Ultraviolet Solar Radiation: Friend or Foe

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Introduction

"The Sun is a star. It does not move." With chagrin, I have to lay claim to those opening sentences as evidence of my own ignorance, in the not too distant past. Even though I was a child of the space race and have vague memories of watching the moon landing, I confess that the skies never held much interest for me. Constellations and the stories behind them, yes and I certainly went through my Astrology phase, even casting detailed charts as to which planet was in which house but the science of it all never quite registered. In retrospect, I think it was because it all seemed so remote. Astronomy was a dead collection of facts: planets, moons, orbital periods with the occasionally hyped, but often disappointing, celestial occurrence thrown in the mix. (Does anybody else remember Comet Kohoutek?)

Next year will mark the 50th anniversary of the Apollo 11 mission. If ever there was a time to get students excited about "the Final Frontier", this should be it. Our tools are better; our understandings are greater, and most importantly, our technology allows us greater access. That said, the original challenge remains, only this time, I'm the teacher. How do I get my students excited about the "Universe" when it seems so disconnected from their daily lives? Since the topic is so vast, no pun intended, how do I narrow my own focus to keep it from being a scatter shot of facts and figures? As a strong proponent of student generated investigations, how do I bring it into the classrooms as more than computer based research?

The answer lies with the students and the very special setting in which I teach. A recent job change means that instead of teaching just sixth graders in class sizes varying from 15-34 students, I'll be teaching K-12 with class sizes of 3-8 students. For medical reasons, all my students have IEPs (Individual Education Plans) with most working below grade level in reading and math due to gaps caused by frequent absenteeism. Some are dealing with debilitating illnesses. Most come from an urban environment with very little exposure to the elements of the night sky due to light pollution. The students at my current placement have had limited hands on science experiences and taken part in even fewer engineering challenges. Rather than give them the information and assess their knowledge through traditional forms, I'm taking a problem based learning approach. Their goal is to create a public service campaign on safe sun exposure.

Rationale

This unit is designed to include the Science and Engineering Practices of the Next Generation Science Standards. It will address the Disciplinary Core Idea of Earth Systems as it applies to the effect that solar energy has on the atmosphere, biosphere, hydrosphere and geosphere. The emphasis will be on the effect of solar radiation on humans. In addition, it will incorporate the common core standards for ELA as students obtain, evaluate, and communicate their findings. The common core standards for math will be addressed as students design, conduct, and analyze their own investigations, using mathematics and computational thinking in data collection and interpretation.

As part of their research, these are a few of the questions they may need to answer: How does solar radiation affect humans? How do we balance getting our daily dose of sunshine to help with vitamin D creation with the need to protect our skin? What are the positive and negative effects of sun exposure? How do we mitigate the risks while still getting the benefits? What is the difference between UV A and UV B radiation? What should we be looking for in terms of sunscreen and/or sunglasses? What is photosensitivity and how could someone be allergic to sunshine? If the sun is so bad then why do people sunbathe or visit tanning salons?

Learning Objectives

Students will use text and multimedia resources to develop content knowledge.
They will create their own questions and interview an expert in the field of dermatology.
They will design, conduct, and analyze the results of their own experiments to determine the effectiveness of different types of sunscreens, sunglasses and/or protective materials.
They will share the results of their research as part of a public service campaign on safe sun exposure.

Content Objectives

Students will be able to describe how the sun's energy interacts with the atmosphere, biosphere, hydrosphere, and geosphere. They will be able to discuss the health benefits and risks associated with exposure to solar radiation.

Background

Mankind's relationship to the Sun has changed throughout the ages. The ancient Egyptians worshipped it through a deity named Ra. Creator of the other gods, Ra was portrayed as having a man's body and the head of a hawk. The head symbolized how the sun flew across the sky each day, travelling by boat by night so as to reappear in the same spot the next morning for the new day's journey. So important was Ra, that he was given other names and other forms to describe him in each part of his daily path across the sky. [1]

Yet even as Ra was worshipped as a God, his effects on the skin were not welcome. A statue of Nofret, wife to Prince Re-hotep, high priest of Heliopolis (the center of Sun worship) found near Memphis shows her to have pale, smooth skin. Records dating back to 2,580BC indicate that she used various cosmetics to maintain the color and texture of her skin.

Through the Middle Ages and across the globe, there is evidence that avoidance of the sun's harsh rays was preferred. In 1356, the Islamic Moroccan Scholar Ibn Battuta wrote of perfect beauty "flawlessly white and very plump"; both attributes most likely achieved by staying in their tents and avoiding the sun. In Europe, both men and women of the upper classes applied lotions of violet and rose oil to protect their skin from the sun when going horseback riding. In Asia, both Chinese and Japanese women, applied white powders to their faces. In 1671, the writer Li Yu, advocated the wearing of dark blue clothes as it made light complexions seem even lighter.

In Europe, Louis XlV, (1638-1715), the Sun King may have sat on the throne but fashionable French society avoided the sun, preferring instead a very pale white complexion. In the 18th and 19th centuries, complexions returned to more natural hues as people became more aware of the long term effects of the toxic materials used in the face paint. Women continued however to avoid the sun, using parasols and straw hats, to protect what little skin showed beyond their clothing. The preference for pale skin was more class driven than race driven. Being able to avoid the effects of the sun meant that you were wealthy enough to avoid doing outside manual labor.

It wasn't until 1855 that sun exposure started to be associated with good health. In that year, Arnold Rikli opened up his clinic in the Alpine region of Slovenia near Lake Bled. He was a naturopath who advocated the use of sun, air, and water to treat a variety of ailments and diseases, including tuberculosis, depression and even madness.

Yet it took until the 1920s for tanning to become linked to beauty. Some lay the blame on designer Coco Chanel for associating sunbathing with pleasure and relaxation. However one shouldn't discount the societal changes caused by the increased mobility offered by cars, and the broadening of roles and relaxing of rules as it applied to women. Sporting a tan meant that you had the time, money, and access to various outside sporting and leisure activities.

Whatever the cause, increased sun exposure meant increased sunburns and the first sun tan lotion was developed in 1927 to "put an end to sunburn, soften and tan the skin." In 1935, Eugene Schueller's company introduced the sunscreen Ambre Solaire, which contained benzyl salicylate which acted to absorb UV rays. Tanning's popularity spread with the introduction in France of annual paid leave. Now people had the means to travel to warmer, sunnier climates where it was easier to get a tan. [2]

By the time I was born in 1960, the tanning revolution was well under way. Today, we may cringe at the old ads but from the 60's through the 80's, the message was the darker the tan the better. The Coppertone Girl was everywhere, accompanied by the slogan "Don't be a paleface, use Coppertone." People didn't buy sunscreen: they bought suntan lotion. Even when labelling started to include SPF (sun protection factor), the goal was to use the lowest one possible. Being olive skinned, I naturally tanned and once I hit my teens, it became the annual summer game to see how dark I could get. I was not alone; by 1978, UV tanning beds had started to appear in the United States. For those who didn't have the time to bake in the sun or the money for tanning sessions, there were and are artificial tanners.

My own pursuit of the perfect tan came to a screeching halt when I was twenty two years old. Fresh out of college, I had started working for my family physician. One day, he called me into the office to help with a patient, a man in his early thirties, who was complaining of a growth in the center of his back. Before seeing it, the doctor's plan was to biopsy a small piece. Once the man removed his shirt, that option disappeared. It was a malignant melanoma, the size of a small child's fist. The best treatment plan at the time was implemented: immediate referral to an oncologist, excision, radiation but it was to no avail. In less than a year, the patient was gone. He didn't use a tanning bed, or even sit out in the sun, but his job as a day laborer often had him working in the hot sun, and often shirtless.

Fast forward 35 years. There has been a significant shift in public opinion toward tanning. While there are still hordes who flock to the beaches to bake, there are just as many who choose to cover up with sunblock, hats and even umbrellas. Clothing manufacturers have responded by creating swim shirts and other garments, specially designed to provide UV-R protection. The accepted wisdom now is to never leave the house without some level of sunscreen year round. Even state legislatures have weighed in with 45 out of 50 having some form of a law that either bans or restricts the use of tanning beds for minors. [3]

So, where does that leave us now and more importantly, in the future? Is the sun really a villain, to be avoided at all costs? Or, is there merit in the work of Rikli and others, who claimed that lots of sun exposure was crucial to ongoing good health? As in most things, perhaps the answer lies somewhere between the two positions with most people requiring some amount of sunlight to be healthy. The key is to determine what that amount is. In order to do that, we need to have a better understanding of what is meant by sunlight and the biological effects of its components.

To start, we need to define sunlight. The sun's energy is transmitted in the form of electromagnetic waves of different wavelengths. More than 90% of it falls within the visible spectrum (400-780 nm) and near infrared spectrum (780-4000 nm). Of special concern to human health is the solar radiation that falls in the Ultraviolet range 100-400 nm. This electromagnetic band is further broken up into UVC (100-280 nm), UVB (280-315 nm) and UVA, (315-400 nm). [4]

This part of the electromagnetic spectrum is further affected by interacting with the Earth's atmospheric components as the waves travel to the surface. This variation in wavelength presented a challenge to scientists concerned with warning people about the negative effects of prolonged sun exposure. To solve that problem, a group of Canadian researchers created the Ultraviolet Index (UVI) in 1992, later adopted by the World Health Organization (WHO) in 1994. The index is designed to provide an easily accessible way for people to evaluate health risks and benefits of exposure to the fluctuating solar radiation. As evidenced from the chart below, the higher the wavelength, the less biological effect. When determining biological effect, scientist refer to it as erythemal solar irradiance. In layman's terms, it means the amount of exposure needed to cause reddening of surface skins cells caused by increased blood flow to superficial capillaries. This increased blood flow is the body's defensive reaction to injury or irritation.

At first glance, the solution seems obvious: avoid exposure to UV-B completely and minimize exposure to the lower wavelengths (higher energy) part of the UV-A spectrum as those are the portions most associated with erythema. Unfortunately, those are also the portions of the electromagnetic spectrum associated with Vitamin D absorption.

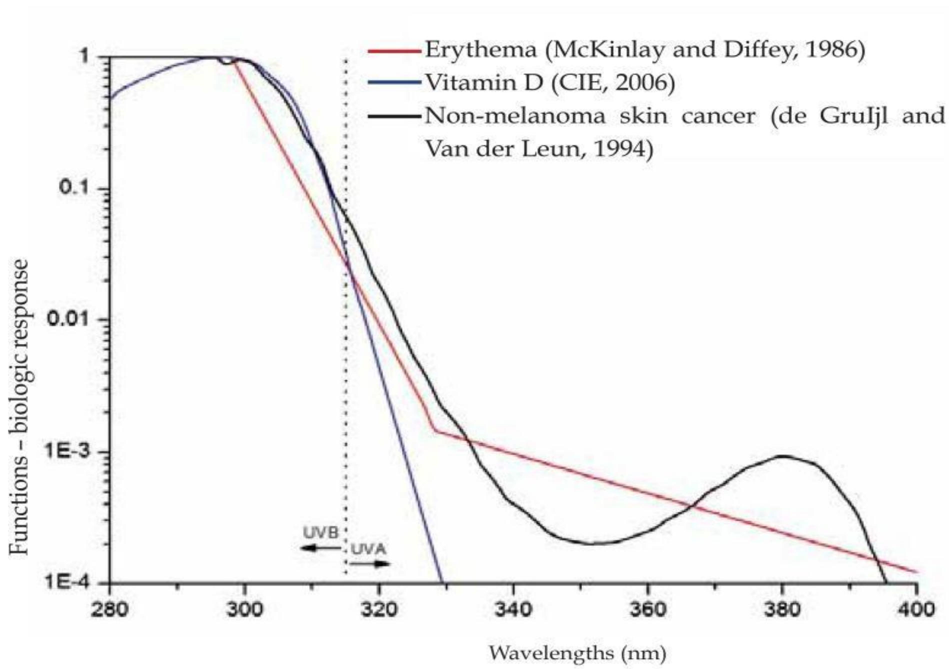

Figure 1: Functions – biologic UV-R response for human beings. Erythema (red line), vitamin D synthesis (blue line), and non-melanoma skin cancer (black line). [5]

Given that some level of exposure to Ultraviolet light is desired, how do you figure out what the proper amount is, taking into account, the different things that affect how it reaches the Earth? Recognizing that it would be impossible and highly inaccurate to make a single recommendation, the World Health Organization, has instead created an advisory scale, with world wide applications. The UV Index number is site specific and changes based on date, weather, and even hour. Noon in January, in North America, will have a different value than San Paulo, in Brazil yet both will have the same precautions for the same UV Index value.

Table 1:

UV Index	Classification of Health Damage	Color Code	Precaution	Recommendations

< 2	Low	Green	Unnecessary	You may remain exposed outdoors without protection.
3-5	Medium	Yellow	Recommended	Look for shade at times close to noon.
6-7	High	Orange	Recommended	Wear a shirt, sunscreen and hat.
8-10	Very High	Red	Indispensable	Avoid exposure close to noon. Make sure that you are in the shade.
>11	Extreme	Violet	Indispensable	Shirt, sunscreen and hat required.

[6]

The UVI is meant to be a universal scale and applicable to all skin types. Although there is a correlation between lightness of skin and the general rate that erythema develops, with lighter skins reacting faster than darker skin, there are other factors that affect photosensitivity. Some of these factors include general health, the types of food consumed, the use of certain drugs/chemicals, whether taken internally or used topically, and other individual organics characteristics. [7]

The UVI recognizes that on any given day at any given place, the amount of UV-R reaching the Earth's surface depends on many factors. Some remain constant for a given place such as longitude, latitude, and altitude. However, the angle at which the Sun's radiation hits the surface at that point is determined by date and time. The reason for our seasons and the change in temperatures and hours of sunlight are due to the Earth's tilt and the angle at which the sun reaches us during our yearly revolution around the Sun. Other factors that are much more varied include atmospheric conditions and the amount of reflective surface. Gases, aerosols, and clouds all affect the amount of radiation and the nature of the surface determines what is absorbed and what is reflected back. It is for these reasons that the UVI can vary greatly for a specific place.

The Atmosphere

To understand the role that gasses play in absorbing UV-R, it is important to understand the Earth's atmosphere. It is made up of several layers, beginning with the troposphere. Extending from the surface to about 10 kilometers, (6.21 miles or 32,789 feet), with some variations due to latitude, it is the layer in which almost all weather occurs. To better understand the size of this invisible layer, it helps to compare it to something that is more easily seen like Mt. Everest. Rising from sea level to a height of 8.8 km, the mountain still does not reach the top of the troposphere. Yet comparisons can be tricky. If instead of thinking about it as a vertical distance, we consider it as an absolute distance, we could drive that amount in only a few minutes. The gasses in this layer are well mixed as the warmer air rises from the Earth's surface, cools and then fall back down. This process is called convection and it is what is responsible for air currents.

The next layer is the stratosphere which extends from 10km to 50 km in altitude. Most commercial flights occur in the lower stratosphere. Here the air actually becomes warmer due to the ozone absorbing the solar radiation. Since the air at the top of the troposphere is cooler than the air in the bottom layer of the stratosphere, there is much less vertical mixing, which means fewer air currents and less wind turbulence. There are many excellent images taken by NASA which show the different layers of the atmosphere while highlighting how they are dwarfed by the vastness of space.

It is in the upper stratosphere, that oxygen absorbs most of the UVC form of solar radiation. UVC-R has the shortest wavelength and is the most energetic, and the most harmful, of this type of radiation.

UVC-R, is so deadly that it has become the industry standard for sterilization of lab equipment and surgical instruments. Created artificially, it kills greater than 99% of microorganisms by damaging the cells so that they can't reproduce. If this form of radiation reached the Earth's surface, almost all life would cease to exist.

In the mid to lower stratosphere (15-30 km above the surface) is the ozone layer where the greatest concentration of ozone gas is found. Although measurements at different parts of the globe may vary, the overall amount has remained relatively stable. Composed of three oxygen atoms, ozone is constantly being created and destroyed. Levels fluctuate based on latitude, sunspots and seasons but usually return to an average level. [8]

Ozone is the gas responsible for absorbing most, but not all, of the UVB-R. This means that some UVB-R still reaches the troposphere along with the longer wavelength

UVA-R. The UVI corresponds to the photo-biological effects on human skin related to these two types of solar radiation.

In addition to gasses, two other types of substances in the atmosphere affect the amount and type of UV-R that reach the Earth's surface. The first are aerosols. Not to be confused with propellants, this definition of aerosol includes any airborne pollutant, natural or anthropic (manmade). Aerosols help bring down the amount of radiation by scattering the waves into other spatial directions. However, although very polluted environments produce more scattering, it is not enough to have a protective effect.

In addition to gasses and aerosols, clouds also play a role in UV-R attenuation. Their effect depends on the nature of the cloud cover. When compared to a clear day, a layer of stratified clouds may reduce UV-R levels by as much as half. An even greater effect is seen with very deep clouds, like storm cumulonimbus. Sometimes, clouds can have the opposite effect, actually raising UV-R levels when they reflect the rays back as in the ice crystals in cirrus clouds or on the laterals of cumulus clouds. Due to the changeable nature of cloud formations, they do not serve as a reliable measure for sun safety.

A better predictor of UV-R is geographic location, especially as it relates to latitude and altitude. Many people wrongly attribute seasons to the changing distance between the Earth and the Sun, after noting that the orbit is elliptical rather than round. Since it is warmer in the spring and summer and gets colder in the fall and winter, our seasons must coincide with our distance from the sun. In reality, the difference between perihelion (closest point of orbit to sun) and the aphelion (furthest point of orbit from the sun) is only around 3%. Furthermore, the change in distance theory also fails to explain why the Northern and Southern hemispheres have opposite seasons. To do that, we must consider the Earth's tilt, also known as the angle of inclination of the earth's rotational axis as regards its revolution around the sun.

At all times, the Earth's angle of inclination of 23 degrees means that the availability of solar radiation is greater near the equator and decreases as you move toward the poles. In addition, because our orbit is not in the same plane, each of the poles and the associated northern and southern hemispheres receive different amounts of the sun's rays depending on the time of year. It is the reason that the Northern and Southern Hemispheres experience opposite seasons and why the poles have such extremes in the amount of daylight.

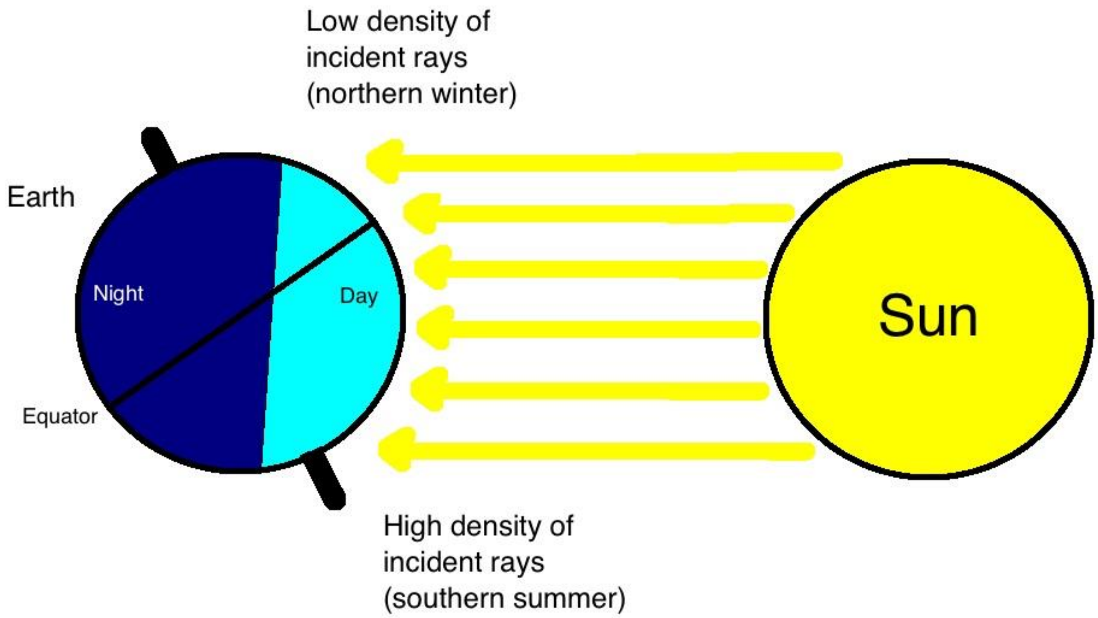

Figure 2

Even within a single day, there are differences in the amount and type of UV-R that reaches the Earth's surface which explains the UVI variation during that period. The Earth's rotation makes it appear as if the Sun starts at the horizon in the east at sunrise, reaches maximum elevation at solar noon, and returns to the horizon in the west at sunset. Its relative position at sunrise and sunset produces a greater scattering of the rays, due to the increased distance the light has to travel in the Earth's atmosphere, resulting in very little UV-R reaching the surface. In contrast, consider solar noon, where the distance the rays travel through the atmosphere are the shortest. Here the maximum amount of UV-R is observed, excluding other factors such as aerosols and clouds. This is the reason why people are advised to minimize their time outside between 10 am and 2 pm.

Although much less significant than latitude, altitude also affects UV-R. Above 1000m altitude, there is an increase in UV-R levels of 5-10% for each kilometer rise in height. This is due to the change in the column depth of air between the sun and us. The smaller the distance, the less scattering of the wavelengths, and the more UV-R that reaches the surface.

Last, the reflective properties of the surface as it relates to UV-R need to be considered. Grass, sand, and asphalt reflect between 1-5%. Fine sand and white painted surfaces can reflect up to 10%. Yet both are insignificant when compared to dry, fresh snow, which can reflect up to 90% of incident UV-R, making sunglasses a must to avoid snow blindness. As early as 2000 years ago, the Inuit cuts slits in walrus bone that allowed them to see out but protected them from the glare.

Equipped with the knowledge of what affects the type and amount of UV-R reaching the Earth's surface, we now need to consider its effects on life, especially as it applies to human health.

Risks of Sun Exposure

Melanoma

What causes some people to develop melanoma while others do not, is believed to be linked to genetics but the exact mechanism is not yet known. What is known, however, is that sun exposure seems to be a two edged sword. It doesn't seem to be the amount of sun that makes the difference but rather the short term effects on the individual. On the whole, outdoor workers have a lower incidence of melanoma compared to indoor workers. The risk factor seems to be whether the sun exposure leads to sunburn, which is associated with doubling the risk of developing melanoma. So why the difference?

The answer seems to lie in cell replication. Although UV-B damages DNA more than UV-A, the effects are moderated by the body's defenses, many of which are linked to the production of Vitamin D. In the case of sustained non-burning sun exposure, the body seems to be protected by increased melanisation and skin thickening or from the increased levels of vitamin D which are used in DNA repair. In contrast, sunburn is a sign of damage to the melanocytes. The melanocytes are responsible for creating melanin which is a skin pigmentation that seems to protect DNA cells from damage caused by UVR. Malignant melanoma seem to develop in cases where the cell replication process goes awry, inducing mutations.

Furthermore, the problem seems to be getting worse, with a steady increase of melanoma diagnosis from 1 per 100,000 people per year in 1935 to 23 per 100,000 per year in 2012. Some explanations have included better reporting, depletion of ozone layer and so greater UVR exposure, the widespread use of tanning beds and an increase in large windows in office buildings. Yet the answer may lie in overall decreased sun exposure rather than increased. In short, our spending less time under the actual sun has resulted in more sunburns, less melanisation, and lower levels of protective Vitamin D. Rather than being helpful, the advice to minimize sun exposure and use sunscreens, may have actually contributed to the rise in melanoma.

As a teacher, a parent and a grandparent, this particular piece of research really bothers me. As a teacher, my initial plan was to have students spread the word about sun protection but now I realize it isn't as cut and dried as I originally thought. As a parent, I used to feel guilty on those occasions when I didn't slather my kids in sunscreen but now think that may have been a good thing. As a grandmother, what advice do I share? Even the use of sunscreens is being re-evaluated with some physicians suggesting that they should carry a warning label about their use being associated with a Vitamin D deficiency. For ethical reasons, it is not feasible to do a double blind study comparing sunscreens to a placebo, especially in view of sunburns at any age being linked to increase melanoma risk. So what should be the recommendation?

On the one hand, the use of sunscreens reduce photo-adaptation and inhibits vitamin D production. Yet on the other hand, while not linked to a reduction in melanoma, one study showed them to be effective in reducing the risk of squamous cell but not basal cell, skin cancer. Other studies, which explored the link between overall sun exposure and the development of squamous and basal cell carcinomas, were equally contentious. After doing a literature review, the US. Preventive Services Task Force, in its May 2012 Final Recommendation Statement on skin cancer counseling stated that studies that measured long-term or total sun exposure had found no association between cumulative sun exposure and either Squamous Cell Carcinoma or Basal Cell Carcinoma. [9]

Diseases of the Eye Associated with UV Radiation

According to the American Academy of Ophthalmology, too much exposure to UV light raises the risk of developing cataracts, growths on the eye and certain types of cancer. In some cases, these conditions take years to develop but not always. Pinguecula and its close relation Pterygium (also known as Surfer's Eye) can appear as early as the late teens and early twenties. The former starts out as a deposit of protein, fat or calcium, on the conjunctiva, usually on the side of the eye closest to the nose. In some cases, it later develops into a Pterygium, which is a fleshy tissue growth that may grow large enough to cover part of the cornea and thus negatively affect vision. Both are thought to be caused by a combination of dry eyes, wind and dust exposure and solar ultraviolet light. People such as skiers, surfers, fishermen, farmers and other outdoor workers who spend a lot of time under the mid-day sun or in reflective UV locations like rivers, oceans and mountains are especially at risk. Skiers face the extra risk of snow blindness. Under certain conditions, permanent damage can happen in a very short period of time. Solar eclipses are especially dangerous as they give a false impression of the sun's rays being blocked.[10],[11]

Benefits to Solar Ultraviolet Radiation

Granted, there are many risks associated with sun exposure but there are also benefits. The best known of which is the sun's role in helping the body produce vitamin D which is essential to good health. "At least 1,000 different genes governing virtually every tissue in the body are now thought to be regulated by 1,25-dihydroxyvitamin D_3(1,25[OH]D), the active form of the vitamin, including several involved in calcium metabolism and neuromuscular and immune system functioning," according to an 2018 updated article in Environmental Health Perspectives[12]

In contrast to other essential vitamins which must be obtained from food, exposing skin to UVB radiation, triggers a photosynthetic reaction. The amount of vitamin D produced depends on how much of the radiation penetrates the skin. Clothing, body fat, sunscreen, environmental blockers and the amount of melanin in the skin, all affect UVB absorption. For a person in a bathing suit, thirty minutes of unblocked summer sun will release anywhere from 10,000 IU (.25mg) to 50,000 IU (1.25 mg) of vitamin D into circulation within 24 hours of exposure. Since melanin seems to inhibit absorption, darker skinned individuals fall on the low end, with fair skinned individuals falling on the high. Individuals, whose amount of melanin has increased through tanning, fall in the middle.

This initial form of vitamin D is subsequently transformed in the liver, kidney and other tissues until it reaches a variety of different forms that do different things within the body.

One key function of vitamin D is bone formation. In children, a deficiency results in rickets, a disease associated with stunted growth and various skeletal deformities, including bowed legs. Older adults are also susceptible with low vitamin D levels causing and exacerbating osteoporosis and osteomalacia.

Having adequate vitamin D levels have been associated with other health conditions as well. Deficiencies have been linked to hypertension, diabetes, certain types of cancer and even multiple sclerosis. What isn't also so clear is how the deficiencies should be addressed between diet and unprotected sun exposure. With so many variables, both environmental, and individual, that affect UVB absorption, it is difficult to reach one recommendation.

In addition to physical well-being, sun exposure is also connected to mental well-being. Like a plant, I consider myself usually phototropic i.e. I orient myself to the light source. Friends who have known me for years will testify that I'm a much more positive person in the summer than in the winter and I'm not alone. Seasonal affective disorder (SAD) is a type of depression, usually associated with fall and winter and ending in the spring, although there are a few people whose trigger is spring. In fall and winter, there are less opportunities for sun exposure. To start, due to the Earth's tilt, there are fewer hours of daylight. The two solstices, Winter, on December 21st and Summer, June 21st, represent the least and greatest amount of daylight in the northern hemisphere, coming in at 9 hours and 20 minutes versus 15 hours respectively. The two equinoxes Vernal (Spring) and Autumnal (Fall) have the same amount of day light of 12 hours. Starting with the fall equinox which occurs, in the northern hemisphere, around September 21, there will be an in balance between hours of light and dark that lasts until March 21st when we reach the Spring Equinox. [13]

Although the exact cause is not known, seasonal depression has been linked to changes in circadian rhythm, a drop in serotonin levels and a change in melatonin levels. As a species, we are diurnal, meaning that we are more active during the daylight hours.

For most of us, we associate light with activity and dark with sleep. In the absence of natural light, our awake sleep patterns can be interrupted. The second possible cause is a drop in serotonin. For a long time, it was thought that less sunshine meant less serotonin; less serotonin, which is a neurotransmitter, meant more depression. Current studies are causing this long held belief to be questioned but it has not yet been totally discarded. [14]

Lastly, there is the connection between sunlight and melatonin. The less sunlight, the more melatonin is produced which is associated with wanting to sleep more.

Non-pharmacological treatments for Seasonal Affective Disorder that have been shown to be effective include light and exercise therapy, used alone or in conjunction. Light therapy can be as simple as getting increased exposure to natural light or using a light box, which is designed to mimic the bright light of the sun but without the exposure to UV radiation. [15]

Strategies

Students will incorporate the 8 Science and Engineering Practices from the Next Generation Science Standards as part of their project based learning. They will be generating questions throughout the unit as part of driving their own learning. They will obtain, evaluate and communicate information, pulling from a variety of text and multimedia resources. They will develop and use models as they plan and carry out their own investigations to determine the efficacy of different sun blocks. They will use mathematics and computational thinking as they analyze and interpret the data from their investigations. They will use that evidence as part of their arguments on safe sun exposure and as part of their engineered sun protection solutions.

Planned Investigations

This problem based unit is applicable to grades seven through eleven, depending on the amount of teacher support. It culminates with students creating a public service campaign on safe sun exposure. Along the way, they will investigate how different materials, lotions, sunglasses, and surfaces, reflect and/or block the sun's radiation. They will conduct interviews with both an ophthalmologist and a dermatologist to learn how the sun can affect skin and eyes. They will interview an endocrinologist on the role that vitamin D has on physical and mental wellbeing.

Lesson 1 - Overview

Opening Scenario

Jenny's parents are refusing to sign the permission slip so that she can go on the class field trip to the beach. The last time she went, she developed sun poisoning. In addition, one of her mom's classmates from high school was just diagnosed with melanoma. Now her parents are so paranoid that they are treating her like she was a vampire and keeping her totally away from the sun. How can we convince them that safe sun exposure is not only possible but necessary for Jenny's physical and mental well-being?

What do we need to do? What information will we need? What questions do we need to answer?

Anticipated questions:

- What is sun poisoning?
- What is melanoma?

At this point, encourage students to write at least three questions, putting each one on a separate sheet of scrap paper. High schoolers can be very self-conscious about sharing ideas. One way I deal with this is by staging a snowball fight of ideas. Students crumple up each of their question papers, stand in a circle and then throw them at each other, picking them off the floor in front of them and re-throwing. In this way, all the ideas are spread throughout the classroom. Students then pick up the slips from the floor nearest them and read the questions of their peers. Working in assigned small groups, they then try and categorize the questions. Moving back into whole group discussion, we create a class question board with students adding the individual questions.

Exit card

Of the questions shared, which one do you think we should investigate first and what would we need to do?

Before the next day, the teacher should separate out the questions into answer through research or answer through experimentation. The unit now splits into two interwoven tracks.

Lesson 2 - Creating Groups Based on Interest

Day 1

I anticipate that students will mostly choose looking at sunscreens as that is what is most familiar to them. Other options could be to consider protective eyewear or fabrics. Within the umbrella of investigating sunscreens, students can compare brands, compare SPFs within a brand, and compare application, both amount and frequency. They could also compare for specific qualities such as being water/sweat proof. Although there is a great deal of research on group dynamics of 4-5 and teachers are encouraged to assign roles, I prefer groups of 3 with students taking turns in the facilitator role.

Students will generate their investigation using the template: question, hypothesis, variable being studied, variables being controlled, materials needed, experimental steps, creating a data table, room for analysis, conclusion, experimental notes and next steps. As high schoolers, they should be familiar with designing an experiment but the teacher should still circulate and help them focus their investigation through questioning.

During this time period, groups are encouraged to pair/share with a group investigating a different aspect of sunscreen usage. I anticipate students may be stumped by how to measure sun protection. Some ways may involve photosensitive paper and/or beads. High tech could include a light meter with low tech looking at construction paper fade. If students reach the frustration level, there are several websites under student resources that provide step-by-step directions. It would be helpful to include pictures for ELL and struggling readers.

Day 2

Students run their investigations. In an ideal world, they will have an undisturbed sunny area in which to conduct their experiments. If that is not possible, students can use ultraviolet lights and/or black lights to simulate UVA and/or UVB. An important safety note is that students should use protective eyewear when using artificial light sources. While most students understand that they shouldn't look directly at the sun, they need to be cautioned about artificial sources.

Day 3

Students reflect on their experiments by analyzing their data. As in the real world, sometimes experimental data doesn't support what seems to be a slam dunk hypothesis; i.e. the higher the SPF, the better the sun protection so the bead covered in SPF 45 should have reacted less than the bead coated in SPF 30. This is where experimental notes and next steps are so important. Through teacher and peer conferencing, students consider other factors that might have affected their results such as coverage, accuracy of SPF label, or sun exposure. Based on their findings, their next steps could involve retesting their original hypothesis with modifications or investigating another aspect involving sunscreen. What they choose to do isn't as important as understanding that science and engineering are both iterative processes.

Day 4

Students share their research using either Google Docs or PowerPoint depending on the available platforms. Students are scored based on both ELA and science content.

Day 5

Whole class returns to the question board and the overarching problem: convincing Jenny's parents to allow her to go to the beach. If students originally brought up clothing and sunglasses as protective wear, students can then be assigned randomly to investigate one or the other using the beads or photographic paper. As before, they create, run, analyze, reflect and share the results of their investigation.

Research Strand

This portion can be taught as the second half of a block period, every other day interspersed with the investigation, or inserted on days when weather conditions are not conducive to carrying out the experiments. Ideally, research should be linked to the class question board. As a general rule, I go back to it throughout the unit, both as summary and as a source for new questions.

Breaking Apart Sunlight

What is light? How is sunlight different than other types of light?

Students will use refraction glasses and prisms to see that different light sources are composed of different wavelengths. Then students look at the spectrum of sunlight and connect that shorter wavelengths have higher energy. They see that non-visible light (ultraviolet light) has more energy than visible light whether it be incandescent or fluorescent. They learn that UVC is used for sterilization in multiple applications including hospital instruments, classroom goggles, and now personal cell phones. This is an ideal time to address a common misconception ROY G BIV, the mnemonic for the colors of visible light revealed in a rainbow: red, orange, yellow, green, blue, indigo and violet. It is the one I used when I taught elementary school and one that I carried in my own head. In English, we read left to right and so by inference, most students think that red has the shortest wavelength and violet the longest when it comes to visible light. I remember struggling with red and blue shifts in physics but it took interacting with a French Canadian professor to see the mnemonic as the source of my confusion.

Learning through STEAM

Using an interactive map, students will create a graph showing how changes in the UV index for North America are connected with the seasons. To help calculate what percentage each part has each month, students will put a transparent grid over the North

American map, and color each section according to the World Health UV Index color chart. From that, they will count the squares to approximate the breakdown. The data lends itself to a variety of different graphing options. For each month, students could create either a circle chart with the relative percentages or a bar graph. This could be done manually or through a graphing app to provide extra student support. It would be useful for students to predict how the percentages will change throughout the year before they do the calculations. Modifications could include having students make predictions by shading in gridded maps and then comparing them to average data.

To help reinforce the idea that seasons, and the associated UV index values are associated with tilt rather than distance from the sun, students should compare data between North America and Australia month by month. As part of the cross-cutting concept of looking for patterns, focus questions should help students see that the areas of lowest UV Index between the two continents at first glance seem reversed. However, a closer analysis shows that they are similar if the orientation switches from North and South to equator to pole.

The associated engineering challenge could involve designing awnings for a backyard deck or patio. Depending on the level of student, this could be as detailed as taking into account the time of year and the angle of the sun's rays throughout the day, or as simple as when they should be put up and when taken down to balance bringing light into the house and sun exposure. Related to their investigation into protective clothing, they could also research how different materials hold up to prolonged sun exposure.

Students could capture the cyclical nature through art in a variety of ways. The simplest could be lines of color that appear, thicken, and thin throughout the year. As long as the axis are labeled correctly, students do not need to start in January. Another way would be for the student to choose/draw an outdoor scene of an actual place. Instead of using realistic colors, they would use the hues of the UV Index.

Formative assessment could include asking students to put the maps in order and then explain their process. They could also be given UVI maps for different areas around the globe and either asked to connect it to a month/season and explain why or given the UVI data and month/season, predict the latitude, again arguing with evidence.

Learning through research/interviews

Before students can argue about what is safe sun exposure, they need to understand the effects, both positive and negative, on humans. There is a great deal of reliable information available on the web and I've included several good sites in student resources. This unit also lends itself to having guest speakers, specifically a dermatologist, ophthalmologist and an endocrinologist, talk about the risks and benefits. Having students interview the professionals gives them a chance to work on their oral language and listening skills. It also benefits ELL and special education students as our listening vocabulary is usually better than our reading vocabulary.

Additional Student Resources

The following web resources are recommended for students.

https://www.acs.org/content/dam/AACT/middle-school/energy/radiation/lab-sunscreen/lab-sunscreen.pdf
This site provides a straightforward lab write up to test the effectiveness of sunscreen.

https://www.epa.gov/sunsafety/dont-fry-day
Students will visit this web site as part of developing their own social media campaign to publicize Don't Fry Day. Students will have the option of developing 3 tweets, 2 Snap-Chat stories or one 30 second-1 minute YouTube video promoting sun protection.

https://www.epa.gov/sunsafety/sun-safety-monthly-average-uv-index#tab-12
http://www.bom.gov.au/jsp/ncc/climate_averages/uv-index/index.jsp?period=jul#maps
This site allows students to demonstrate understanding of UV index by connecting color changes in US with seasons.

https://www.healthline.com/health/depression/benefits-sunlight
This site explains the benefits of sun exposure overall.

https://www.mydr.com.au/eye-health/eyes-in-the-sun,
https://www.caringvillage.com/2017/07/19/top-5-eye-problems-resulting-from-uv-exposure/, https://www.skincancer.org/prevention/sun-protection/for-your-eyes/how-sunlight-damages-the-eyes
These two sites are excellent resources on eye health.

https://www.ndcancercoalition.org/image/cache/Tab5_Nanosense_34.pdf

This is an excellent source which includes a PowerPoint defining different types of solar radiation. It also includes a step by step lesson which looks at opacity and blocking UV radiation.

http://solar-center.stanford.edu/activities/UVBeads/UV-Bead-Instructions.pdf
This lab is designed for primary level students and doesn't require any specialized lab equipment.

https://www.teachengineering.org/activities/view/cub_sun_lesson01_activity1
Although designed for an 8th grade class, these activities are not too low level for high school students. There are also links to two related high school investigations.

http:/www.time.com/4888327/why-sunlight-is-so-good-for-you/
This site details the benefits of sun exposure on mental health.

https://www.verywellhealth.com/effects-of-sun-on-the-skin-1068724
Students do a web quest using the following vetted sources to discuss the negative effects that sun exposure has on the skin.

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Appendix

NGSS (Next Generation Science Standards)

ESS2.D The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundations for the global climate systems.

ESS2.E The biosphere and Earth’s other systems have many interconnections that cause a continual co-evolution of Earth’s surface and life on it.

PS4.A The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy.

Common Core Standards

CCSS.ELA-LITERACY.RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

CCSS.ELA-LITERACY.RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

CCSS.ELA-LITERACY.WHST.9-10.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.