NanoLeap

Nanoscale Materials and Their Properties

Objectives, Essential Understandings, and Standards Addressed

This module builds upon the big ideas in a general chemistry course. Assessing students on those topics is necessary scaffolding in order to assess them for understanding nanoscience topics.

Table 3: Big Ideas and Essential Understandings

Big Idea/Essential Understanding
EU1: Measurement and Size Nanoscience is the study of the fundamental principles of molecules and structures having at least one dimension lying roughly between 1 and 100 nanometers.
EU2: Interdisciplinary Nature Nanoscience includes the scientific concepts involved in biology, chemistry, and physics
EU3: Properties of Matter Objects have physical and chemical properties. At the nanoscale level, a large fraction of an object's atoms, ions, or molecules are exposed at its surface; therefore, the object's physical and chemical properties are dominated by surface interactions.
EU4: Scientific Instruments Scientific instruments can be used to characterize properties of objects, their structure and surfaces, even if the objects cannot be seen.
EU5: Applications/ Public Policy A sound understanding of nanoscience is required to develop applications of nanotechnology and to inform public policy

Table 4: Module Objectives and Alignment to Standards

NSES Content Standards Addressed	Big Idea/Essential Understanding	Lesson 1/ Objective
Physical Science **Structure of Atoms** Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge.	**EU1: Measurement and Size** Nanoscience is the study of the fundamental principles of molecules and structures having at least one dimension lying roughly between 1 and 100 nanometers.	1. Define nanoscience as the study of the fundamental principles of structures having at least one dimension lying roughly between 1 and 100 nanometers.
		a) Compare and contrast the size of atoms, ions, and molecules to the size of nanoparticles.
		b) Identify structures that are appropriately measured in nanometers.
		c) Compare and contrast nanoparticle samples to atomic and macro-level samples in terms of the particle size, number of atoms, and operational model.
Science in Personal and Social Perspectives Science and Technology in Local, National, and Global Challenges Individuals and society must decide on proposals involving new research and the introduction of new technologies into society.	**EU5: Applications/ Public Policy** A sound understanding of nanoscience is required to develop applications of nanotechnology and to inform public policy.	2. Explain the importance of nanoscience research and technology.
		3. Evaluate the ethical considerations associated with nanoscience research and nanotechnology.
Science and Technology **Understandings about Science and Technology** Scientists in different disciplines ask different questions, and use different methods of investigation.	**EU2: Interdisciplinary Nature** Nanoscience includes the scientific concepts involved in biology, chemistry, and physics.	4. Recognize the interdisciplinary nature of nanoscience.
Science as Inquiry **Understandings about Scientific Inquiry** Scientists rely on technology to enhance the gathering and manipulation of data.	**EU4: Scientific Instruments** Scientific instruments can be used to characterize properties of objects, their structure, and surfaces, even if the objects cannot be seen.	5. Identify the requirements of nanoscience and nanotechnology, including:
		a) new production methods,
		b) new measurement instruments, and
		c) a cleanroom environment for nanoscale research and technology.

NSES Content Standards Addressed	Big Idea/Essential Understanding	Lesson 2/ Objective
Physical Science **Structure of Atoms** Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge.	**EU3: Properties of Matter** At the nanoscale level, a large fraction of an object's atoms, ions, or molecules are exposed at its surface; therefore, the object's physical and chemical properties are dominated by surface interactions.	6. Define extendable solids. a) Identify elements and compounds that form extendable structures. b) Compare and contrast extendable solids.
Physical Science Structure and Properties of Matter Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element. Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.	**EU3: Properties of Matter** At the nanoscale level, a large fraction of an object's atoms, ions, or molecules are exposed at its surface; therefore, the object's physical and chemical properties are dominated by surface interactions.	7. Recognize that an extendable nanostructure's physical and chemical properties are dominated by surface interactions. a) Relate the size and properties of a sample (both macro-samples and nano-samples) to the ratio of surface particles to interior particles in the sample. b) Define surface energy. c) Compare and contrast the physical and chemical properties of metallic elements and ionic compounds at both the macro and nano scale (i.e., melting point, electrical conductivity, color, reactivity, catalysis, adsorption).
Science in Personal and Social Perspectives Science and Technology in Local, National, and Global Challenges Individuals and society must decide on proposals involving new research and the introduction of new technologies into society.	**EU5: Applications/ Public Policy** A sound understanding of nanoscience is required to develop applications of nanotechnology and to inform public policy	8. Evaluate the implications of nanoscale research and technology.

NSES Content Standards Addressed	Big Idea/Essential Understanding	Lesson 3/ Objective
Physical Science **Structure and Properties of Matter** The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.	**EU3: Properties of Matter** At the nanoscale level, a large fraction of an object's atoms, ions, or molecules are exposed at its surface; therefore, the object's physical and chemical properties are dominated by surface interactions.	9. Identify elements that can form discrete nanoparticles. a) Recognize that discrete nanoparticles are a result of covalent bonding patterns.
Physical Science **Structure and Properties of Matter** Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.	**EU3: Properties of Matter** At the nanoscale level, a large fraction of an object's atoms, ions, or molecules are exposed at its surface; therefore, the object's physical and chemical properties are dominated by surface interactions.	10. Compare and contrast the properties of several allotropes of carbon (i.e., graphite, diamond, fullerenes). a) Analyze the covalent bonding patterns of carbon and the resulting three dimensional shapes of molecules and carbon allotropes. b) Relate the bonding and structure of carbon nanoparticles to their properties (i.e., corannulene, buckyballs, fullerenes, nanotubes).
Science in Personal and Social Perspectives Science and Technology in Local, National, and Global Challenges Individuals and society must decide on proposals involving new research and the introduction of new technologies into society.	**EU5: Applications/ Public Policy** A sound understanding of nanoscience is required to develop applications of nanotechnology and to inform public policy.	11. Explore the potential applications of carbon nanoparticles and nanotechnology. a) Define nanotechnology as the use of discrete nanoparticles to produce useful products and materials. b) Compare and contrast endohedral (cage) and exohedral fullerene compounds and their applications. c) Describe the properties and potential uses of carbon nanotubes.