Red Light, Green Light: An Exploration of Light and Photosynthesis

by Elizabeth Kerr, 2022 CTI Fellow
Bain Elementary School

This curriculum unit is recommended for:
K-2 Science and Literacy

Keywords: photosynthesis, light, filter, grow lamp, scientific method, Predict-Observe-Explain (P-O-E)

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: This unit will look at light and how it is a requirement of plants to survive. Different wavelengths of light affect photosynthesis differently. Students will work to design an experiment to observe how different wavelengths of light affect the plant's growth. This will lead into a discussion on food chains/webs, where students will discover that the sun and plants are the beginning of every chain/web. This unit will require students to take measurements and record data at least once a week for at least three weeks.

I plan to teach this unit during the coming year to 21 students in First Grade, Science.

Red Light, Green Light: An Exploration of Light and Photosynthesis

Elizabeth Kerr

Introduction

Why do leaves change color? Why are leaves green in the spring and summer? What happens when plants do not have any light? These questions are common to elementary students. Early elementary students have started making observations of the world around them and are starting to question what they see.

This is the perfect time to start introducing students to how the world works. Light is often taken for granted. Students love to be in the sunlight, but do not stop to think about how important light is to our existence. Without light, life probably would not exist on our Earth. Not only does it nourish our bodies, it kickstarts every food chain and web. In this unit, students will explore the importance of light to our daily lives and in the process of photosynthesis.

Rationale

pho·to·syn·the·sis | \ ˌfō-tō-ˈsin(t)-thə-səs \

Definition of *photosynthesis*
: synthesis of chemical compounds with the aid of radiant energy and especially light
especially **:** formation of carbohydrates from carbon dioxide and a source of hydrogen (such as water) in the chlorophyll-containing cells (as of green plants) exposed to light.[1]

Students need to understand why light is so important to our daily lives. This will help them to better conceive of the connections between all living things. The sun and plants are the beginning of every food chain/web. Therefore, understanding the best ways to help plants to grow supports all life on Earth.

The lessons in this unit will help students to design an experiment, record their observations and analyze the data collected. These are college and career ready skills that students will need to compete in the world later in life.

School Demographics

Bain Elementary School sits adjacent to the Bain Academy historical site in Mint Hill, a suburb of Charlotte, North Carolina. Bain Academy was founded in 1889 by John Bain. It is thought that he had a strong desire to improve the lives of the people around him. So, as a longtime member of Philadelphia Presbyterian Church, the church granted him permission to fund the school on the current site.

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[1] "Definition of PHOTOSYNTHESIS."

From the beginning, the school attracted students from all over. It is not so different now. Families moving to the area, often examine the schools in the area and find Bain to be a good fit. It is a community school with a great deal of parental involvement.

Students at Bain are inquisitive and enthusiastic learners. There are many opportunities for them to explore different aspects of their learning. Students can participate in the morning closed-circuit newscast, Safety Patrol, Art, Music, Physical Education, Media Literacy and our own B5 Sensory Lab (designed to help students build core strength and engage their senses in different ways).

We currently serve approximately 770 students. These students represent many different nationalities and backgrounds. These students thrive in working together and learning about each other's cultures. As this shows, Bain has a long history of serving the families in the Mint Hill area.

Content

What is light? This is a question that scientists have been working to answer for over 300 years. Some of these ideas will be discussed here: light as a particle, light as a wave and light as energy. This will help students and teachers to understand how light affects the process of photosynthesis.

Is Light a Particle?

Early Greeks thought that light emanated from the eye in rays. Some theorized that vision was achieved when light rays from the eye hit an object. Conversely, others theorized that the object itself emitted light and when the rays hit our eyes the object was able to be seen.[2]

Newton expanded on this theory with his famous light experiments. He developed the "corpuscular theory" in relation to light. Corpuscles travel in straight lines and when the corpuscles hit the retina, vision was achieved. However, his theory could not explain interference, diffraction and polarization of light.[3]

This leads to Einstein's work on photons and the photoelectric effect. His work was so highly regarded he won the Nobel Peace Prize. He stated that a photon with enough energy could strike the surface of metal and eject an electron from the metal. Furthermore, Einstein discovered that different wavelengths of light carried different amounts of energy. The violet, indigo, blue colors of the visible light spectrum have shorter wavelengths and more energy than the red and orange colors of the spectrum.[4] Einstein kickstarted the study of quantum mechanics with this discovery.[5]

Is Light a Wave?

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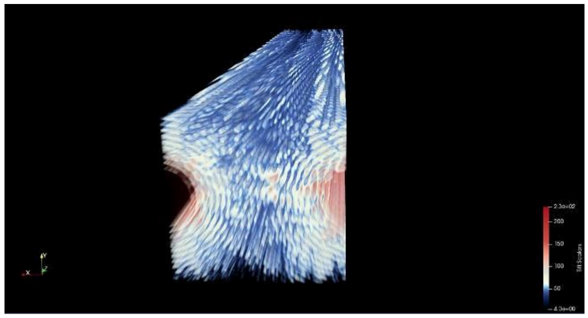
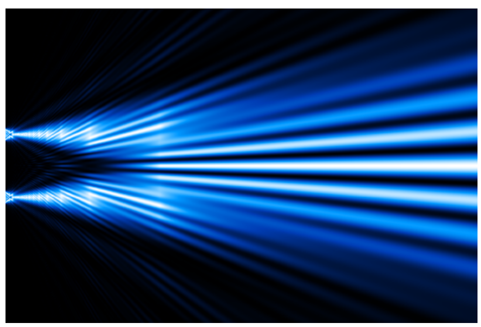
[2] "How Light Works."
[3] "Corpuscular Theory of Light – Physics and Radio-Electronics."
[4] "Photon - Energy Education."
[5] published, "Photoelectric Effect."

Around the same time that Newton was publishing his "corpuscular theory," Italian physicist Francesco Grimaldi, was already thinking of light as a wave. He observed what happened when light passed through water (refraction). Almost 100 years later, Thomas Young demonstrated that light can exhibit interference and that different colors of light have different wavelengths.



Interference and Diffraction of Monochromatic Light as it Exits Two Pinholes, Captured From Purpose-Built 3D Scanner[6]



Simulation of the double-slit experiment with electron[7]

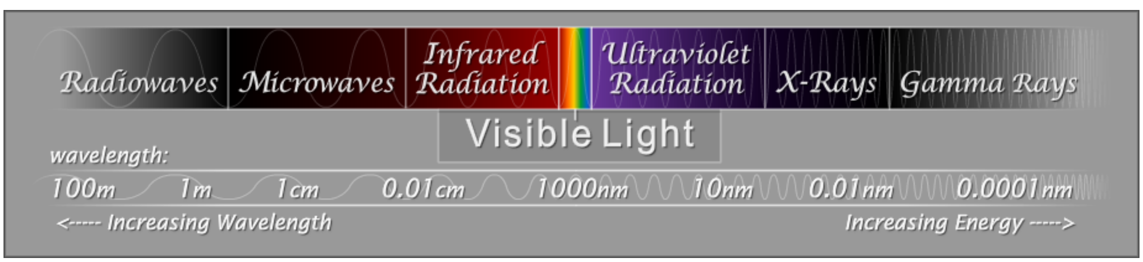
Young worked to design an experiment to prove light interference. In his experiment, he struggled to find appropriate light sources with the tools of the time. He found a way to divide sunlight coming through a pinhole into two beams of light. When the beams met again, interference could be seen. Using his equation, he was able to measure the interference that was shown, and therefore find different wavelengths in sunlight.[8]

[6] Make, *English*.
[7] Gondran, *English*.
[8] "Physics Tutorial: Young's Experiment."

Diagram showing the increase in wavelength across the visible spectrum from violet to red.[9]

Scientists now can find the exact wavelength of light/radiation in the visible spectrum and past. Per the diagram above, longer wavelengths have less energy and shorter wavelengths have greater energy. So now, how do infrared light and ultraviolet light fit in?

Light/energy beyond the visible spectrum was discovered in 1800 by Sir William Herschel. He observed heat coming from the light diffracted by a prism. He placed his thermometers just past the red end of the spectrum. He found that the temperature there was even warmer than the red end of the spectrum. Herschel concluded that light we could not see was causing the rise in temperature. Infrared radiation was discovered.[10]



A chart to show the electromagnetic spectrum.[11]

Photosynthesis

Photosynthesis is the process by which plants use light, water and carbon dioxide to create a sugar that is used for food. This process gives off oxygen as a by-product.[12] There are many steps involved in photosynthesis, but they can be broken down into two categories: light-dependent reactions and light-independent reactions. The light-dependent reactions require a steady stream of sunlight. Furthermore, there are more forms of photosynthesis.

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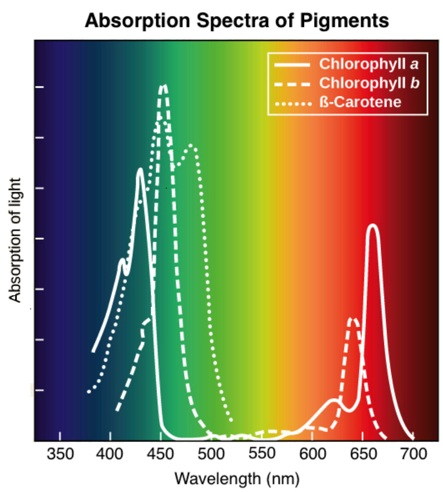
[9] DrSciComm, *English*.
[10] *Discovery of the Electrmagnetic Spectrum by Frederick William Herschel*.
[11] "Electromagnetic_Spectrum.Png (920×200)."
[12] "Photosynthesis | National Geographic Society."

Some forms produce higher levels of carbon which allow plants in low-light, arid environments to thrive.[13]

Photosynthetic cells contain two types of chlorophyll, Chlorophyll a and Chlorophyll b. Chlorophyll is a green pigment that absorbs the light needed to start the process of photosynthesis. Chlorophyll a absorbs violet-blue and red-orange wavelengths and reflects green-yellow wavelengths. This is what causes plants to appear green to our eyes.[14]

The role of chlorophyll b is to increase the number of wavelengths that can be absorbed. Plants that do not receive much sunlight have more chlorophyll b. The extra energy created is transferred to chlorophyll a. Chlorophyll b is an accessory pigment to chlorophyll a, while chlorophyll a is the primary pigment needed for photosynthesis.[15]

Photosynthesis is essential for life on Earth. As stated before, each food chain/web begins with light from the sun and then leads to plants. This process creates oxygen. An average house plant can produce up to 2.4 liters of oxygen a day. The graph below shows the optimal wavelengths at which chlorophyll absorbs. The peaks on the graph illustrate the wavelengths of light that chlorophyll absorbs the most of. Here chlorophyll a and b both absorb light at 450 nanometers (blue) and again at around 625 to 650 nanometers (orange to red).



Absorption spectra for key pigments in photosynthesis[16]

The valleys are the wavelengths that are reflected, 450-600 nanometers (yellow to green). Since this shows that green and yellow wavelengths are reflected, plants and chlorophyll appear to be green to our eyes.

Begin with the End in Mind: Unit Goals and Outcomes

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[13] "Photosynthesis | National Geographic Society."
[14] "Introduction to Photosynthesis."
[15] "What Are the Roles of Chlorophyll A & B?"
[16] "Wavelengths of Light and Photosynthetic Pigments (Article) | Khan Academy."

While teaching this unit, the students will:
- Read several non-fiction texts.
- Graph data points on a basic template.
- Record observations by writing or drawing.
- Measure the growth of plants using standard and metric measurements.

At the conclusion of this unit, students will be able to:
- Discover which colors of light help plants to grow the most.
- Explain Food Webs and Food Chains.
- Understand that light is made of different colors.

The Plan: Instructional Implementation

Materials needed to implement this unit are:
- 5 small plants of the same type, size labeled A, B, C, D, E
- 4 grow lamps
- light filters: red, green, blue (see Appendix 4)
- black light and fixture (see Appendix 4)
- 5 covers or boxes large enough to cover the plants and grow lamps (should not let any white light touch the plants)
- Chart paper (K-W-L chart,
- *Plants are Living Things* by Bobbie Kalman (available for free to educators on Epic! Online Library)
- *Plants Need Sunlight* by Christine Peterson (available for free to educators on Epic! Online Library)
- diffraction gratings
- rulers, one per child
- *Photosynthesis* by Torrey Maloof (available for free to educators on Epic! Online Library)
- *The Energy We See: A Look at Light* by Jennifer Boothroyd (available for free to educators on Epic! Online Library)
- light box or other light source
- prisms
- small mirrors
- *Light* by Carolyn Bernhardt (available for free to educators on Epic! Online Library)

Vocabulary:
- living thing
- plant
- photosynthesis
- sunlight
- spectrum
- wavelength
- chlorophyll
- filter

- reflect
- source
- absorption

Day One, Introduction to Unit, Plants Make Their Own Food

Have students think about plants. Complete a K-W-L chart with the class collecting information about what they know already, what they wonder about and what they would like to learn.

Ask if plants are living things. If they are, why? (Plants need air, water, food, sunlight and space to grow. Plants produce seeds which produce other plants like themselves. Plants grow and change.).

Read *Plants are Living Things* by Bobbie Kalman (available on Epic! Online Library, free to educators). Refer to K-W-L chart at the end of the lesson to see what needs to added or corrected.

Point out the information on pages 18-19 of book. Tell students that they will be doing an experiment to see if they can find ways to help plants make their food more effectively and grow more efficiently.

Students can draw a picture of a plant and label the ways that they know a plant is a living thing for their Exit Ticket.

Day Two, Sunlight

In this session, students will be looking at sunlight. Remind students of the things needed to help plants make their own food (water, nutrients from the soil, carbon dioxide and sunlight).

Begin by reviewing the K-W-L chart. Ask students if anything needs to be added to any column.

Read *Plants Need Sunlight* by Christine Peterson (available on Epic! Online Library, free to educators). Discuss the ways that sunlight helps plants to make their own food. Introduce the term **photosynthesis** (the process by which plants use air, water and light to make their own food).

There is more to sunlight than meets the eye. Pass out the diffraction gratings to each student. Explain that this is a tool that will help them see what light is made of. Students should be able to see the white light broken up into the colors of the electromagnetic spectrum. Have students use the diffraction gratings to look at the lights in the classroom.

After an appropriate amount of time, bring the students together to discuss what they saw. Students should notice that they saw rainbows through the diffraction gratings. The white sunlight can be broken up into the colors of the rainbow. Ask the class what they think might happen IF they were to use the gratings to look at the sun. The light from the sun should also show a rainbow.

Have students use the Exit Ticket located in Appendix 2 to explain what they saw.

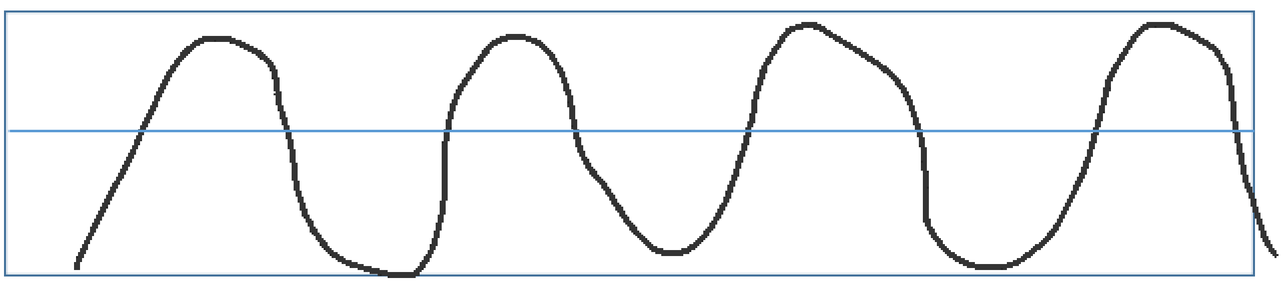
Day Three, More About Light

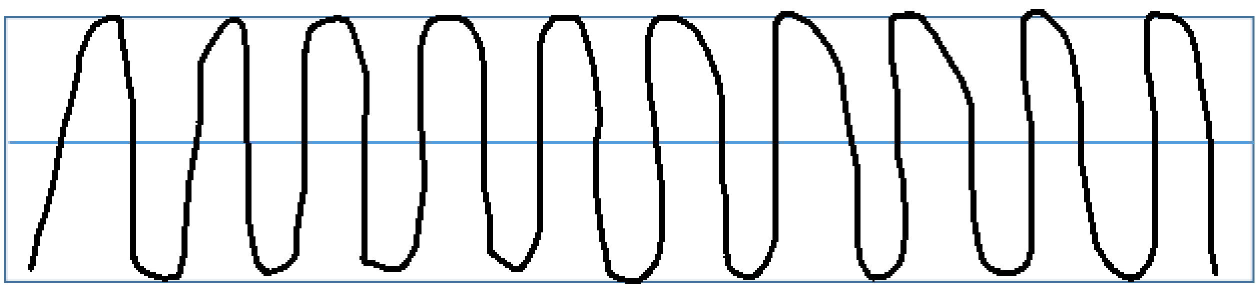
In the previous session, students learned that plants need sunlight and that sunlight is comprised of all the colors of the rainbow. In this session, students will do some activities with white light.

Remind students how the white light was shown to be made of all colors through the diffraction gratings they used. Read *The Energy We See: A Look at Light* by Jennifer Boothroyd, pages 4-5, 10, and 23-29.

Show students how they can diffract white light into the colors of the rainbow (the electromagnetic spectrum) using a flashlight and a CD. You can also have a light box set up for students to use with prisms (the light box can get hot, so supervise carefully).

After an appropriate amount of time to explore, discuss how light travels as a wave with students. Show students a diagram of a wave. Show a diagram of a long wavelength and a diagram of a short wavelength.





Explain to students that each color travels on its own wavelength. The shorter wavelengths have more energy and the longer wavelengths have less energy. Ask which colors students think would fit each category.

Reds, oranges and yellows have longer wavelengths and less energy. Blues and violets have shorter wavelengths and more energy. Propose the question: Do certain wavelengths of light help plants to grow better? Is regular sunlight the best for plants? How could we find out?

Have students complete Exit Ticket for Day Three.

Day Four, Setting Up the Experiment

In the previous session, students learned that light travels in waves and certain colors have certain wavelengths. Students were supposed to make a prediction as to which color they thought would help plants grow the best.

In this session, students will share their ideas for how to set up an experiment to see if certain wavelengths of light help plants to grow better.

After an appropriate amount of time for discussion, show students the plants and the grow lamps. One grow lamp each should have a red or green filter on it. One grow lamp should have no filter. Set up the black light and fixture. Show students how the grow lamps work. Have the class use the diffraction gratings to look at light through each filter. Note any observations.

Next, show students each plant. The plants should be of the same type and size (as much as possible). The class will be studying these plants throughout the lab. Ask students to think carefully about how they will be able to know which plant is growing the most efficiently (the plant will be taller, fuller, greener).

Have students begin their experiment by measuring the height of each plant, first in standard measurement and then, in metric. This will be the benchmark. Students should record their measurements in the sheet used. This can be added as a Google Doc or an assignment made in the Classkick app. This will enable students to take and upload photographs to their documentation (see Appendix 2).

Set up the grow lamps. Plant A is the control plant. This plant should be left in regular classroom lighting and watered. Plant B should be placed under a box with the green filter. Plant C should be placed under a box with the red filter. Plant D should be placed under a box with the black light. Plant E should be placed under a box without any light at all.

Students should take their measurements of each plant and upload a picture of each plant to their online recording sheet (included in Appendix 2). This should be completed once a week for three weeks (or more often if you choose).

Day Five, What is Photosynthesis?

In the previous session, students set up their experiment to see if certain wavelengths of light helped plants to grow more efficiently. In this session, students will learn more about photosynthesis.

Review and add to K-W-L chart. Ask students what they know about photosynthesis. Add to chart. Ask students what questions they have and add those to the chart.

Read *Photosynthesis* by Torrey Maloof (available on Epic! Online Library, free to educators). Focus on the parts of a plant. How does each part help the plant accomplish photosynthesis? (roots, stem, leaves, petals, seeds). See Exit Ticket, Day 5.

At the conclusion of the lesson today, leave time for students to observe each plant. Data does not need to be recorded.

Day Six, Why Do Plants Appear to be Green?

Review the K-W-L chart from the previous sessions. Pose the question to students, "Why do you think plants appear to be green?" Record the suggestions from the students.

Next, set up the light box. Turn out the lights in the room. Show how the light moves from the light box through the space. Then, show how the light can **reflect** off the mirrors. Show what happens when the light travels through a prism. You can maneuver the prisms to break part of the visible spectrum off into a different direction. Explore.

Discuss what reflection means. Read *Light* by Carolyn Bernhardt. Focus on pages 8-15. Explain to students that it is the reflected light that we see. The reflected light helps our eyes to determine the colors of objects. Leaves appear green to our eyes because of the pigment that reflects green and yellow light.

What does this mean for our plants? If green light is reflected and not absorbed, does it help with photosynthesis?

Have students complete Exit Ticket for Day 6 (see Appendix 2).

Day Seven, The First Link in the Food Chain

Review the work in the previous session on reflected and absorbed light. Ask again why plants appear green to our eyes.

Now, why is all of this important? Watch this video, Fabulous Food Chains: Crash Course Kids #7.1[17]. Discuss with your students. Note how the presenter especially pointed out that food chains begin with energy from the sun and move to plants next. No photosynthesis, no plants!

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[17] *Fabulous Food Chains*.

Have students explain why every food chain begins with the sun and plants. Then, have students work in small groups to make the food chains found in Appendix 2. Students should cut the strips apart and link them in the correct order.

Upon completion, share each food chain with the class. Students should note that every chain begins with the sun. This is the Exit Ticket for Day 7.

Day Eight, The First Strand in the Food Web

Review the work in the previous session. Have students discuss what they remember about the beginning of every food chain. Why is that important? Why is photosynthesis important in our food chains?

Now, ask students if they noticed that more than one kind of animal eats grass or flowers. Does more than one type of animal eat an insect? What about rabbits? What does that mean in our food chain?

When living things are connected in more than one way, it makes a web! Plants are just as important in a food web as they are in a food chain. Watch Food Webs: Crash Course Kids, #21.2.[18] Discuss what is learned in the video (that all living things are interconnected and something happening to one part of the chain/web affects all of the other elements in the chain/web).

See Exit Ticket for Day 8 in Appendix 2.

Days Nine and Ten, Compiling and Analyzing the Data, Final Product

After having the experiment set up for approximately three weeks (or long enough for students to observe differences in the plants), have students analyze their data.

Students should graph the growth of each plant. What do they notice about their observations? Which plant showed the most growth?

Next, have students take their final pictures/draw their final pictures. What do the students notice about their pictures over the course of three weeks? Which plant is the greenest and most full?

Using the report page in Appendix 2, have students write about the observations. What conclusions can they draw from looking at all of their data? Students should be sure to state their opinion as to which light helped the plants grow the most and kept them the most healthy.

When their reports are complete, have students complete the self-evaluation in Appendix 2.

[18] *Food Webs*.

Appendix 1: Implementing Teaching Standards

Teaching Standards Addressed in this Unit

1.L.2 Summarize the needs of living organisms for energy and growth.

1.L.2.1 Summarize the basic needs of a variety of different plants (including air, water, nutrients, and light) for energy and growth.

1.L.2.2 Summarize the basic needs of a variety of different animals (including air, water, and food) for energy and growth.

NC.1.MD.2 Measure lengths with non-standard units.

- Express the length of an object as a whole number of non-standard length units.
- Measure by laying multiple copies of a shorter object (the length unit) end to end (iterating) with no gaps or overlaps.

NC.1.MD.4 Organize, represent, and interpret data with up to three categories.

- Ask and answer questions about the total number of data points. • Ask and answer questions about how many in each category.
- Ask and answer questions about how many more or less are in one category than in another.

NC.RI.1.1 Ask and answer questions about key details in a text.

NC.RI.1.2 Identify the main topic and retell key details of a text.

Appendix 2: Implementing the Unit

Day One Exit Ticket

Name: ___________________________________ Date: ______________________

Draw a picture of a plant. Label what makes it a living thing.

Day Two Exit Ticket

Name: ___________________________________ Date:________________________

Draw a picture of what you saw through the diffraction grating.

Day Three Exit Ticket

Name: __________________________________ Date: ________________________

Which wavelength of light do you feel would help plants to grow the best? Why?

Day Four

	Week of:	Week of:	Week of:
Plant A (control plant)	Standard:	Standard:	Standard:
	Metric:	Metric:	Metric:
Plant B (green filter)	Standard:	Standard:	Standard:
	Metric:	Metric:	Metric:
Plant C (red filter)	Standard:	Standard:	Standard:
	Metric:	Metric:	Metric:
Plant D (black light)	Standard:	Standard:	Standard:
	Metric:	Metric:	Metric:
Plant E (no light)	Standard:	Standard:	Standard:
	Metric:	Metric:	Metric:

	Week of:	Week of:	Week of:
Plant A (control plant)			
Plant B (green filter)			
Plant C (red filter)			
Plant D (black light)			
Plant E (no light)			

Day Five Exit Ticket

Name: ____ Date:________________________

Draw diagram of a plant. Label each part of the plant and tell how it helps the plant go through photosynthesis.

Day Six Exit Ticket

Name: ____ Date:________________

If plants reflect green light, what colors of the visible spectrum do you think will help plants grow the most?

Day Seven

The Sun
grass
grasshopper
bird
snake

The Sun
flower
insect
frog
snake

The Sun
algae
small fish
larger fish
pelican

The Sun
dandelions
rabbit
fox
mountain lion

Day Eight

6 inches			
5 inches			
4 inches			
3 inches			
2 inches			
1 inch			
Plant A (control plant)	**Date:**	**Date:**	**Date:**

6 inches			
5 inches			
4 inches			
3 inches			
2 inches			
1 inch			
Plant B (green filter)	**Date:**	**Date:**	**Date:**

6 inches			
5 inches			
4 inches			
3 inches			
2 inches			
1 inch			
Plant C (red filter)	**Date:**	**Date:**	**Date:**

6 inches			
5 inches			
4 inches			
3 inches			
2 inches			
1 inch			
Plant D (black light)	**Date:**	**Date:**	**Date:**

6 inches			
5 inches			
4 inches			
3 inches			
2 inches			
1 inch			
Plant E (no light)	**Date:**	**Date:**	**Date:**

Days Nine and Ten

Final Student Self-Assessment

Concept	Score
I did my best work.	
I thought carefully about the results of my experiment.	
I stated my result clearly.	
I know what photosynthesis is and can explain it to someone else.	
I can explain how light helps plants to grow.	

*Smiley faces[19]

[19] "Free Image on Pixabay - Emoji, Smile, Sad, Emoticon, Smiley."

Appendix 3: Annotated Teacher Resources

Supplemental Texts and Resources

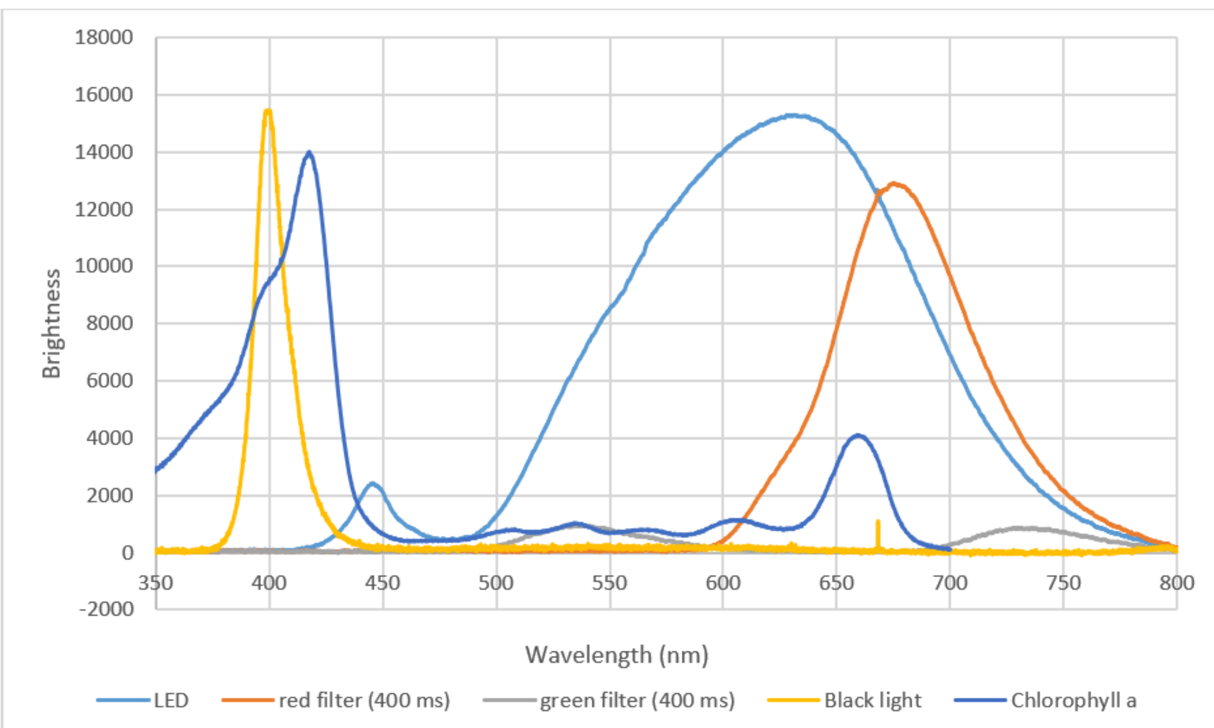
Is light a particle or a wave? - Colm Kelleher[20]

The Science of Light and Color for Kids: Rainbows and the Electromagnetic Spectrum - Freeschool[21]

Why Are Plants Green Instead of Black? SciShow[22]

Below is a graph to demonstrate the wavelengths of light that are reflected and absorbed through the filters. This graph is provided courtesy of Dr. Susan Trammell, University of North Carolina - Charlotte. Look closely at the peaks in the graph and how they coincide with peaks in Chlorophyll a.

Grow lamp with no filter: 1.1 meters



[20] *Is Light a Particle or a Wave?*
[21] *The Science of Light and Color for Kids*.
[22] *Why Are Plants Green Instead of Black?*

Appendix 4: Unit Materials, Important Information

Filters used were purchased from www.stagespot.com. These are actual theatrical lighting gels.

Red filter: Roscolux, Medium Red, 27
Green Filter: Rosco Cinegel, VS-Green, 2004

Cost is $10 per 2 x 2 sheet. These sheets can be cut and used several times.

Black Light:
Bluex Bulbs 2 Pack LED Black Light Bulb, 9W A19 E26 Blacklight Bulb Level 385-400nm
Distances from top of plant to light source so intensity is same for all sources:

- Green light: 0.2 meters (20 cm)
- Red light: 0.75 meters (75 cm)
- Black light: 1.1 meters

This information is provided courtesy of Dr. Susan Trammell, University of North Carolina-Charlotte.

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Endnotes