Unit Overview

Teacher Materials

Contents

For Anyone Planning to Teach Nanoscience…
Read This First!

Nanoscience Defined

Nanoscience is the name given to the wide range of interdisciplinary science that is exploring the special phenomena that occur when objects are of a size between 1 and 100 nanometers (10^{-9} m) in at least one dimension. This work is on the cutting edge of scientific research and is expanding the limits of our collective scientific knowledge.

Nanoscience is "Science-in-the-Making"

Introducing students to nanoscience is an exciting opportunity to help them experience science in the making and deepen their understanding of the nature of science. Teaching nanoscience provides opportunities for teachers to:

- Model the process scientists use when confronted with new phenomena
- Address the use of models and concepts as scientific tools for describing and predicting chemical behavior
- Involve students in exploring the nature of knowing: how we know what we know, the process of generating scientific explanations, and its inherent limitations
- Engage and value our student knowledge beyond the area of chemistry, creating interdisciplinary connections

One of the keys to helping students experience science in action as an empowering and energizing experience and not an exercise in frustration is to take what may seem like challenges of teaching nanoscience and turn them into constructive opportunities to model the scientific process. We can also create an active student-teacher learning community to model the important process of working collaboratively in an emerging area of science.

This document outlines some of the challenges you may face as a teacher of nanoscience and describes strategies for turning these challenges into opportunities to help students learn about and experience science in action. The final page is a summary chart for quick reference.

Challenges & Opportunities

1. You will not be able to know all the answers to student (and possibly your own) questions ahead of time …

Nanoscience is new to all of us as science teachers. We can (and definitely should) prepare ahead of time using the resources provided in this curriculum as well as any others we can find on our own. However, it would be an impossible task to expect any of us to become experts in a new area in such a short period of time or to anticipate and prepare for all of the questions that students will ask.

… This provides an opportunity to model the process scientists use when confronted with new phenomena.

Since there is no way for us to become all-knowing experts in this new area, our role is analogous to the "lead explorer" in a team working to understand a very new area of science. This means that it is okay (and necessary) to acknowledge that we don't have all the answers. We can then embrace this situation to help all of our students get involved in generating and researching their own questions. This is a very important part of the scientific process that needs to occur before anyone steps foot in a lab. Each time we teach nanoscience, we will know more, feel more comfortable with the process for investigating what we don't know, and find that there is always more to learn.

One strategy that we can use in the classroom is to create a dedicated space for collecting questions. This can be a space on the board, on butcher paper on the wall, a question "box" or even an online space if we are so inclined. When students have questions, or questions arise during class, we can add them to the list. Students can be invited to choose questions to research and share with the group, we can research some questions ourselves, and the class can even try to contact a nanoscientist to help us address some of the questions. This can help students learn that conducting a literature review to find out what is already known is an important part of the scientific process.

2. Traditional chemistry and physics concepts may not be applicable at the nanoscale level …

One way in which both students and teachers try to deal with phenomena we don't understand is to go back to basic principles and use them to try to figure out what is going on. This is a great strategy as long as we are using principles and concepts that are appropriate for the given situation.

However, an exciting but challenging aspect of nanoscience is that matter acts differently when the particles are nanosized. This means that many of the macro-level chemistry and physics concepts that we are used to using (and upon which our instincts are based) may not apply. For example, students often want to apply principles of classical physics to describe the motion of nanosized objects, but at this level, we know that quantum mechanical descriptions are needed. In other situations it may not even be clear if the macroscale-level explanations are or are not applicable. For example, scientists are still exploring whether the models used to describe friction at the macroscale are useful in predicting behavior at the nanoscale (Luan & Robbins, 2005).

Because students don't have an extensive set of conceptual frameworks to draw from to explain nanophenomena, there is a tendency to rely on the set of concepts and models that they do have. Therefore, there is a potential for students to incorrectly apply macroscale-level understandings at the nanoscale level and thus inadvertently develop misconceptions.

… This provides an opportunity to explicitly address the use of models and concepts as scientific tools for describing and predicting chemical behavior.

Very often, concepts and models use a set of assumptions to simplify their descriptions. Before applying any macroscale-level concept at the nanoscale level, we should have the students identify the assumptions it is based on and the situations that it aims to describe. For example, when students learn that quantum dots fluoresce different colors based on their size, they often want to explain this using their knowledge of atomic emission. However, the standard model of atomic emission is based on the assumption that the atoms are in a gaseous form and thus so far apart that we can think about their energy levels independently. Since quantum dots are very small crystalline solids, we have to use different models that think about the energy levels of the atoms together as a group.

By helping students to examine the assumptions a model makes and the conditions under which it can be applied, we not only help students avoid incorrect application of concepts, but also guide them to become aware of the advantages and limitations of conceptual models in science. In addition, as we encounter new concepts at the nanoscale level, we can model the way in which scientists are constantly confronted with new data and need to adjust (or discard) their previous understanding to accommodate the new information. Scientists are lifelong learners and guiding students as they experience this process can help them see that it is an integral and necessary part of doing science.

3. Some questions may go beyond the boundary of our current understanding as a scientific community…

Traditional chemistry curricula primarily deal with phenomena that we have studied for many years and are relatively well understood by the scientific community. Even when a student has a particularly deep or difficult question, if we dig enough we can usually find ways to explain an answer using existing concepts. This is not so with nanoscience! Many questions involving nanoscience do not yet have commonly agreed upon answers because scientists are still in the process of developing conceptual systems and theories to explain these phenomena. For example, we have not yet reached a consensus on the level of health risk associated with applying powders of nanoparticles to human skin or using nanotubes as carriers to deliver drugs to different parts of the human body.

… This provides an opportunity to involve students in exploring the nature of knowing: how we know what we know, the process of generating scientific explanations, and its inherent limitations.

While this may make students uncomfortable, not knowing a scientific answer to why something happens or how something works is a great opportunity to help them see science as a living and evolving field. Highlighting the uncertainties of scientific information can also be a great opportunity to engage students in a discussion of how scientific knowledge is generated. The ensuing discussion can be a chance to talk about science in action and the limitations on scientific research. Some examples that we can use to begin this discussion are: Why do we not fully understand this phenomenon? What (if any) tools limit our ability to investigate it? Is the phenomenon currently under study? Why or why not? Do different scientists have different explanations for the same phenomena? If so, how do they compare?

4. Nanoscience is a multidisciplinary field and draws on areas outside of chemistry, such as biology, physics, and computer science…

Because of its multidisciplinary nature, nanoscience can require us to draw on knowledge in potentially unfamiliar academic fields. One day we may be dealing with nanomembranes and drug delivery systems, and the next day we may be talking about nanocomputing and semiconductors. At least some of the many areas that intersect with nanoscience are bound to be outside our areas of training and expertise.

… This provides an opportunity to engage and value our student knowledge beyond the traditional areas of chemistry.

While we may not have taken a biology or physics class in many years, chances are that at least some of our students have. We can acknowledge students' interest and expertise in these areas and take advantage of their knowledge. For example, ask a student with a strong interest in biology to connect drug delivery mechanisms to their knowledge about cell regulatory processes. In this way, we share the responsibility for learning and emphasize the value of collaborative investigation. Furthermore, this helps engage students whose primary area of interest isn't chemistry and gives them a chance to contribute to the class discussion. It also helps all students begin to integrate their knowledge from the different scientific disciplines and presents wonderful opportunities for them to see the how the different disciplines interact to explain real world phenomena.

Final Words

Nanoscience provides an exciting and challenging opportunity to engage our students in cutting edge science and help them see the dynamic and evolving nature of scientific knowledge. By embracing these challenges and using them to engage students in meaningful discussions about science in the making and how we know what we know, we are helping our students not only in their study of nanoscience, but in developing a more sophisticated understanding of the scientific process.

References

Luan, B., & Robbins, M. (2005, June). The breakdown of continuum models for mechanical contacts. *Nature 435*, 929-932.

Table 1. Challenges of teaching nanoscience and strategies for turning these challenges into learning opportunities.

	The Challenge…	Provides the Opportunity to…
1	You will not be able to know all the answers to student (and possibly your own) questions ahead of time	Model the process scientists use when confronted with new phenomena: Identify and isolate questions to answer Work collectively to search for information using available resources (textbooks, scientific journals, online resources, scientist interviews) Incorporate new information and revise previous understanding as necessary Generate further questions for investigation
2	Traditional chemistry and physics concepts may not be applicable at the nanoscale level	Address the use of models and concepts as scientific tools for describing and predicting chemical behavior: Identify simplifying assumptions of the model and situations for intended use Discuss the advantages and limitations of using conceptual models in science Integrate new concepts with previous understandings
3	Some questions may go beyond the boundary of our current understanding as a scientific community	Involve students in exploring the nature of knowing: How we know what we know The limitations and uncertainties of scientific explanation How science generates new information How we use new information to change our understandings
4	Nanoscience is a multidisciplinary field and draws on areas outside of chemistry, such as biology and physics	Engage and value our student knowledge beyond the area of chemistry: Help students create new connections to their existing knowledge from other disciplines Highlight the relationship of different kinds of individual contributions to our collective knowledge about science Explore how different disciplines interact to explain real world phenomena

Clear Sunscreen: Overview, Learning Goals & Standards

Type of Courses:	Chemistry, Physics
Grade Levels:	9-12
Topic Area:	The interaction of light and matter
Key Words:	Nanoscience, nanotechnology, light scattering, electromagnetic spectrum, organic compounds, inorganic compounds
Time Frame:	6 class periods (assuming 50-minutes classes), with extensions available

Overview

Traditional inorganic sunscreens use "large" zinc oxide particles which effectively block the full spectrum of ultraviolet (UV) light, but also scatter visible light, giving the cream an undesirable white color. Because of this, people often apply too little sunscreen or choose another, less effective, kind. If nanosized particles of zinc oxide are used instead, the cream is transparent because the diameter of each nanoparticle is much smaller than the wavelength of visible light and thus does not scatter the light. Given our increased awareness of the dangers of long wave ultraviolet (UVA) light (which many other sunscreens do not block), a full spectrum sunscreen that people are willing to use is an important tool for preventing skin cancer.

Enduring Understandings (EU)

What enduring understandings are desired? Students will understand:

1. How the energies of different wavelengths of light interact differently with different kinds of matter.
2. Why particle size can affect the optical properties of a material.
3. That there may be health issues for nanosized particles that are undetermined at this time.
4. That it is possible to engineer useful materials with an incomplete understanding of their properties.
5. There are often multiple valid theoretical explanations for experimental data; to find out which one works best, additional experiments are required.
6. How to apply their scientific knowledge to be an informed consumer of chemical products.

Essential Questions (EQ)

What essential questions will guide this unit and focus teaching and learning?

1. What are the most important factors to consider in choosing a sunscreen?
2. How do you know if a sunscreen has "nano" ingredients?
3. How do "nano" sunscreen ingredients differ from most other ingredients currently used in sunscreens?

Key Knowledge and Skills (KKS)

What key knowledge and skills will students acquire as a result of this unit? Students will be able to:

1. Describe the mechanisms of absorption and scattering by which light interacts with matter.
2. Describe how particle size, concentration and thickness of application affect how particles in a suspension scatter light.
3. Explain how the phenomenon of seeing things in the world is a human visual response depending on how light interacts with objects.
4. Evaluate the relative advantages (strong blockers, UVA protection) and disadvantages (possible carcinogenic effects, not fully researched) of using nanoparticulate sunscreens.

Prerequisite Knowledge

This unit assumes that students are familiar with the following concepts or topics:

1. Atoms, molecules, ionic and covalent compounds
2. Atomic energy levels, absorption of light
3. Light waves, frequencies, electromagnetic spectrum, color

NSES Content Standards Addressed

K-12 Unifying Concepts and Process Standard

As a result of activities in grades, K-12, all students should develop understanding and abilities aligned with the following concepts and processes: (2 of the 5 categories apply)

- Evidence, models and explanation
- Form and function

Grades 9-12 Content Standard A: Science as Inquiry

Abilities Necessary to Do Scientific Inquiry

- **Formulate scientific explanations and models.** Student inquiries should culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students should engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation. (12ASI1.4.)
- **Analyze alternative explanations.** This aspect of the standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models are best. In other words, although there may be several plausible explanations, they do not all have equal weight. Students should be able to use scientific criteria to find the preferred explanations. (12ASI1.5.)

Understandings about Scientific Inquiry

- **Scientific explanations**. Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge. (12ASI2.5)

Grades 9-12 Content Standard B: Physical Science

Chemical Reactions

- **Energy and chemical reactions.** Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog. (12BPS3.2)

Interactions of Energy and Matter

- **Waves**. Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter. (12BPS6.1)
- **Electromagnetic waves**. Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength. (12BPS6.2)
- **Discrete amounts of energy in atoms/molecules.** Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance. (12BPS6.3)

Grades 9-12 Content Standard E: Science and Technology

Understandings about Science and Technology

- **Scientists in different disciplines use different methods.** Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines. (12EST2.1)

Grades 9-12 Content Standard F: Science in Personal and Social Perspectives

Personal and Community Health

- **Personal choice concerning fitness and health involves multiple factors.** Personal choice concerning fitness and health involves multiple factors. Personal goals, peer and social pressures, ethnic and religious beliefs, and understanding of biological consequences can all influence decisions about health practices. (12FSPSP1.3)

Science and Technology in Local, National, and Global Challenges

- **Individuals and society must decide on proposals of new research/technologies.** Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them. Students should understand the appropriateness and value of basic questions--"What can happen?"--"What are the odds?"--and "How do scientists and engineers know what will happen?" (12FSPSP6.4)

Grades 9-12 Content Standard G: History and Nature of Science

Nature of Scientific Knowledge

- **All scientific knowledge is subject to change as new evidence becomes available.** Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore unlikely to change in the areas in which they have been tested. In areas where data or understanding are incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest. (12GHNS2.3)

Historical Perspectives

- **Scientific knowledge evolves over time, building on earlier knowledge.** The historical perspective of scientific explanations demonstrates how scientific knowledge changes by evolving over time, almost always building on earlier knowledge. (12GHNS3.4)

Unit at a Glance

Overview

The Clear Sunscreen Unit has been designed in a modular fashion to allow you maximum flexibility in adapting it to your student's needs. Lessons 1 and 2 provide basic coverage of the dangers of UV exposure, the mechanisms by which sunscreens work and the factors that determine their appearance. Combined with Lesson 5 (culminating activities), they make up the basic sequence for the unit. Lessons 3 and 4 are each extensions of one of the topics covered in lesson 2 (absorption and appearance) and can be added individually to the unit to increase coverage of that topic.

Lesson	Basic Sequence	Optional Extensions
Lesson 1: Introduction to Sun Protection	√	
Lesson 2: All About Sunscreens	√	
Lesson 3: How Sunscreens Block: The Absorption of UV Light		√
Lesson 4: How Sunscreens Appear: Interactions with Visible Light		√
Lesson 5: Culminating Activities	√	

In addition, most lessons contain an interactive presentation and one or more options for activities so you can tailor the depth and duration of the lesson to meet your needs. The following pages contain a suggested sequencing of activities for both the basic and full unit, but of course there are many other combinations possible.

Suggested Sequencing of Activities for Basic Unit

Lesson	Teaching Days	Main Activities and Materials	Learning Goals	Assessment	Homework
Lesson 1: Introduction to Sun Protection	2 days: *Day 1*	Sun Protection: Understanding the Danger PowerPoint and Discussion Initial Ideas: Student Worksheet	EU: 1, 6 KKS: 4	Initial Ideas Worksheet	Read UV Protection Lab Activity and generate hypotheses
	Day 2	UV Protection Lab Activity		UV Protection Activity Worksheet	Finish UV Protection Activity Worksheet
Lesson 2: All About Sunscreens	2 days: *Day 1*	All About Sunscreen PowerPoint and Discussion	EU: 2, 3, 4, 5, 6 KKS: 1, 2, 3, 4		Read Sunscreen Ingredients Activity
	Day 2	Sunscreen Ingredients Activity Reflection on Guiding Questions		Sunscreen Ingredients Activity Worksheet Reflection on Guiding Questions	
Lesson 5: Culminating Activities	2 days: *Day 1*	Consumer Choice Project (Performance Assessment) OR Quiz and Final Reflection on Guiding Questions	EU: 1, 2, 3, 4, 6 KKS: 1, 2, 3, 4	Final Reflections Worksheet Quiz	Prepare to share pamphlets
	Day 2 *(15 min only for quiz choice)*	Sharing of Consumer Choice Pamphlets and Final Reflection on Guiding Questions OR Return and review of quizzes		Project Scoring Rubric and Peer Feedback Form	

Suggested Sequencing of Activities for Full Unit

Lesson	Teaching Days	Main Activities and Materials	Learning Goals	Assessment	Homework
Lesson 1: Introduction to Sun Protection	2 days: *Day 1*	Sun Protection: Understanding the Danger PowerPoint and Discussion Initial Ideas: Student Worksheet	EU: 1, 6 KKS: 4	Initial Ideas Worksheet	Read UV Protection Lab Activity and generate hypotheses
	Day 2	UV Protection Lab Activity		UV Protection Activity Worksheet	Finish UV Protection Activity Worksheet
Lesson 2: All About Sunscreens	2 days: *Day 1*	All About Sunscreen PowerPoint and Discussion	EU: 2, 3, 4, 5, 6 KKS: 1, 2, 3, 4		Read Sunscreen Ingredients Activity
	Day 2	Sunscreen Ingredients Activity Reflection on Guiding Questions		Sunscreen Ingredients Activity Worksheet Reflection on Guiding Questions	Absorption of Light by Matter: Student Reading
Lesson 3: How Sunscreens Block: The Absorption of UV Light	1 Day	Discussion of Absorption Reading How Sunscreens Block: The Absorption of UV Light PowerPoint and Discussion Reflection on Guiding Questions	EU: 1 KKS: 1	Reflection on Guiding Questions	Scattering of Light by Suspended Clusters: Student Reading
Lesson 4: How Sunscreens Appear: Interactions with Visible Light	2-3 days: *Day 1*	How Sunscreens Appear: Interactions with Visible Light PowerPoint Slides and Discussion Introduction of Sunscreens Animation Activity (creation or viewing pre-made ones)	EU: 1, 2, 6 KKS: 1, 2, 3		Continue to work on animations
	Day 2	Work on Animation Creation **OR**		Animation Worksheet Reflection on Guiding	Prepare to present animations

Lesson	Teaching Days	Main Activities and Materials	Learning Goals	Assessment	Homework
		Discussion of Pre-Made Animations and Reflection on Guiding Questions		Questions	
Lesson 4 (continued)	*Day 3* *(animation creation only)*	Class Presentation and Discussion of Student Animations Reflection on Guiding Questions		Animation Scoring Rubric Reflection on Guiding Questions	
Lesson 5: Culminating Activities	2 days: *Day 1*	Consumer Choice Project (Performance Assessment) OR Quiz and Final Reflection on Guiding Questions	EU: 1, 2, 3, 4, 6 KKS: 1, 2, 3, 4	Final Reflections Worksheet Quiz	Prepare to share pamphlets
	Day 2 *(15 min only for quiz choice)*	Sharing of Consumer Choice Pamphlets and Final Reflection on Guiding Questions OR Return and review of quizzes		Project Scoring Rubric and Peer Feedback Form	

What **enduring understandings (EU)** are desired? Students will understand:

1. How the energies of different wavelengths of light interact differently with our skin and vision.
2. Why particle size can affect the optical properties of a material.
3. That there may be health issues for nanosized particles that are undetermined at this time.
4. That it is possible to engineer useful materials with an incomplete understanding of their properties.
5. There are often multiple valid theoretical explanations for experimental data; to find out which one works best, additional experiments are required.
6. How to apply their scientific knowledge to be an informed consumer of chemical products.

What **essential questions (EQ)** will guide this unit and focus teaching and learning?

1. How do "nano-sunscreens" differ from traditional sunscreens?
2. What is the best kind of sunscreen to use and why?
3. Should nanoproducts have special regulations associated with them?

What **key knowledge and skills (KKS)** will students acquire as a result of this unit? Students will be able to:

1. Describe the mechanism of absorption and scattering by which light interacts with matter.
2. Describe how particle size, concentration and chemical / solvent identity (refractive index), affect how particles in a suspension scatter light.
3. Explain how the phenomenon of seeing things in the world is a human visual response depending on how light interacts with these objects.
4. Evaluate the relative advantages (strong blockers, UVA protection) and disadvantages (possible carcinogenic effects, not fully researched) of using nanoparticulate sunscreens.

Alignment of Unit Activities with Learning Goals

Learning Goals	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5
Presentation	*UV Dangers*	*All About Sunscreens*	*Absorption*	*Appearance*	-
Activity	*UV Protection Lab Activity*	*Sunscreen Label Activity*	*Student Reading*	*Animation Activity*	*Consumer Choice Project*
Assessment	*Lab Results/ Initial Ideas Worksheet*	*Label Results/ Reflection Worksheet*	*Reflection Worksheet*	*Animation/ Reflection Worksheet*	*Consumer Pamphlets/ Quiz*
Students will understand…					
EU 1. How the energies of different wavelengths of light interact differently with different kinds of matter.	•		•	•	•
EU 2. Why particle size can affect the optical properties of a material.		•		•	•
EU 3. That there may be health issues for nanosized particles that are undetermined at this time.		•			•
EU 4. That it is possible to engineer useful materials with an incomplete understanding of their properties.		•			•
EU 5. There are often multiple valid theoretical explanations for experimental data; to find out which one work best, additional experiments are required.		•			
EU6. How to apply their scientific knowledge to be an informed consumer of chemical products.	•	•		•	•

Learning Goals	**Lesson 1**	**Lesson 2**	**Lesson 3**	**Lesson 4**	**Lesson 5**
Presentation	*UV Dangers*	*All About Sunscreens*	*Absorption*	*Appearance*	-
Activity	*UV Protection Lab Activity*	*Sunscreen Label Activity*	*Student Reading*	*Animation Activity*	*Consumer Choice Project*
Assessment	*Lab Results/ Initial Ideas Worksheet*	*Label Results/ Reflection Worksheet*	*Reflection Worksheet*	*Animation/ Reflection Worksheet*	*Consumer Pamphlets/ Quiz*
Students will be able to…					
KKS1. Describe the mechanism of absorption and scattering by which light interacts with matter		•	•	•	•
KKS2. Describe how particle size, concentration and thickness of application affect how particles in a suspension scatter light.		•		•	•
KKS3. Explain how the phenomenon of seeing things in the world is a human visual response depending on how light interacts with objects.		•		•	•
KKS4. Evaluate the relative advantages (strong blockers, UVA protection) and disadvantages (possible carcinogenic effects, not fully researched) of using nanoparticulate sunscreens	•	•			•

Alignment of Unit Activities with Curriculum Topics

Chemistry

Unit Topic	Chapter Topic	Subtopic	Clear Sunscreen Lessons	Specific Materials

Structure of Matter	Electron Configuration	Radiant Energy	• Lesson 1 (L1): Introduction to Sun Protection
			• Lesson 2 (L2): All about Sunscreens
			• Lesson 4 (L4): How sunscreens appear: scattering
			• Lesson 5 (L5): culminating activities
				Slides
				• L1: 1-14 (15-17 optional)
				• L2: 2, 16-25
				• L4: All Slides
				Activity/Handout
				• L1
				  o UV Protection Lab Activity
				  o Summary of Sun Radiation
				• L2
				  o Light Scattering by 3 Sunscreens handout
				  o Sunscreen Ingredient Activity
				  o FDA Approved Sunscreen Ingredients
				• L4
				  o Reading: Scattering of Light by Particles
				  o Ad Campaign Project w/ ChemSense animation
				• L5
				  o Consumer Choice Pamphlet project
				  o Student Quiz

Structure of Matter	Electron Configuration	Quantum Theory	• Lesson 3 (L3): How sunscreens block: absorption	**Slides** • L2: 8 • L3: All Slides • L4: 8, 9
Chemistry of our World	Carbon Compounds	Organic Chemistry	• Lesson 2 (L2): All About Sunscreens • Lesson 3 (L3): Absorption	**Slides** • L2: 5-10 • L3: 5-9 **Activity/Handout** • L2: Summary of FDA Approved Sunscreen Ingredients

Physics

Unit Topic	Chapter Topic	Subtopic	Clear Sunscreen Lessons	Specific Materials
Mechanics	Potential Energy and Conservation of Energy	Absorption Dispersion/scattering	• Lesson 2 (L2): All About Sunscreens • Lesson 3 (L3): The Science Behind Sunscreen Protection: Absorption • Lesson 4 (L4): The Science Behind Sunscreen Appearance: Scattering	**Slides** • L2: 8-10, 14, 18-24 • L3: (most) • L4: (most) **Activity** • Sunscreen Animation
Atomic Physics	Atomic Models	Electromagnetic spectrum Frequency/ wavelength	• Lesson 1 (L1): Intro to Sun Protection	**Slides** • L1: 7
Electricity and Magnetism	Electromagnetic Waves	Photoelectric effect E=hf; energy levels	• Lesson 3 (L3): The Science Behind Sunscreen Protection: Absorption • Lesson 4 (L4): The Science Behind Sunscreen Appearance: Scattering	**Slides** • L3: 3, 6-7, 14 • L4: 5, 8

Environmental Science

Unit Topic	Chapter Topic	Subtopic	Clear Sunscreen Lessons	Specific Materials
Atmosphere and Climate Energy	The Ozone Shield	The Ozone Hole: The Effects of Ozone Thinning	• Lesson 1 (L1): Intro to Sun Protection • Lesson 2 (L2): All About Sunscreens • Lesson 3 (L3): How Sunscreens Block: Absorption • Lesson 4 (L4): How Sunscreen Appear: Scattering • Lesson 5 (L5): Ad Campaign Project	**Slides** • L1-L4: All slides **Activity/Handout** • L1: UV Bead Lab • L2: o Sunscreen ingredients Activity o Light Scattering by Three Sunscreens o Reflection on the Guiding Questions • L3: o Reading: Absorption of Light by Matter o Reflecting on the Guiding Questions • L4: o Reading: Scattering of Light by Particles o Sunscreens & Sunlight Animations • L5: Ad Campaign Project

Biology

Unit Topic	Chapter Topic	Subtopic	Clear Sunscreen Lessons	Specific Materials
The Human Body	Skeletal, Muscular, and Integumentary System	The Integumentary System	• Lesson 1 (L1): Intro to Sun Protection • Lesson 2 (L2): All About Sunscreens • Lesson 3 (L3): How Sunscreens Block: Absorption • Lesson 4 (L4): How Sunscreen Appear: Scattering • Lesson 5 (L5): Culminating Activities (Optional)	**Slides** • L1, L2, L4: All slides • *L3: Use with instructor's discretion [1]* **Activity/Handout** • L1: UV Bead Lab • L2: ○ Sunscreen Ingredients Activity ○ Light Scattering by Three Sunscreens ○ Reflections on the Guiding Questions • *L3: Use with instructor's discretion [1]* • L4: ○ Reading: Scattering of Light Particles ○ Sunscreens & Sunlight Animations ○ Ad Campaign Project

[1] Clear Sunscreen Lesson 3 requires some schema of chemistry and physics and can be used with biology students but this is at the instructor's discretion. Instructor should gauge student's depth of understanding behind the chemistry and physics concepts used in this particular lesson.

List of Sunscreen Products that Use Nanoparticulate Ingredients

(All Sunscreens listed as: Brand – Products)

Sunscreens that use nanoparticulate ZnO and/or TiO_2 as their only active ingredients:

- Alba Botanica - Sun (sold at Trader Joes)
- Clinique - Super City Block
- Fallene - Total Block Suncare Line
- Peter Thomas Roth - Ultra-Lite Titanium Dioxide Sunblock
- Blue Lizard - Sensitive Sunscreen
- SkinCeuticals - Daily Sun Defense
- Team Estrogen - All Terrain TerraSport Sunblock
- SunSmart – Therapeutics Line
- Wet Dreams – All Natural Sunscreen Line (Australian Surf Brand)

Sunscreens that use nanoparticulate ZnO and/or TiO_2 as one of their active ingredients along with organic ingredients:

- Dermatone – All products
- Banana Boat - "Surf" and Sensitive Skin Sunscreens
- Long's - Ski & Surf Sunscreen
- BullFrog – SPF 45
- Banana Boat – BabyMagic and Kids Sunscreen
- Coppertone - Spectra 3
- No Ad – Kids Sunblock
- Panama Jack - Surf ' N Sport Clear Zinc

Clear Sunscreen Pretest/Posttest: Teacher Answer Sheet

20 points total

1. In what ways are "nano" sunscreen ingredients similar and different from other ingredients currently used in sunscreens? For each of the four categories below, indicate whether "nano" sunscreen ingredients are "similar" or "different" to organic and inorganic ingredients and explain how. (1.5 points each, total of 12 points)

	Organic Ingredients (e.g. PABA)	**Inorganic Ingredients (e.g. Classic Zinc Oxide used by lifeguards)**
Chemical Structure	Similar or **[Different]** How: Nano ingredients are small ionic clusters while organic ingredients are molecules.	**[Similar]** or Different How: Nano ingredients are a kind of inorganic ingredients. Bother are ionic clusters but the nano clusters are smaller.
Kinds of Light Blocked	Similar or **[Different]** How: Organic ingredients each block a small part of the UV spectrum (generally UVB) while nano ingredients block almost the whole thing,	**[Similar]** or Different How: Both nano ingredients and traditional inorganic ingredients block almost the whole UV spectrum.
Way Light is Blocked	**[Similar]** or Different How: Both nano and organic ingredients block UV light via absorption. (The specific absorption mechanism is different, but students are not expected to report this)	**[Similar]** or Different How: Both nano and inorganic ingredients block UV light via absorption.
Appearance on the Skin	**[Similar]** or Different How: Both nano and organic ingredients appear clear on the skin.	Similar or **[Different]** How: Traditional inorganic ingredients appear white on the skin while nano ingredients appear clear.

2. Briefly describe one benefit and one drawback of using a sunscreen that contains "nano" ingredients: (1 point each, a total of 2 points)

> Benefits:
>
> - Block whole UV spectrum
> - Appear clear, people less likely to underapply
>
> Drawbacks:
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> - New chemicals not fully studied; possible harmful effects still unknown. FDA is not treating nano-versions of known chemicals as new; needed health studies may not occur.
> - Very small particles are more likely to cross membranes and get into unintended parts of the body

3. What determines if a sunscreen appears white or clear on your skin? (4 points)

> Answer:
>
> - Particle size.
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> Explanation:
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> - Particles whose diameters are ≈ ½ λ are most likely to scatter light of that wavelength.
> - Since visible light has λ ≈ 400-800 nm, particles with a diameter of 200-400 nm (traditional inorganic ingredients) scatter visible light the most. The scattered rays that are reflected towards our eyes are of all colors in the spectrum, making the sunscreen appear white.
> - Particles smaller than 100 nm in diameter (nano and organic ingredients) do not scatter light appreciably. The sunlight passes through them and reaches our skin where the blue/green wavelengths are absorbed. The red/orange/yellow wavelengths are reflected towards our eyes making the skin appear its characteristic color.

4. How do you know if a sunscreen has "nano" ingredients? (2 points)

> Ingredients list contains inorganic ingredients (zinc oxide or titanium dioxide) and sunscreen appears clear on the skin.