cubes or rectangular blocks.

Cresol red dye is an acid / alkali indicator dye. In the alkali conditions of the gelatin it is red or purple but when it gets exposed to acid it turns a light yellow color.

Gelatin is used for these tests as it is permeable and so it acts like a cell. It is easy to cut the required sizes and the hydrochloric acid can diffuse at an even rate through it.

2. Fill a small beaker with 100cm3 of 0.1 molar Hcl. This is a sufficient volume of acid to ensure that all the block sizes are fully covered in acid when dropped into the beaker.

3. Drop one of the blocks into the beaker and record the time it takes for the red dye to disappear, and record in the table.

Dimensions (mm)	Surface Area	Volume (mm2)	Surface Area/volume Ratio	Test 1	Test 2	Test 3	Average Time
5x5x5	150	125	1.2:1	7.02	6.57	4.53	6.16

4. This test should be repeated for all the sizes of blocks three times to ensure a fair test. Fresh acid should be used for each block to ensure that this does not affect the experiment's results.

5. The surface area / volume ratio and an average of the results can then be worked out. A graph of Time against Surface Area to Volume Ratio can then be plotted. From this graph you will be able to see how the surface area affects the time taken for the hydrochloric acid to penetrate to the center of the cube.

Interpretation

In all the blocks of gelatin the rate of penetration of the hydrochloric acid should have been the same , but
all the blocks take different amounts of time to clear because of they are different sizes. As the blocks get
bigger it takes longer for the hydrochloric acid to diffuse through all the block and to clear the dye.
It takes longer to reach the center of the cube even though the rate of diffusion is the same for all
the blocks.

Annotated Bibliography/Resources

1. Hunt, Geoffrey, and Mehta, Michael (2006) *Nanotechnology : Risk, Ethics, and Law*, London/Earthscan

   This book is a global overview of the state of Nanotechnology and Society in Europe, the USA, Japan and Canada, examining the ethics, the environment and public health risks, and the governance and regulation of this most promising, and potentially most dangerous of all technologies.

2. Karn et al., (2006) *Nanotechnology and the Environment: Applications and Implications.* American Chemical Society.

   In this book, science, engineering and technology has the potential to substantially enhance environmental quality, sustain ability through utilizing nanomaterials to improve detections and sensing techniques for biological and chemical toxins, removal and destruction contaminants, and the discovery of new "green" industrial processes that reduce energy and resource use and generation of waste products.

3. Atkinson, William Illsey (2005) *Nanocosm: Nanotechnology and ate big Changes Coming from the Inconceivably Small*. New York N.Y. Amacon Am. Mang. Assoc.

   Nanocosm reveals a spectacular view of the immediate future of Nanotechnoloy and its applications in medicine, computing, manufacturing, engineering, and countless other area that effect our world, redefining how we work, play and live.

4. Theodore, Louis, and Kunz (2005*) Nanotechnology: Environmental Implications and Solutions.* John Wiley and Sons, Inc.

   Nanotechnology is revolutionizing the chemical, telecom, pharmaceutical health care, aeorspace, and computer industries. Professor Theodore and Dr. Kunz provide a concise review of nano-fundamentals and explore background issues surrounding nanotechnology and its environmental impact.

5. Foster, Lynn E. (2006) *Nanotechnology Science, Innovation and Opportunity*. Prentice Hall, Boston.

   this book is organized into four sections: history and development drivers of innovation, the players that drive the technology forward, the specific areas of nanoscale materials and the convergenc of science at the nanoscale that foreshadow a transformation and revolutionary change in society and highlights ethical considerations in the advance of nanotechnology.

6. David, Kenneth and Thompson, Paul, B. *What Can Nanotechnology Learn From Biotechnology*? Amsterdam Food Science and Technology , International Series. This book explores the diverse territory of proponents and opponents of challenging, but potentially risky technologies. New technologies force two kinds of extra-technical risks: public acceptance risk and regulatory risk.

7. Rodgers,P. (29 June 2006) "Nanoelectronics:Single file" *Journal of Nature Nanotechnology (online)* (http://en.wikipedia.org/wiki/Nanotechnology)

8. Jones, Gail M. *Nanoscale Science : Activities for Grades 6-12,* NSTA Press. These lessons help teach nanosciece to students.

9. http://en. willipede.org/wiki/nanotechnology
This article explores the origins, fundamental concepts, current research, tools and techniques, applications, and implications of nanotechnology.

10. http://www.nsos.at/frame_home.htm
This article explores how the mature field of surface science is an important and necessary contributor to the field of nanoscience.

11. http://www.nano.gov/html/facts/faqs.html
Questions are answered and information is given in this article about nanotechnology about its future, funding and future workforce neeeds.

12 .http://www.Neil Johan.com/projects/biology/sa-vol.htm
This website contains the third lesson of this unit.

13. http:// www.crnano.org/whatis.htm
What is nanotechnology gives a basic definition, meaning of and four generations of the development of nanotechnology.

Appendices-Standards

National Science Content Standards

1. Content Standard A
   * Abilities necessary to do scientific inquiry

2. Content Standard B
   * Structure and properties of matter
   * Chemical reactions

Academic Standards for Science and Technology and Environment and Ecology
Pennsylvania Department of Education

I. 3.2 Inquiry and Design

A. Explain and apply scientific and technological knowledge

* Explain how new information may change existing theories and practice.

B. Apply process knowledge to make and interpret observations

* Measure materials using a variety of scales

II. 3.3 Biological Sciences

A. Describe the similarities and differences that characterize diverse living things

* Describe how the structures of living things help them function in unique ways

III. 3.4 Physical Science, Chemistry and Physics

A. Describe concepts about the structure and properties of matter.

* Identify elements as basic building blocks of matter that cannot be Broken down chemically

* Know that atoms are composed of even smaller sub-atomic structures whose properties are measurable.

IV. 3.6 Technology Education

A. Explain biotechnologies that relate to related technologies of propagating, growing Maintaining, adapting, treating and converting.

* Identify and explain the impact that a specific medical advancement has Had on society.

* Explain the factors that were taken into consideration when a specific object Was designed

B. Explain information technologies of encoding, transmitting, receiving, storing, Retrieving and decoding.

* Demonstrate the effectiveness of image generating techniques to Communicate a story.

C. Apply physical technologies of structural design, analysis and engineering, Personnel relations, financial affairs, structural production, marketing research and

Design to real world problems.

* Apply concepts of design engineering and production engineering in the Organization and application of a manufacturing activity.

V. 3.7 Technological Design

A. Describe the safe and appropriate use of tools, materials and techniques to answer Questions and solve problems,.

* Identify use of tools, machines, materials, information, people, money, energy And time that meet specific design criteria

* Describe safe procedures for using tools and materials

* Asses materials for appropriateness of use.

VI. 3.8 Science, Technology and Human Endeavors

A. Analyze the relationship between societal demands and scientific and technological Enterprises.

* Identify changes in society as a result of a technological development.

B. Analyze how human ingenuity and technological resources satisfy specific human Needs and improve the quality of life.

* Identify interrelationships between systems and resources

C. Identify the pros and cons of applying technological and scientific solutions to Address problems and the effect upon society.

* Describe the positive and negative expected and unexpected effects of specific Technological developments

* Describe ways technology extends and enhances human abilities.