



Lesson 5: Culminating Activities

Teacher Materials

Contents

- Culminating Activities: Teacher Lesson Plan
- Consumer Choice Project: Teacher Instructions & Grading Rubric
- The Science Behind the Sunscreen Quiz: Teacher Answer Key
- Clear Sunscreen Final Reflections: Teacher Instructions & Answer Key



Culminating Activities: Teacher Lesson Plan

Orientation

This lesson is designed to have students consolidate their learning and reflect on how their ideas have changed over the course of the unit.

- The Consumer Choice Project is a performance assessment that has students integrate their learning from the unit into a pamphlet to inform consumers about nanoparticulate sunscreens, how they work and their benefits and drawbacks. It includes a teacher grading rubric and peer feedback forms.
- The Science Behind the Sunscreen Quiz is a traditional assessment that asks students a series of closed and open ended questions about the material in the unit.
- The Final Reflections activity asks students to review their reflections from each of the unit activities, answer the essential questions of the unit and compare their current thinking with their thinking from the beginning of the unit. Students also are asked to identify how their ideas have changed and what things (if any) they are still unsure about. These can serve as final discussion points or ideas for future investigation.

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?

Enduring Understandings (EU)

Students will understand:

(Numbers correspond to learning goals overview document)

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.
6. How to apply their scientific knowledge to be an informed consumer of chemical products.

Key Knowledge and Skills (KKS)

Students will be able to:

(Numbers correspond to learning goals overview document)

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.



Culminating Activities Timeline (Pamphlet Performance Assessment)

Day	Activity	Time	Materials
Day 1 (50 min)	Hand out the Consumer Choice Project: Student Instructions and walk through the assignment and grading criteria with students. Assign or let students pick the groups or 3 or 4 that they will work in. Have students work in their teams to create the pamphlets. Circulate through the room answering questions and probing student work.	10 min 40 min	Copies of Consumer Choice Project: Student Instructions White paper and colored markers or computers with access to a printer.
<i>Homework:</i> Continue to work on the pamphlets *Note: Depending on the depth of student work you may want to extend the activity to a second class period.			
Day 2 (50 min)	Have students share their pamphlets with the whole class and fill out the peer feedback forms for other teams' pamphlets. Have students work individually or in small groups to fill out the Reflecting on the Guiding Questions: Student Worksheet. Discuss the Essential Questions and the group's collective ability to answer them based on the work done in the unit and answer any remaining student questions.	25 min 10 min 15 min	Copies of Consumer Choice Project: Peer Feedback Form Copies of Final Reflections: Student Worksheet Copies of Final Reflections: Teacher Instruction & Answer Key



Culminating Activities Timeline (Quiz)

Day	Activity	Time	Materials
Day 1 (50 min)	Hand out the quiz and have students work on it on their own.	25 min	Copies of The Science Behind the Sunscreen: Student Quiz
	Have students work individually or in small groups to fill out the Reflecting on the Guiding Questions: Student Worksheet.	10 min	Copies of Final Reflections: Student Worksheet
	Discuss the Essential Questions and the group's collective ability to answer them based on the work done in the unit and answer any remaining student questions.	15 min	Copies of Final Reflections: Teacher Instruction & Answer Key
Day 2 (15 min)	Hand back the corrected quizzes and go over the answers with students.	15 min	The Science Behind the Sunscreen Quiz: Teacher Answer Key



Consumer Choice Project: Teacher Instructions & Grading Rubric

Introduction

SmartShopper, the consumer advocacy group, has heard a lot in the media about the new clear sunscreens with nanoparticulate ingredients coming out on the market. Consumers have been contacting them lately to ask them if these new products are better than traditional sunscreens, if they are safe to use, and how to know if a sunscreen uses nanoparticulate ingredients. To help consumers decide whether these products are right for them, SmartShopper has decided to produce a pamphlet that tells consumers all they need to know about these new products. SmartShopper also will need to take a position on whether or not they endorse the use of the sunscreens and justify this position based on a comparison of the benefits and risks backed up with science. They turn to you and your team to create this pamphlet.

Requirements

SmartShopper asks that your pamphlet makes full use of both sides of an 8.5 x 11 piece of paper folded into thirds for easy distribution (see “How to Make a Pamphlet”) and contains:

- A brief overview of what nanoparticulate sunscreen ingredients are and how they are similar and how they are different from other active sunscreen ingredients.

Nanoparticulate sunscreen ingredients are inorganic UV blockers. This means that they are made out of the same atoms and have an ion lattice structure like standard inorganic sunscreen ingredients, but the particle size (the number of atoms that group together) is much smaller.

They are different from organic UV blockers which are usually conjugated carbon compounds and exist as discrete molecules (i.e. particle size doesn't vary).

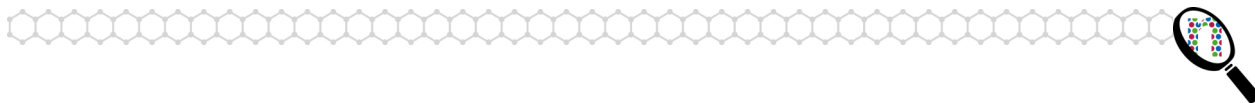
- A list of common nanoparticulate active sunscreen ingredients and how to know if your sunscreen contains them.

Zinc Oxide and Titanium Dioxide

The sunscreen may claim “goes on clear” if the nano-versions are used. You can also look at the actual color of applied sunscreen to see if it is the nano-version.

- An explanation of how sunscreens with nanoparticulate ingredients work to block UV light from reaching the skin and the benefits of using them (including advantages over other sunscreen ingredients).

Sunscreens with nanoparticulate ingredients block UV rays by absorbing them. Benefits are full UV coverage, clear appearance and no allergic reactions (traditional inorganic ingredients give full coverage but are not clear (often causing people to use too little); organic ingredients are clear but only block part the UV range and can cause allergic reactions)



- A explanation of why nanoparticulate sunscreen ingredients are clear and a diagram that illustrates the science principles involved.

The opacity of a material depends on the degree to which it scatters light.

Nanoparticles are so much smaller than the wavelength of visible light that they do not scatter it effectively.

Thus, visible light passes through the sunscreen, to the skin's surface where some rays (blue / green) are absorbed and some rays (red / yellow) are reflected. When the receptors in our eyes received by the reflected rays we they produce the image of our skin that we see.

- A transmission versus wavelength graph that supports this explanation.

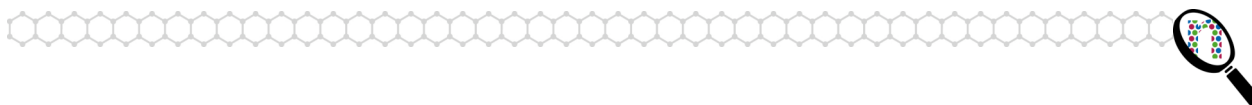
Students do not need to create this graph themselves – they can use a graph from the unit materials or find one online. The important concept is that they interpret the graph correctly by relating the % transmission at different wavelengths with appearance (white/clear) and UV blocking ability for differently size ZnO particles.

- An explanation of the possible downsides / dangers of using sunscreens with nanoparticulate ingredients.

The process of absorption excites an electron (giving it energy) that can lead to side reactions. Some of these side reactions can create to free radicals (particles known to contribute to cancer) or damage DNA. In addition, because nanoparticles are so small, it may be easier for them to penetrate and circulate throughout the body.

The biggest issue with nanoparticulate ingredients is not that they are necessarily more dangerous than other ingredients but that because they are new, they have not been fully researched yet.

- SmartShopper's position on the use of sunscreens nanoparticulate ingredients (do you endorse their use?) with justification of this position based on a comparison of the benefits and risks involved.



How to make a pamphlet

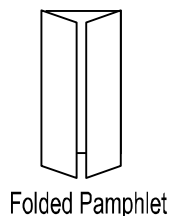
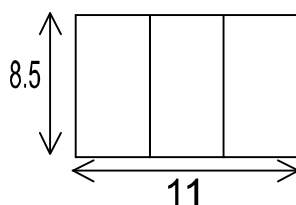
It is up to you how “professional” you want your students to make their pamphlets. If you have two class periods or less to devote to this project, we suggest that you have your students focus on the content and produce “draft versions” of the pamphlet.

By Hand:

Take a regular piece of 8.5 x 11 paper turn it sideways. Fold the paper into thirds and crease it firmly. This is what the pamphlet will look like when it’s done. When you unfold the paper, you can use the creases as column guides. It is good to make the front and back of your pamphlet on different pieces of paper and use a copying machine to make the pamphlet double sided in case you decide to make changes along the way.

With a Computer:

Open a new document in Microsoft Word. Go to File>Page Setup to choose a Landscape Orientation and make all of the margins 0.5 inches. Go to Format>Columns to choose 3 columns and click the check box for Line Between. You will need to either use a printer that will print double-sided or print the two sides of your pamphlet separately and use a copying machine to make them double sided.



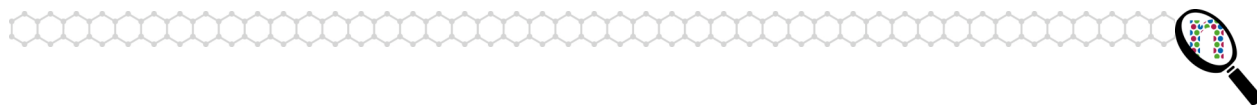
Folded Pamphlet

Evaluation

SmartShopper will evaluate the pamphlets based on the following criteria:

- All required information is present and correct
- Scientific explanations are used to back up pamphlets claims
- Effective use of diagram and graph to enhance explanation of why nanoparticulate sunscreen ingredients are clear
- Convincing argument weighing all the relevant information for position taken on nanoparticulate sunscreen use
- All team member contributed and worked together to produce the animations

See full rubric on the last page.



Rubric for Consumer Choice Pamphlet Evaluation

Category	Novice (1) Absent, missing or confused	Apprentice (2) Partially developed	Skilled (3) Adequately developed	Masterful (4) Fully developed
Required Information <ul style="list-style-type: none"> Overview of nanoingredients List of common nanoingredients How UV light is blocked and advantages over other blockers Why nanoingredients are clear Visible light scattering diagram Transmission graph Possible downsides Position on use 	0 - 1 parts of the required information are present.	2 - 4 parts of the required information are present.	5 – 7 parts of the required information are present.	All 8 parts of the required information are present.
	Few of the required elements are accurately depicted.	Some of the required elements are accurately depicted.	Most of the required elements are accurately depicted.	All of the required elements are accurately depicted.
Pamphlet claims are backed up with accurate scientific explanations	Few of the claims are backed up.	Some of the claims are backed up.	Most of the claims are backed up.	All of the claims are backed up.
Transmission graph is correctly interpreted <ul style="list-style-type: none"> % T is the correctly read from graph %T correctly related to 1. Visible opacity, 2.UVA blocking and 3. UVB blocking. 	1 or none of the key aspects of the graph are correctly interpreted.	2 of the key aspects of the graph are correctly interpreted	3 of the key aspects of the graph are correctly interpreted	All 4 key aspects of the graph are correctly interpreted
Effective use of diagram to show visual transparency of sunscreen <ul style="list-style-type: none"> Diagram includes sun, photons, skin, nanoparticle sunscreen, skin, and observer No scattering of visible light Skin absorbs blue/green light Observer sees red/yellow skin 	1 or none of the key aspects of the interaction are correctly shown.	2 of the key aspects of the interaction are correctly shown.	3 of the key aspects of the interaction are correctly shown.	All 4 key aspects of the interaction are correctly shown.
Convincing argument to support position on nanoparticulate sunscreen use <ul style="list-style-type: none"> Uses all available information Information interpreted with respect to user concerns Both pros and cons considered Justification for position taken 	0 - 1 key aspects of the argument are given effectively.	2 key aspects of the argument are given effectively.	3 key aspects of the argument are given effectively.	All 4 key aspects of the argument are given effectively.
Teamwork <ul style="list-style-type: none"> All team members contributed significantly to the project Group worked together to manage problems as a team 	Few team members contributed to the project.	Some team members contributed to the project.	Most team members contributed to the project.	All team members contributed to the project.
	Group did not address the problems encountered.	Group did not manage problems effectively.	Problems in the group managed by one or two individuals.	Group worked together to solve problems.



The Science Behind the Sunscreen Quiz: Teacher Answer Key

30 points total

1. Why is UV light a source of health concern when visible and infrared light are not? (2 points)

- UV light is a higher frequency light than visible and infrared and thus has a higher energy per photon.
- This higher energy allows it to do damage even though the total amount of UV light reaching the earth is less than for visible and infrared light.

2. List 2 kinds of damage to the body caused by UV radiation. (2 points)

Any of the following four answers are acceptable.

- Sunburn
- Pre-mature skin aging
- Skin cancer
- Cataracts

3. Explain in your own words why it is important to block UVA light. (2 points)

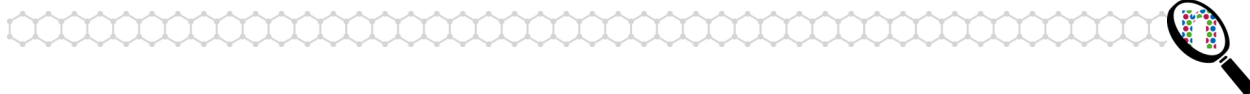
- Even though it does not cause short-term damage like sunburns, UVA light has been found to cause long term damage including premature skin aging and skin cancer.
- It is especially dangerous because it has been found to penetrate more deeply into the skin than UVB light and because the effects are not immediately apparent, we may not realize that damage is being done.

4. How do you know if a sunscreen protects against UVA light (now and future)? (2 points)

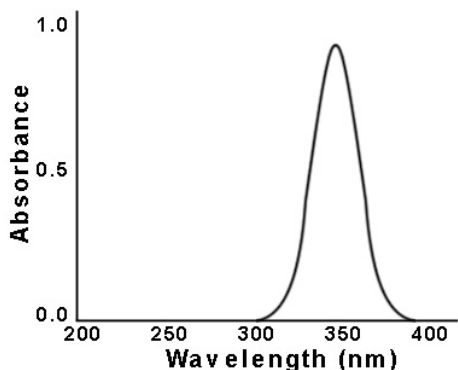
- Currently, the only way to tell how well a sunscreen protects against UVA rays is by looking at the ingredients and knowing which ones absorb UVA light.
- A new FDA rating for UVA light based on a 4-star system should be implemented in the next few years (more stars will equal greater UVA protection).

5. How do you know if a sunscreen protects against UVB light? (1 point)

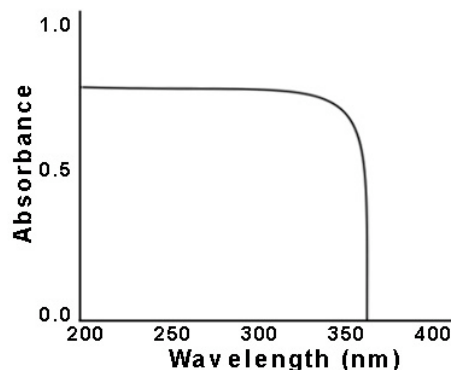
- A sunscreen's SPF (Sunburn Protection Factor) number indicates its ability to absorb UVB light (a higher number equals greater UVB protection).



6. For each of the following absorption graphs, circle the correct answers for a) what kind(s) of light are strongly absorbed and b) whether it is an organic or inorganic sunscreen. (4 points)



- a) ☒ UVA ☐ UVB
b) ☒ Organic ☐ Inorganic



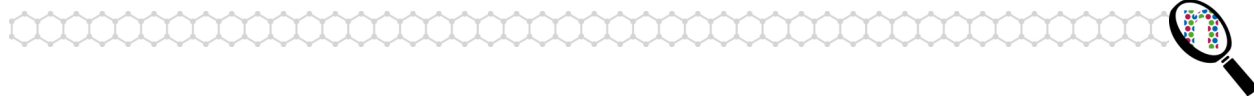
- a) ☐ UVA ☒ UVB
b) ☐ Organic ☒ Inorganic

7. Why do sunscreens that use nano-sized TiO_2 clusters appear clear on our skin while sunscreens that use traditional sized TiO_2 clusters appear white? (5 points)

- Suspended clusters scatter light maximally for wavelengths twice as large as their diameter.
- Since visible light has $\lambda \approx 400\text{-}800\text{ nm}$, cluster with a diameter of $200\text{-}400\text{ nm}$ (such as traditional TiO_2) scatter much visible light.
- The scattered rays that are reflected towards our eyes are of all colors in the spectrum, making the sunscreen appear white.
- Clusters smaller than 100 nm in diameter (such as nano TiO_2) do not scatter appreciably in the visible range.
- The visible light passes through the sunscreen and is reflected by our skin. Thus our skin color is what we see, making the nano-sized TiO_2 particles effectively clear.

8. How do you know if a sunscreen has “nano” ingredients? (2 points)

- Contains inorganic ingredients (ZnO or TiO_2)
- Sunscreen appears clear on the skin.



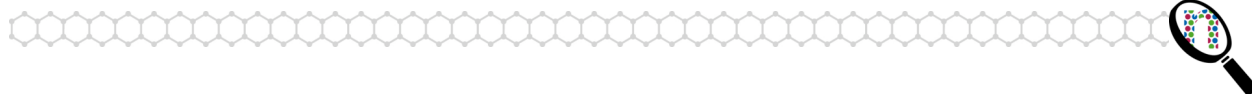
9. Briefly describe one benefit and one drawback of using a sunscreen that contains “nano” ingredients: *(1 point each, a total of 2 points)*

Benefits *(Either of the following answers is acceptable)*

- Block whole UV spectrum
- Appear clear, people less likely to underapply

Drawbacks *(Either of the following answers is acceptable)*

- 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



10. 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 point each, total of 8 points)

	Organic Ingredients (e.g. PABA)	Inorganic Ingredients (e.g. Classic Zinc Oxide used by lifeguards)
Chemical Structure	Similar or <input checked="" type="checkbox"/> Different How: Nano ingredients are small ionic clusters while organic ingredients are molecules.	<input checked="" type="checkbox"/> Similar or Different How: Nano ingredients are a kind of inorganic ingredients. Both are ionic clusters but the nano clusters are smaller.
Kinds of Light Blocked	Similar or <input checked="" type="checkbox"/> Different How: Organic ingredients each block a small part of the UV spectrum (generally UVB) while nano ingredients block almost the whole thing.	<input checked="" type="checkbox"/> Similar or Different How: Both nano ingredients and traditional inorganic ingredients block almost the whole UV spectrum.
Way Light is Blocked	<input checked="" type="checkbox"/> 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)	<input checked="" type="checkbox"/> Similar or Different How: Both nano and inorganic ingredients block UV light via absorption.
Appearance on the Skin	<input checked="" type="checkbox"/> Similar or Different How: Both nano and organic ingredients appear clear on the skin.	Similar or <input checked="" type="checkbox"/> Different How: Traditional inorganic ingredients appear white on the skin while nano ingredients appear clear.



Clear Sunscreen Final Reflections: Teacher Instructions & Answer Key

The goal of this exercise is for students to reflect on their learning and evaluate how their ideas and their confidence in them has changed since the unit began. The answers to the questions on page two are also a final check for you to see where students are and if they have any misconceptions that need to be addressed. Possible student answers are listed below, these are compiled based on completion of the entire unit. If you have only done selected lessons with your class, some of the answers may not apply. Please refer to the teacher's version of the reflection sheets associated with each lesson for lesson-specific answers.

Now that you have come to the end of the unit, go back and look at the reflection forms you filled out after each activity and try to answer the guiding questions below. Write down answers each question below and then evaluate how confident you feel that each idea is true.

1. What are the most important factors to consider in choosing a sunscreen?	How sure are you that this is true?		
	Not So Sure	Kind-of Sure	Very Sure
It is important to choose a sunscreen that provides good protection against both UVA and UVB.			
A sunscreen's SPF number tells us how well the sunscreen protects against UVB rays.			
For UVA protection, until the new FDA rating is approved, the only way to tell how well a sunscreen protects against UVA rays is by looking at the ingredients.			
Inorganic ingredients (ZnO and TiO ₂) absorb both UVA and UVB, so sunscreens that include them have broadband protection.			
Organic ingredients each block a specific wavelength range that can be in the UVA or UVB range. To ensure broadband protection, it is important to choose a sunscreen that has a combination of ingredients that will absorb both kinds of light. Avobenzone and Ecamsule are the two FDA approved organic ingredients that absorb strongly across the UVA range.			
It is also important to choose a sunscreen that we like in terms of appearance and smell to make sure that we use enough of it to be effective.			



2. How do you know if a sunscreen has “nano” ingredients?	How sure are you that this is true?		
	Not So Sure	Kind-of Sure	Very Sure
“Nano” ingredients are smaller versions of traditional inorganic ingredients (ZnO and TiO ₂) that go on clear.			
If a sunscreen contains Zinc Oxide or Titanium Dioxide, but appears clear on our skin, then it likely contains nanoparticles of ZnO or TiO ₂ .			
Traditional ZnO and TiO ₂ clusters appear white because they are > 200 nm in diameter and thus scatter all colors of visible light back towards our eyes. (Maximum scattering occurs at $\lambda = 2 * \text{diameter}$).			
ZnO and TiO ₂ nanoparticles are < 100 nm in diameter and thus do not scatter appreciably in the visible range. The visible light passes through the sunscreen and is reflected by our skin, thus the sunscreen appear clear.			

3. How do “nano” sunscreen ingredients differ from most other ingredients currently used in sunscreens?	How sure are you that this is true?		
	Not So Sure	Kind-of Sure	Very Sure
Most ingredients currently used in sunscreens are organic ingredients. These are individual molecules that absorb narrow bands of the UVA or UVB spectrum.			
“Nano” sunscreen ingredients are inorganic and very similar to traditional inorganic ingredients (large ZnO and TiO ₂ clusters) – they are made up of the same kinds of atoms and have the same formula unit, thus they absorb strongly in both the UVA and UVB range up to their cutoff wavelength: 380nm (ZnO) or 365 nm (TiO ₂).			
However, because the nano inorganic clusters are much smaller in size than traditional inorganic ones (<100 nm in diameter as opposed to > 200nm), they don’t scatter visible light (maximum scattering occurs at $\lambda = 2 * \text{diameter}$) and thus appear clear on our skin.			



Now go back to the worksheet you filled out with your initial ideas at the beginning of the unit and mark each idea with a ✓ if you still believe it is true, an X if you don't think that it is true and a ? if you are still unsure. Then answer the following questions.

1. What ideas do you have now that are the same as when you started?

2. What ideas are different and how?

3. What things are you still unsure about?