To TAN

or NOT to TAN?

Students learn about sunscreens through an inquiry activity based on the learning cycle

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Science instructors sometimes avoid inquiry-based activities due to limited classroom time. Inquiry takes time, as students choose problems, design experiments, obtain materials, conduct investigations, gather data, communicate results, and discuss their experiments. While there are no quick solutions to time concerns, the 5E learning cycle seeks to minimize time demands (Bybee 1997). I used the phases of the 5E learning cycle—engagement, exploration, explanation, extension, and evaluation—as a guide when creating the following lesson that teaches students about sunscreens and ultraviolet (UV) radiation.

The beginning of the school year is a good time to discuss the importance of sunscreen and ultraviolet radiation because summer is still fresh in the minds of students who are returning from an extended vacation. This lesson would also work well as an end-of-the-year, presummer reminder for students to take care of their skin during the hot summer months. Teachers can also discuss sunscreens and UV radiation at anytime throughout the school year, especially during lessons about the sun and as a reminder for students that sunscreens should be used year-round. This lesson addresses the National Science Education Standards (see "Addressing the Standards").

Content overview

Before beginning the activities outlined in this article, teachers should provide a content overview so that students gain an understanding about UV radiation, skin cancer, and what safety precautions to take. Although the sun is necessary for life, too much sun exposure can lead to adverse health effects, including skin cancer. More than one million people in the United States alone are diagnosed with skin cancer each year (ACS 2005; DFCI 2005; and Naylor 2000).

UV radiation

Because of the dangers of skin cancer, protecting skin from the sun is vital, and sunscreen use is very important. Used properly, certain sunscreens help protect human skin from some of the sun's damaging UV radiation. The wavelengths of light that damage skin are UVA and UVB.

Both UVA and UVB radiation have been linked to skin cancer and a weakening of the immune system (Naylor 2000; Sinha and Hader 2002). The radiation also contributes to premature aging of the skin and can cause cataracts and skin color changes (Kimbrough 1997; Naylor 2000).

UVA rays (320–400 nm), which are not absorbed by the ozone layer, cause tanning in the short-term and aging in the long-term (Alam 2002; Naylor 2000). UVA rays penetrate into the deeper layer of the skin where they break up the elastin and collagen fibers. When this material is damaged, the skin becomes wrinkled. In addition, research shows that UVA rays suppress the immune system of the skin, making it more susceptible to the development of skin cancer (Godar et al. 2003; Sinha and Hader 2002).

UVB rays, which are partially absorbed by the ozone layer, mostly affect the surface of the skin and are the primary cause of sunburn (Alam 2002; Reuther 1998). UVB is a shorter wavelength of light (290–320 nm) than UVA. The shortterm effect of UVB is sunburn and the longterm effect is skin cancer (Naylor 2000; Urbach 2001).

Scientists measure the amount of UV rays that reach Earth's surface to help the public estimate sunlight exposure during outdoor activities and avoid overexposure. The National Weather Service and the U.S. Environmental Protection Agency developed the UV Index to predict the level of radiation exposure (1–11+ scale) expected for each day (EPA 2004). Individuals can use the UV Index as a guide to help protect their bodies from excess exposure to UV rays.

Skin and sunscreen

Everyone, regardless of race or skin color, is subject to the potential unfavorable effects of overexposure to the sun. However, some people might be more vulnerable to certain conditions.

Skin type affects the degree to which some people burn and the time it takes them to burn. The U.S. Food and Drug Administration (FDA) classifies skin type on a scale from I to VI (1997). Individuals with skin types I and II have fair skin and tend to burn rapidly and more severely. Individuals with skin types V and VI, though capable of burning, have darker skin and do not burn as easily.

Obviously, individuals with lighter skin have to be more careful in the sun, but protection from harmful UV rays is important for everyone regardless of skin type. Consumer sunscreen products generally contain a variety of chemicals that absorb and reflect UV light, thereby protecting the skin. The FDA requires that all sunscreens contain a Sun Protection Factor (SPF) label (1999). The SPF reveals the relative amount of sunburn protection that a sunscreen can provide an average user (tested on skin types I, II, and III) when used correctly. Sunscreens with an SPF of at least 15 are recommended. An SPF of 30 is not twice as protective as an SPF of 15; rather, when properly used, an SPF of 15 blocks 93% of UVB radiation and an SPF of 30 blocks 97% of UVB (The Skin Cancer Foundation 2005).

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Engaging, exploring, and . . .

Once teachers complete a content overview of UV radiation and sunscreen, they can move on to the inquiry-based portion of the lesson, which includes two activities. As already mentioned, I used the 5E learning cycle as a guide when developing the entire lesson plan.

Engage

During the engage stage, the teacher can create interest in the subject of UV radiation and the importance of sunscreen by decorating the classroom with a beach motif and assigning one student as a potential sunbather. The teacher can then raise questions such as: *What are the effects of sunlight on skin? What at the molecular level allows one person to tan while another may burn? Does it matter whether the sunscreen is a gel, cream, or spray? Should the sunscreen be water-resistant or waterproof? Is a tanning bed a safe alternative to the beach? How is exposure to sunlight beneficial? If too much exposure to the sun can cause DNA mutations and cancer*

Addressing the Standards.

The activities described in this article relate to the following National Science Education Standards (NRC 1996):

- Content Standard A (9–12)
  Science as inquiry (p. 173)
- Content Standard B (9–12)
  Structure and properties of matter (p. 178)
  Chemical reactions (p. 179)
  Interactions of energy and matter (p. 180)
- Content Standard E (9–12)
  Understandings about science and technology (p. 192)

FIGURE 1

Testing sunscreen effectiveness.

The following activity tests the effectiveness (the UV screening ability) of various sunscreens of different SPF ratings in protecting the public from harmful UV rays. Students should be encouraged to design experiments with their own variables given some of the materials and equipment listed here. Possible questions include: *Do people wear enough sunscreen? Do more expensive sunscreens work better than less expensive sunscreens? Does old sunscreen perform differently than new sunscreen? Does sunscreen brand matter? Do the beads or paper change color? Does exposure to UV light affect lotion-coated beads?*

Materials

- Samples of commercial sunscreens with different SPFs
- Samples of other substances (mineral oil and zinc oxide) used as sunscreen
- Overhead transparencies, clear plastic baggies, or petri dishes
- UV beads or sun-sensitive paper
- Student-designed data sheet
- Sunny day
- Various sunglasses, fabrics, outdoor locations
- Chemical splash goggles, aprons, and gloves (Safety note: Sunscreens can burn eyes)

CAUTION

Methods

(Note: The teacher can decide to allow students to design various activities, providing as much structure and guidance as deemed appropriate.)

Before you begin:

- Determine the variable you will be testing (e.g., brand sunscreen, SPF, time of day).
- Coat a set of approximately 10 UV beads with the sample sunscreens depending on your procedure.
- Let each set dry for about 15–30 minutes before beginning your investigation.

Possible investigations:

- Take three to five sets of about 10 UV beads and soak each set in a different sunscreen (e.g., SPF 4, SPF 8, SPF 15, SPF 30, or SPF 50.) You can also soak one set with mineral oil or zinc oxide depending on what you are testing.
- Place each set of coated UV beads in a Petri dish or baggie (sun-sensitive paper can be used instead of UV beads; cover the paper with clear plastic and apply the sunscreen to the plastic).
- Take another set of UV beads and do not apply a sunscreen to that set (it will serve as the control).
- Place each set of labeled beads on a sturdy piece of cardboard or tray.
- Cover each set with a dark cloth as you position them outside.
- Expose each set to direct sunlight every 15 seconds for 2–5 minutes or longer. Observe and record the time and the beads' reaction (color change).
- The teacher will then provide you with an unknown (the teacher provides each group of students with a different unknown).
- Discuss the effects of sunscreen and try to identify what SPF was applied to the beads.
- Graph the average time it took for a change to appear in the beads' colors for each SPF.
- Possible extensions and variations: compare the effectiveness of different sunglasses, study the absorption of UV by various fabrics or window glass, or investigate the effect of changing the location or time of day.

in humans, why doesn't this happen to the DNA of plants, which are out in the sun all of the time? The teacher should elicit responses from students, which will help indicate what they understand and will point out any misconceptions they might have. During this engagement stage, students should be asking questions, too, and discussing what they know about UV radiation and the sun.

Explore

For the explore stage, students should be given the opportunity to work together without direct instruction from the teacher. During this stage, students should test predictions, record observations and ideas, and share results with classmates through inquiry-based activities such as the ones described in Figures 1 and 2. Students can also design their own inquiry investigations that are simple and relatively easy to complete. Students should begin by brainstorming what variable(s) they want to test and what methods they could use to test the variable(s). Potential investigations might include the following: *Do more expensive sunglasses provide better UV protection than less expensive sunglasses? Do darker-colored sunglasses provide better UV protection than lighter sunglasses? Is the UV protection on nontinted prescription lenses as effective as that of sunglasses? Can UV radiation pass through clothing?*

The teacher can also have students mathematically determine the appropriate SPF for their skin type using the following ratio: SPF value = time it takes to burn with sunscreen / time it takes skin to burn without sunscreen. The teacher also could create a web-based activity on sunscreens, such as "Spring Break Chemistry," which is online at *www-dept.usm.edu/~pt3/info/00-03/lesson_plans/plans/extra/013webquest.html* (Hill and McDonald 2003).

Explain

The teacher should encourage students to explain concepts and key terms (*What is in a sunscreen?; How do you choose a proper sunscreen?; What are: sunblock, electromagnetic spectrum, SPF, minimal erythermal dose (MED), melanoma, and DNA mutations?*) in their own words by having them present the results from the activities in Figure 1 and 2 to the class and listen critically to their classmates' findings. The teacher can also ask for evidence and clarification of students' explanations during their presentations and raise counterarguments about their results. Students should share observations and findings. During the explanation stage, the teacher may need to provide expanded defi-

FIGURE 2

Identifying the absorption spectra of sunscreens.

UV-Vis spectrophotometers can measure a solution's absorbance of wavelengths in the UV region of the electromagnetic spectrum (EMR), in some cases measuring wavelengths as short as 190 nm. If you have a UV-Vis spectrophotometer, the following activity will allow students to measure and graph the absorbance spectra of sunscreen solutions. Students test several sunscreens to determine the wavelengths of UV radiation absorbed by each product, and plot the absorbance of the sunscreen versus the concentration (Katz 2003) or the wavelength.

Materials

- Samples of commercial sunscreens with different SPFs
- UV-Vis absorbance spectrophotometer and cuvettes
- Distilled water (for rinsing glassware)
- 25–150 mL beakers or flasks
- 2-propanol (isopropyl alcohol, isopropanol)
- Parafilm
- Stirring rods and pipettes
- Chemical splash goggles, gloves, and aprons

Methods

(Note: The teacher can decide to allow students to design various activities, providing as much structure and guidance as deemed appropriate. Students can investigate the effects of varying concentration, SPF levels, and wavelength. In some cases, it may be advisable for the teacher to prepare the diluted solutions in advance and perhaps assign different student groups to specific tasks.)

Preparation of diluted sunscreen solutions:

1. Place 1 drop (0.1–0.2 g) of sunscreen into a 150 mL beaker. [Optional: also determine its mass.]
2. Add 30.0 mL of 2-propanol (isopropanol) [Safety note: 2-propanol is flammable and may be harmful by inhalation, ingestion, or skin absorption. Its vapor may cause a flash fire. Use in a well-ventilated area and do not expose to open flames or sources of electrical sparks (e.g., switches). (Best if done under a fume hood.)]
3. Stir until the sunscreen forms a milky mixture
4. Heat and agitate in a hot water bath (50.0°C) for ~ 1 minute if needed to dissolve the sunscreen. [Safety note: Use care not to get burned by hot water or burner.]
5. Return to room temperature and agitate for ~ 1 minute.
6. Add enough 2-propanol to the solution to bring its volume to 50.0 mL.
7. Using a pipette, transfer 1.00 mL of the solution into a new flask, and add enough fresh isopropanol to bring the volume to 50.0 mL.
8. Optional: Calculate the concentration of sunscreen in g/L, using the mass from step 1. Remember that the solution was diluted by a factor of 50.
    - First calculate the concentration by dividing grams by liters. Remember to convert 50.0 mL to L.
    - Divide this concentration by 50 to obtain the concentration of the final solution.
9. Label and cover to prevent evaporation.
10. Repeat for each sunscreen sample.

Measuring absorbance:

- Refer to and follow the spectrophotometer guidelines to measure the absorbance spectrum (nm) for each sample using the UV light range from ~ 300–400 nm. For each sunscreen tested, measure and record the absorbance at 10 nm increments from 300–400 nm.
- Graph the percentage absorbance (y-axis) vs. wavelength (x-axis).
- Compare the various sunscreens tested. Depending on your investigation and that of other groups, you might be able to answer the following questions:
    - At which wavelength did each sunscreen absorb the best?
    - Which sunscreen absorbed the most across range of wavelengths tested?
    - How did the SPF ratings affect absorbance?
    - Did the sunscreens tested protect from UVA or UVB or both? Can you tell from your data?

Extensions

- Investigate an unknown sunscreen solution provided by your teacher.
- Compare and contrast the absorbance ranges for each sample with the advertised statements on the sunscreen packaging.
- Reference site: *www.chymist.com/Sunscreens.pdf*

nitions (e.g., chemical and physical barrier aspect of suncreens) and explanations (e.g., what SPF numbers and MED mean) using students' learning experiences as a basis for an active discussion.

Extend

To extend the activities, students could investigate how the incidence of skin cancer varies from state to state, explore the chemistry of sunglasses, or collect data with the use of a schoolwide sunscreen survey. In the extend stage, students should use collected information to ask questions, propose solutions, experiment, and record observations.

Evaluate

Student evaluation should take place throughout the learning activity with short quizzes, journal recordings, formal lab reports, portfolios, and grading rubrics. The teacher needs to observe how students' new knowledge, skills, and application of new concepts affect their thinking. Students should present their experimental findings to the class. If all groups performed the same basic experiment, students should explain any differences in the results. If not, students can compare and contrast what was learned in the various experimental procedures.

In addition, students should assess their own learning with a student rubric. The teacher can ask students open-ended questions such as: *If you worked at a company that developed and sold sunscreen products, what would be the top three chemical characteristics that these products should possess and why?* The teacher should assess whether or not students used observation, evidence, and previously accepted explanations when formulating their answers. The teacher can also ask the following questions to encourage future investigations: *Do some materials (fabrics) provide more UV protection than others? Does location (e.g., asphalt parking lot, sandy beach, or swimming pool) affect UV exposure? Does old sunscreen perform differently than new sunscreen?*

Inquiry-based learning

As shown in this article, science instructors concerned with limited classroom time due in part to demands to cover content can still create successful inquiry lessons using the 5E learning cycle. The phases of the learning cycle can help guide both teachers and students in conducting inquiry-based lessons designed to teach students the fundamentals of science. Through the activities described in this article, students will have a chance to improve their inquiry ability and develop an understanding of sunscreens. ■

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On the web

For additional information on sun protection visit the U.S. Environmental Protection's Sunwise Program website at *www.epa.gov/sunwise/index.html* and MedicineNet.com at *www.medicinenet.com/script/main/art.asp?articlekey=46376*. A good overview of controversies surrounding sunscreens can be found at the Food and Drug Administration site, *www.fda.gov/fdac/features/2000/400_sun.html*. The American Chemical Society offers information about sunscreen action and common active sunscreen ingredients at *www.chemistry.org/portal/a/c/s/1/feature_ent.html?id=5d9a97807fc011d6e2d64fd8fe800100*.