"An Introduction to the Nanoscale: Surface Area and Volume"

This module introduces the basic principle that underlies many nanotechnology applications.

The Big Nano Concept:
As the object size gets smaller, the surface area-to-volume ratio gets larger. At the nanoscale, this ratio is huge.

ACTIVITY 1: Same Material—Different Behavior

Learning Goal
*The **physical form** of a solid influences the degree to which it interacts with its environment: the more spread out the solid is, the more readily it interacts.*

Part A: "Will it Burn?" — ease of burning steel wool vs. steel nail

Part B: "Disappearing Water" — time for pellet vs. powder form of superabsorbent polymer to absorb water

Part C: "A Little Bit of Sugar" — measure dissolving time of different forms of candy (mint, ribbon, granulated sugar, powdered sugar, cotton candy)

Standards:

primary

NSES Physical Science *Chemical Reactions*
Chemical reactions can take place in time periods ranging ... Reaction rates depend on how often the reacting atoms and molecules encounter one another, on the temperature, and on the properties—including shape—of the reacting species.

AAAS 2061 Structure of Matter *Chemical Reactions*
The rate of reactions among atoms and molecules depends on how often they encounter one another, which is affected by the concentration, pressure, and temperature of the reacting materials.

secondary

NCTM Geometry
Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest ...

NSES Science as Inquiry *Abilities Necessary to Do Scientific Inquiry*
Formulate and revise scientific explanations and models using logic and evidence.

Learning performances

- predict degrees of reaction between a solid material with varying amounts of surface area and molecules encountered by this surface
- measure liquid volume, solid mass, and time
- describe the application of a model of dimensional changes (i.e., 3D, 2D, 1D)
- interpret data from different types of systems to induce a relationship between the amount of surface area and the degree of interaction with the environment

ACTIVITY 2: Powers of 10 and Scale

Learning Goal

The magnitudes involved with the nanoscale can be represented with powers of 10 and scaling.

Part A: "Just Add Water" — compare 1-D change to volume change of a "growing animal" made of a superabsorbent polymer

Part B: "Expressing a Large Span of Distances" — measure lengths of different magnitudes, and create a relative representation scheme

Part C: "It's All Relative: Expressing Scale" — express scaled heights: 1) Alice (in Wonderland) tall and small; 2) student scaled to a globe of Earth (to ~ 30 nm)

Part D: "Scaling from Macro to Nano" — construct poster with a macro-to-nano theme

Standards:

primary

NCTM Numbers and Operations: Develop a deeper understanding of very large and very small numbers and of various representations of them.

secondary

AAAS 2061 Common Themes *Scale: Represent Numbers*: Representing large numbers in terms of powers of ten makes it easier to think about them and to compare things that are greatly different.

AAAS 2061 Habits of Mind *Computation and Estimation: Compare Numbers*
Express and compare very small and very large numbers using powers-of-ten notation.

AAAS 2061 Habits of Mind *Computation and Estimation Ratios and Proportions*
Use ratios and proportions, including constant rates, in appropriate problems.

NCTM Geometry: Describe sizes, positions, and orientations of shapes under informal transformations such as flips, turns, slides, and scaling.

AAAS 2061 Habits of Mind *Computation and Estimation Models*: Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or that are too vast to be changed deliberately, or that are potentially dangerous.

NSES Unifying Concepts and Processes *Systems, Order, and Organization Models*
Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

NCTM Numbers and Operations
Create and use representations to organize, record, and communicate mathematical ideas.

Learning performances

- predict: (1) lengths covering a wide range, (2) student height scaled to the nanoscale, and (3) volume changes.
- express quantities as powers of 10
- generate a "cognitive tool" to produce a visual representation to relate a wide range of lengths
- express quantities as proportions to determine scale
- conceptualize the smallness of the nano scale relative to the macro scale

ACTIVITY 3: Surface Area and Volume

Learning Goal

*The **surface area to volume ratio** changes with the **shape** or **size** of an object. This ratio changes dramatically in the nano scale.*

Part A: "Ideal Two-Dimensional Objects" — create shapes with minimum and maximum perimeter-to-area ratios

Part B: "Properties of Three-Dimensional Objects" — create shapes with minimum and maximum surface area-to-volume ratios

Part C: "To the Limit" — for constant shape, varying size: graph the surface area-to-volume ratio

Standards:

primary

AAAS 2061 Mathematical World *Shapes*

When the linear size of a shape changes by some factor, its area and volume change disproportionately: area in proportion to the square of the factor, and volume in proportion to its cube. Properties of an object that depend on its area or volume also change disproportionately.

secondary

NCTM Geometry: Analyze properties and determine attributes of 2- and 3-dimensional objects.

NCTM Geometry: Explore relationships ... among classes of 2- and 3-D geometric objects, make and test conjectures about them, and solve problems involving them.

NSES Unifying Concepts and Processes *Systems, Order, and Organization: Models*

Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

AAAS 2061 Mathematical Representation *Graphical Representation*

Graphs can show a variety of possible relationships between two variables. ...

NCTM Geometry: Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest ... .

Learning performances

- construct physical geometric models that minimize or maximize the surface area-to-volume ratio as a function of shape
- propose models that approach minimum and maximum limits (going beyond what can be built)
- show via calculations and graphing that surface area-to-volume ratio is inversely related to size
- construct an explanation of how surface area-to-volume ratio changes with size and with shape