Waving Hello to Glow

by Keira Freeman, 2020 CTI Fellow
Carmel Middle School

This curriculum unit is recommended for:
6th Grade Science

Keywords: Keywords

Waves, Light Wave, Fluorescence, Crest, Trough, Wavelength, Amplitude, Frequency, Longitudinal Wave, Transverse Wave, Medium, Reflection, Refraction, Rarefaction, Transmission, Opaque, Transparent, Translucent, Absorption, Electromagnetic Spectrum, Atom, Matter, Mass, Volume, Solid, Liquid, Gas, Molecule, Nonrenewable Energy, Solar Energy, Bioluminescence, Chemiluminescence, Photoluminescence, Conduction, Expansion, Contraction, Electrical Energy, Conductors, Insulators

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

Synopsis: This unit plan will address the sixth grade science topics of waves and light, as well as renewable energy. Students will learn about what makes a wave and about how energy transfers through waves. They will also dive deeper into their understanding of light waves and visible light, as well as the electromagnetic spectrum. They will use their knowledge of light absorption, reflection, and emission to understand how and why things fluoresce. Students and teachers live in a world where they are surrounded by light and fluorescence. From computer screens, to fireflies, to glowsticks, students have all interacted with fluorescence, even if they were unaware. During this unit, students will see the potential for renewable energy systems created from fluorescent materials. Students will finish their unit by creating their own solar cell from natural sources. They will come away from this unit more knowledgeable about light, luminescence and energy, and with more ideas for how to keep our world energy efficient.

I plan to teach this unit during the coming year to 180 students in 6th grade Science.

Introduction

Rationale

I found many of my students were bored learning about waves and light because they could not imagine all the colors they see are just reflections of light and that this small spectrum of what we see is part of a much larger one. I want students to understand light and waves but also create a way to make it memorable. I feel using fluorescence, I can add to two units where students are excited and making creative connections to their learning. Knowing what things are made of and how we see them and why they work the way they do will help students in and out of school. My goal is for this unit to inspire students to shine.

School/ Student Demographics

Carmel Middle School consists of about 1227 students of diverse backgrounds. Geographically, the school is located in an affluent suburban setting of Charlotte, NC in the Charlotte-Mecklenburg School District. The demographics at Carmel are 47% White, 32% Hispanic, 17% Black, and 4% Other. These demographics have been changing in the past three years and class sizes have been getting larger. At Carmel we like to consider our school as, "a slice of Charlotte" since we have such a diverse population and have students from all walks of life. 39.4% of students received 4's and 5's according to the NC Essential Standards for Science on the grade 8 Science EOG[i]. 37.9% of Students across the school are economically disadvantaged according to the Charlotte Mecklenburg School Report for 2019- 2020 school year[ii]. These students as well as all students receive assistance from our fantastic PTSA. They provide materials and resources for classroom teachers and students. My school also has church partnerships that provide books, resources, gift cards, and programs like Friday morning tutoring (once we are able to be in person again) to our students. These students all live in Charlotte, each have their own personal Chromebooks, some with phones and iPads as well that use fluorescent lighting and see fluorescence in places they would never imagine.

I have been teaching at Carmel Middle School for four years and this is my second year in my current position. I teach sixth grade science on a rotating A day B day schedule. I teach the same lesson to six different classes over the course of two days. My students attend my class every other day throughout the school year in seventy-five minute blocks. I teach fifteen classes per week. There is an average of thirty students per class. This unit will be taught to all of my sixth graders, around 185 students. I will teach the mini unit on waves for about three weeks and the mini unit on renewable and nonrenewable energy for about three weeks. Each class will be taught the lessons every other day for six days each, totaling about twelve classes. I will also share the content with my PLC and hope that every student will be able to participate in my curriculum unit.

I teach about half of Carmel's sixth grade population. Based on data from 2018-2019 EOY data we know 48.9% of students entering 6th Grade across the school received a 3,4, or 5 on their reading EGO in fourth grade[iii]. My team consists of many English Language Learners so I will be working with many students who are not native speakers. I also have many students in Extraordinary Children who tend to need assistance and support. As science is heterogeneously grouped at Carmel, I have many ELL students grouped with honors and Academically or Intellectually Gifted students. The 6th grade demographics are similar to the school totals. They consist of 434 students, 48% White, 35% Hispanic, 14% Black, and 3% Other[iv]. Therefore, my classes are a heterogeneous group of students of varying abilities and science backgrounds. I create differentiated activities within the North Carolina State Science Standards to meet the diverse educational needs of my students.

Background

My science curriculum is based on the North Carolina Standard Course of Study with consideration given to the 2009 Science Essential Standards that have been in effect starting during the 2012-2013 school year[v]. I paced my instruction based on the 2020-2021 CMS pacing guide for 6th grade science. Students will be provided opportunities for laboratory investigations this year (online or in person). As a class we will spend time learning to use appropriate tools and techniques to gather, analyze, and interpret data. My class time is typically divided into direct instruction, guided practice or additional investigation, independent practice or group inquiry activity, explanation of results and time to ask additional questions or share ideas. Students are aware of how class is structured online and are aware it will be similar in the classroom as well.

I engage students by including hands-on activities and interactive labs, and/or investigations during most class periods. We will incorporate academic conversations and effective question-stems as a focus in class due to their importance not only throughout Carmel but the district as well. I incorporate the use of a Promethean Board, Zoom, and video clips from Discovery Education, You Tube, and National Geographic on a regular basis. I have access to technology in my virtual and in person classroom for virtual labs and online simulations and students use their Chromebooks every day which they can use for additional research or web activities.

Unit Goals

The goal for this unit is to tie together students' understanding of atoms and molecules with the electromagnetic spectrum and light energy, to eventually create a renewable energy source. Students will touch on their prior knowledge of atoms and molecules. They will be able to see the make-up of different atoms and molecules, especially carbon- based molecules. They will get a peek into double and single bonds and how different combinations of atoms can make molecules with different shapes and different functions.

Students will then move on to learn more about waves, visible light, the electromagnetic spectrum and sight. They will learn the parts of the wave and the different types of waves. They will understand that visible light is a type of wave in the electromagnetic spectrum that can be reflected, absorbed, or emitted.

Some effects of electromagnetic waves include absorption, scattering, and change in temperature. In technology, the change in temperature is a huge determining factor. Students will learn about luminescence which produces energy without producing heat. They will have learned about conduction, contraction and expansion through conductors and insulators. They will be able to apply their knowledge of conduction and insulation to help them see the different materials used for sources of renewable energy. In this unit, students will use examples such as titanium, glass, and electrolytes to create their own dye sensitized solar cells.[vi]

Teachers Guide
Content Research

Before beginning the fluorescence section of the unit, students will need to fully understand how a wave works. Typically we look at transverse and longitudinal waves and point out troughs, crests, wavelength, amplitude, and frequency. Students will understand waves transmit energy and can produce light and sound. Students will learn that things can be "seen" when light waves emitted or reflected by it enter the eye.

We will then learn about the electromagnetic spectrum, or a very small part called *visible light*. Human eyes respond only to this narrow range of wavelengths of electromagnetic waves where the differences of wavelength within that range are perceived as differences of color.

Light is a form of energy emitted by the Sun as well as light-producing objects on Earth. Light can be absorbed or reflected by objects depending upon the properties of the object and the type and angle of light when it hits the object. Some materials scatter light and others allow light rays to pass through, but refract the light by changing its speed. The structure of the human eye can detect many colors in visible light that are reflected by objects.

Then we can go on to talk about the other parts of the electromagnetic spectrum, most importantly here, ultraviolet light. Students will understand that the sun gives us more than just rays from the visible light spectrum, that the sun gives off light we cannot see such as ultraviolet rays.[vii] This is where we can start getting into the subject of fluorescence. Students will understand fluorescence occurs when the absorbed radiation is in the ultraviolet region of the spectrum, and thus invisible to the human eye, while the emitted light is in the visible region. This gives the fluorescent substance a distinct color that can be seen only when exposed to ultraviolet (UV) light. Fluorescence is a member of the universal luminescence family of processes. In this group:

> susceptible molecules emit light from electronically excited states created by either a physical (for example, absorption of light), mechanical (friction), or chemical mechanism. Generation of luminescence through excitation of a molecule by ultraviolet or visible light photons is a phenomenon termed photoluminescence, which is formally divided into two categories, fluorescence and phosphorescence, depending upon the electronic configuration of the excited state and the emission pathway. Fluorescence is the property of some atoms and molecules to absorb light at a particular wavelength and to subsequently emit light of longer wavelength after a brief interval, termed the fluorescence lifetime. The process of phosphorescence occurs in a manner similar to fluorescence, but with a much longer excited state lifetime.[viii]

Students will learn, and toward the end of the unit students will complete a lab, that shows examples of how fluorescence impacts their everyday lives.

One way the students can see fluorescence without UV exposure is through experimenting with temperature and reaction rate. Students will know how chemical reactions work and how temperature can increase the rate of reaction. Raising the temperature results in both more frequent and higher energy collisions. Increasing the temperature of the liquid mixture increases the average kinetic energy of the molecules. “At lower temperatures, there are fewer collisions and most of the collisions that do occur between reactants do not have sufficient energy to form products.”[ix] In a chemiluminescent reaction such as this one, at elevated temperature, the increased reaction rate can be perceived as increased brightness of the light being given off by the light stick. At cold temperatures, the light stick glows less brightly because in a given time period, fewer reactant molecules are colliding with sufficient energy to form the products. In a light stick, there is typically a thin walled-glass ampule containing hydrogen peroxide solution floating in a solution of a phenyl oxalate ester with a fluorescent dye. During the reaction, an "intermediate" is produced which transfers energy to the fluorescent dye molecule. When the dye molecule absorbs energy, the energy is used to raise electrons to an excited state. When the dye molecule returns to the ground state, the excited electrons return to the ground state and energy in the form of light is emitted.[x] Students will know how we see certain wavelengths of light and how ultraviolet light can be emitted and seen under certain circumstances.

The other unit I plan to incorporate fluorescence into is understanding the characteristics of energy transfer and interactions of matter and energy. This is where we explain the suitability of materials for use in technological design based on a response to heat and electrical energy. Students will understand light and other electromagnetic waves can warm objects. How much an object's temperature increases depend on how intense the light striking its surface is, how long the light shines on the object, and how much of the light is absorbed. When light interacts with matter it is either absorbed, transmitted, refracted) and/or reflected (scattered).[xi] Students need to know the difference between renewable and nonrenewable energy as well. Some thermal energy in all materials is transformed into light energy and radiated into the environment by electromagnetic waves; that light energy can be transformed back into thermal energy when the electromagnetic waves strike another material.

In the process of absorbance and fluorescence, light energy put into the processes isn't always used efficiently, some gets lost to the environment. For example, when materials appear red, it absorbs everything and reflects red. When there is no light, there is no light to reflect red. On the other hand, certain colors absorb at one wavelength fluoresce or emit at a lower wavelength. Some materials absorb a certain color of light, for example the blue light, and when it relaxes back to its ground state- it will fluoresce green.

One of the more important aspects is the difference between absorbance, reflection, and emission. Emission is when light get absorbs by a substance, and then is re-emitted as light. When a person sees the color green, they are seeing green light that is not be absorbed, but rather reflected off of a material. For example, fluorescence in fluorescent markers works mainly because the marker absorbs blue light due to their arrangement of atoms. After the electrons are excited, and they relax, the energy does not release as heat, but rather, the energy is released as a photon through fluorescence. It looks yellow because it is absorbing at the blue end of the spectrum and not the yellow end. Another example would be soaking spinach in a solvent (such as ethanol) overnight. Spinach leaves appear green because the leaves absorb blue and red light but not green. Shining UV light on a solution obtained from soaking the leaves will cause it to fluoresce red. You will always see the lowest light being emitted, or in this case, red light.[xii] In an absorbance and emission spectrum, you can see higher energy peak(s) where the energy is absorbed, and lower energy peak(s) where the light is emitted.

There are many different types of fluorescence the students will learn about including bioluminescence, chemiluminescence, photoluminescence, and electroluminescence. All of those processes rely on the fact that basic fluorescence of the excited state of molecules - they differ in the path to get to that excited state. "Fluorescence is one of many forms of luminescence, the emission of light not resulting from heat… All luminescence requires some input of energy to cause the light emission, and the varieties are distinguished by where that energy comes from."[xiii] It is powerful for students to be able to connect the bioluminescence of molecules with the electroluminescence we see on our phone screens. All different forms of luminescence but all producing fluorescent light

Bioluminescence and chemiluminescence are when chemical reactions make the energy. In bioluminescence biochemical reactions occur in living organisms (like fireflies). There are many bioluminescent organisms that produce their own light for mating, prey avoidance, counterillumination, communication, and other purposes. Fireflies are a well-known example on land. Bioluminescence is found very widely in the ocean, both near the surface in plankton, and in many deep-sea creatures.[xiv]

Photoluminescence is when a substance absorbs electromagnetic radiation or photons. Photons are "the smallest discrete amount or quantum of electromagnetic radiation. [They are] the basic unit of all light."[xv] This group consists of fluorescence or the "rapid (nanoseconds) emission of photons as electrons jump from excited state to ground level" and phosphorescence or the "delayed (milliseconds to hours) emission of photons that have been trapped in a 'forbidden' state."[xvi] Glow in the dark materials such as the stickers on the ceilings in children's' rooms are an example of phosphorescence, absorbing energy while they are exposed to light and releasing it over time.

Electroluminescence is when an electric current passing through a substance makes the electrons go into an excited state and emit light. Light-emitting diodes (LEDs) work by electroluminescence, with a current passing through a semiconductor material. LEDs use inorganic semiconductors and are around 10^{-3}m in size. Organic LEDs are an even thinner version that use molecular semiconductors. They are around 10^{-9}m or 0.000000005 m[xvii].

Traditional lightbulbs work through incandescence, which is light emitted by a substance as a result of heating. On the other hand, fluorescent lights work through a combination of electroluminescence and fluorescence as follows:

> When you turn the light on, electrical current flows through the electrodes. The voltage causes electrons to move through the argon gas to the other side of the tube. The energy from this transition causes mercury to turn from a liquid into a gas. Electrons and charged atoms collide with the gaseous mercury atoms. The collisions increase the electrons' energy levels. As electrons return to their normal energy level, energy is released as photons, creating invisible-spectrum light that the human eye can't see. The phosphor powder in the glass tube interacts with the invisible-spectrum light, producing white light that the human eye can see.[xviii]

Most lights are fluorescent now because this method is more efficient. More energy is converted into light than heat compared to the incandescent lights.

Finally, students will have learned about how energy is transferred and different materials that are better at conducting and insulating, for example metals and plastics. They will understand that certain materials that are good for the environment in general can produce waste that can detriment the environment overall. Students will read about solar energy and understand solar power cells can create a lot of toxic waste in the end. Plants naturally produce energy through sunlight in photosynthesis. The goal of a solar cell is to mimic this process to produce electrical energy. Although solar cells have been around for a long time, their use for energy generation is not widespread. This is because traditional solar cells are expensive and inefficient. Students will learn about creating a solar cell using blackberries, chlorophyll, pomegranate seeds, beets and others. Blackberries contain a strongly light-absorbing dye molecule called anthocyanin, which occurs in many types of fruits and berries. And the more light that the device are able to absorb, the more energy they can produce. In this experiment the students will make a dye-sensitized solar cell that is efficient, uses safe materials and is inexpensive. It will help students see how solar cells can be used in the future and help keep the Earth clean.

Instructional Implementation

Students will learn about ways they are able to view light and fluorescence all around them. Students can connect their learning to many different subjects. For example in math, students will be interpreting and analyzing graphs and data throughout the unit. In Language Arts they will be reading and annotating different articles from primary sources from important figures and experts in the field. Students will see the importance of light and color over different points in history, such as the through dies and therefore trade and economy. Finally, students will also understand the importance of light, color, and glow in art media and technology. Students will be able to understand the science behind many of the things they see every day.

Teaching Strategies

This unit will be very student focused. Strategies such as turn and talk and warmups will be used almost every lesson. Students will participate in academic conversation, jigsaws, as well as hands on group labs and activities. Some activities we are doing in this unit include brain dumps, KWLQ Chart which is just like a KWL chart but allows students to write down any questions they still have, and a 3 circle Venn-diagram to compare and contrast three topics.

Lessons/ Activities

Lesson 1: Intro to Waves

Warm Up: Brain dump on waves- have students list everything they think of when they think of waves

1. As a class, watch "Bill Nye Waves"[xix]
    a. Students will understand that waves transfer energy not matter, they will also see how waves travel through different mediums.
2. Students will they will take notes on the two types of waves- transverse and longitudinal- and write examples.
3. Students will also write the definitions of wavelength, frequency, amplitude, crest and trough in their glossaries.

Exit Ticket: Students will label a transverse wave[xx]

Lesson 2: What is Light?

Warm Up: Students will complete the "Know" and "Want to Know" sections of a KWLQ Chart about the subject of "Light"[xxi]

1. Watch Ted Ed "Light waves, visible and invisible"[xxii] video as a class. Fill in new things they learned in the "Learn" section and any questions they have in the "Questions" section. Have students turn and talk with a partner to discuss new things they learned.
2. Students will read Ducksters "Science of Light" with a partner and complete their KWLQ charts.[xxiii]

3. Each group will share out the information they learned that they consider the most relevant and the teacher will keep a class list. If needed- to start the class off: "Light waves do not need a medium. They do not need matter to transmit energy."

Exit Ticket: Ducksters 10 Question Check for Understanding[xxiv]

Lesson 3: What is the Electromagnetic Spectrum?

Warm Up: Review Waves Vocabulary with a Quizlet

1. Students will learn the different parts of the electromagnetic spectrum by reading and annotating the "Waves of the Electromagnetic Spectrum" article.[xxv]
    a. From this article students will be able to identify the size of the wavelengths in specific areas of the spectrum and recognize examples of the different types of waves and understand that although we cannot see all the different waves moving around in our atmosphere there is a very select region that we are able to see called visible light. Students will know that Ultra Violet light is not visible with the human eye.
2. Students will work independently to complete the questions at the end of their reading.[xxvi]

Exit Ticket: As a class students will label and color their own electromagnetic spectrum[xxvii] (APPENDIX)

Lesson 4: Reflection, Absorption, Transmission, and Refraction

Warm Up: List the seven types of electromagnetic waves and an example for each

1. As a class make a foldable for reflection, absorption, transmission, scattering, and refraction, which must have the definition, a picture of what this phenomenon looks like, and an example.[xxviii]
2. Watch "Light Absorption, Reflection, and Transmission" video and fill in those areas of the foldable.[xxix]
3. Watch "Understanding Refraction" video and fill in foldable.[xxx]
4. Watch "Why Is the Sky Blue?" to fill in the final section "Scattering."[xxxi]

Exit Ticket: Write a paragraph (at least six sentences) summarizing what you learned today.

Lesson 5: How Do Eyes Work?

Warm Up: As a class watch the Brain Pop "Eyes" and answer the Quiz questions[xxxii]

1. With a partner explore Ducksters "Sight and the Eye" and answer the quiz questions.[xxxiii]
2. Label eye diagram.[xxxiv]
3. Write a paragraph (minimum of 4 sentences) on how we see.

Exit Ticket: Compare and contrast the electromagnetic spectrum, visible light, and sight using a three circle Venn Diagram.[xxxv] Discuss with the class.

Lesson 6: What is Energy?

Warm Up: List as many sources of energy as you can. (Students know energy is the ability to do work and that energy cannot be created or destroyed.)

1. Renewable vs. Nonrenewable energy Notes
    a. Renewable energy: -natural energy which does not have a limited supply.
       -can be used again and again, and will never run out.
       Examples include: tidal, wave, wind, wood, biomass, hydro-electric, geothermal, and solar
    b. Non-renewable energy: -an energy resource that is not replaced or is replaced only very slowly by natural processes

-Fossil fuels are continually produced by the decay of plant and animal matter, but the rate of their production is extremely slow, very much slower than the rate at which we use them.

Examples include: coal, oil, nuclear, natural gas, tar sands and oil shale

2. Popcorn Non-renewable/ Renewable Activity.[xxxvi]

Exit Ticket: Choose one of the following and respond in a paragraph (at least four sentences)-

a. What could be some effects of population growth, natural disasters, disease, and advanced technology systems on resource availability?
b. What are some advantages and disadvantages of using renewable resources in place of non-renewable resources?

Lesson 7: Fluorescence

Warm Up: Students will write the definition of emission at the top of their notes for the day. According to the Encyclopedia Britannica, emission is when "an electron of relatively high energy may jump to a condition of lower energy, giving off the energy difference as electromagnetic radiation."[xxxvii]

1. Students will be broken up into six groups to research their type of luminescence (bioluminescence, chemiluminescence, and photoluminescence)
2. As a class we will read "The phenomenon of luminescence" section together.[xxxviii]
3. Then in their groups students will research their form of luminescence using their section of the reading and complete their luminescence sheet.[xxxix] They will become an expert on their type of luminescence.
4. After researching and filling out their sheets, groups will "jigsaw" to contain one person from each different group. Each expert will explain their luminescence while everyone else fills out their chart. This continues and as each person shares all the students receive information about all the different examples.

Exit Ticket: Create a poster containing types of luminescence discussed today. Include a title, definitions, drawings, examples and color.

Lesson 8: Blackberry Lab

Warm Up: The teacher will improve students molecular literacy by introducing the concept of molecules as a unique assembly of atoms where often times this assembly is just composed of carbon, hydrogen, and oxygen. Using Avogadro the teacher can show students different structures and makeup of molecules such as water (H_2O), carbon dioxide (CO_2), and sugar ($C_6H_{12}O_6$).[xl] Just like making a cake versus making pancakes, we use the same "ingredients" but get very different results, the same happens with these different carbon atoms.

1. In groups, students will read the Background Information before starting the lab.[xli]
2. As a class we will discuss the answers to the 5 "Recap questions."[xlii]
3. In groups, students will go through the lab Step by Step eventually creating their own dye sensitized solar cell.[xliii]
4. Class discussion

Exit Ticket/ Assessment: Clean up station. Write two paragraphs (at least four sentences each) about this lab. In the first paragraph explain what you did and what you learned from this experiment. In the second paragraph explain how this relates to energy, light, and luminescence.

Assessments

Students will be assessed informally every day through warm ups and exit tickets. Students will complete the Blackberry Lab and analyze their learning as a formal grade at the end of the unit.

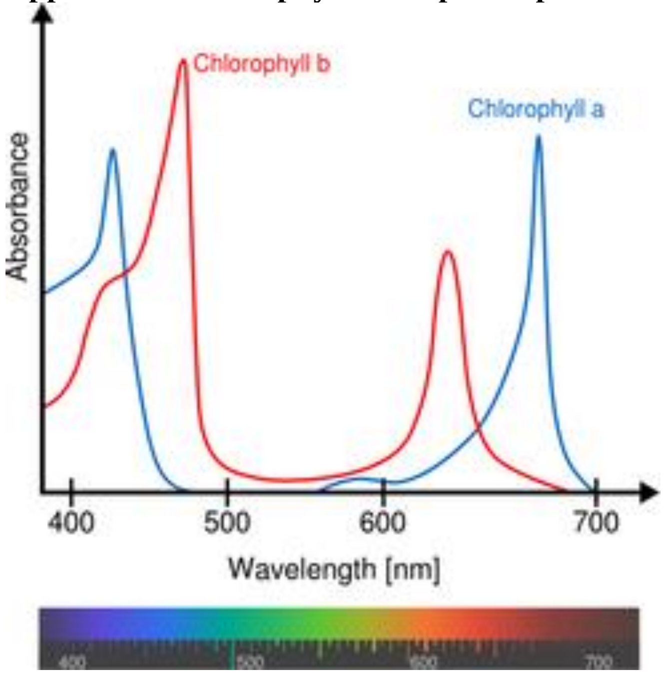
Differentiation

Work will be differentiated in several different ways. Students will receive text engineered articles which will scaffold long articles and allow them to chunk text and better understand what they are reading. In many of their readings they will have guiding questions throughout to keep track of the new information they are receiving. Students will be grouped selectively for certain assignments to be sure all learners can contribute to class discussion and feel pride in their work. Students will also work in groups or with partners so they will have their classmates as assets. Students will also have the resources of their glossaries. Students keep a glossary in the back of their notebooks with important vocabulary and will update them throughout the unit. This will be a reference for difficult texts. During guided notes and activities with written work, I will provide students with a solution station so they do not miss important information.

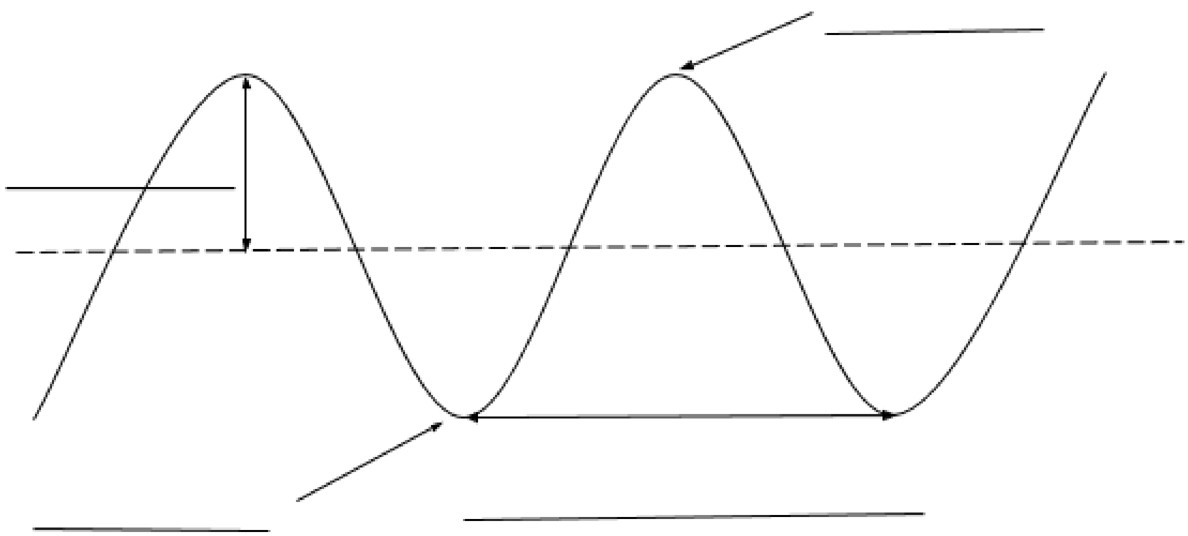
Appendix 1: Implementing Teaching Standards

6.P.1.1 Compare the properties of waves to the wavelike property of energy in earthquakes, light and sound. Students will be able to understand the different parts of the wave and how light waves transfer light energy.
6.P.1.2 Explain the relationship among visible light, the electromagnetic spectrum, and sight. Students will understand the importance of the electromagnetic spectrum and how different wavelengths yield different type of waves and different colors of visible light.
6.P.2.1 Recognize that all matter is made up of atoms and atoms of the same element are all alike, but are different from the atoms of other elements. Students will dive into the makeup of different chemicals and naturally occurring substances to gain a deeper understanding of atoms and molecules.
6.P.3.2 Explain the effects of electromagnetic waves on various materials to include absorption, scattering, and change in temperature. Students will understand that different materials can absorb, emit, and reflect light waves. They will use this knowledge to understand the concepts of fluorescence.
6.P.3.3 Explain the suitability of materials for use in technological design based on a response to heat (to include conduction, expansion, and contraction) and electrical energy (conductors and insulators). Students will build their own solar energy cells to better understand conduction. They will need to use specific materials and certain chemicals to produce energy.

Appendix 2: Chlorophyll Absorption Spectrum



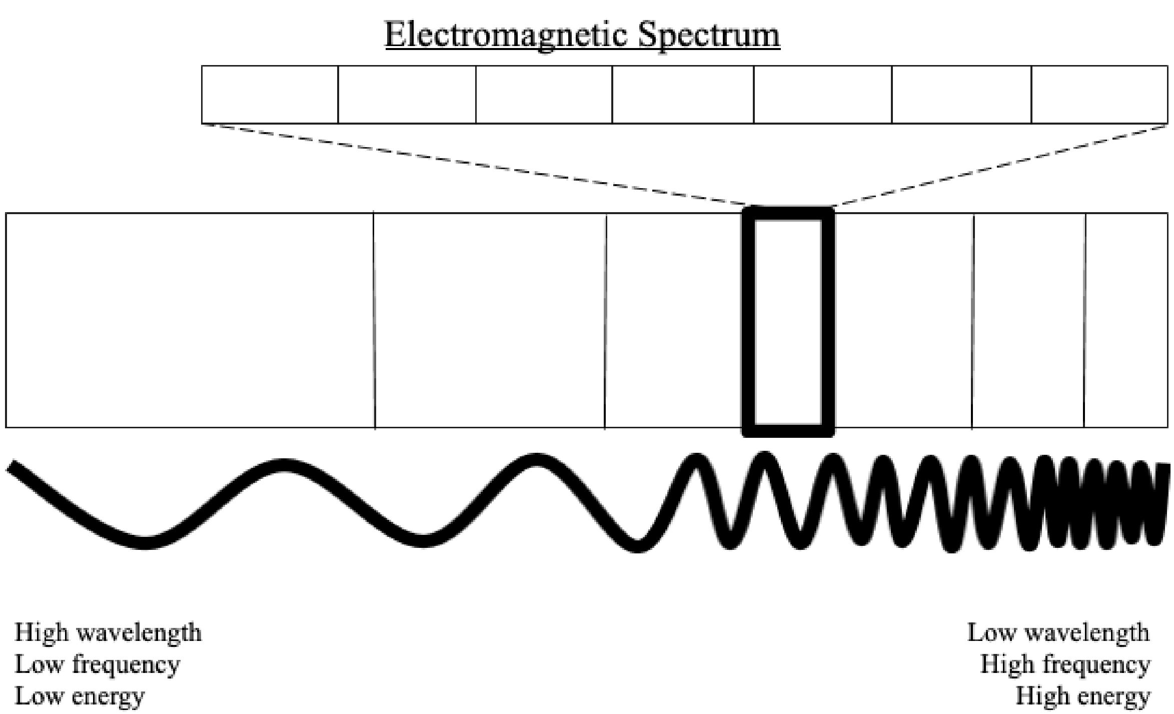
Appendix 3: Parts of a Transverse Wave



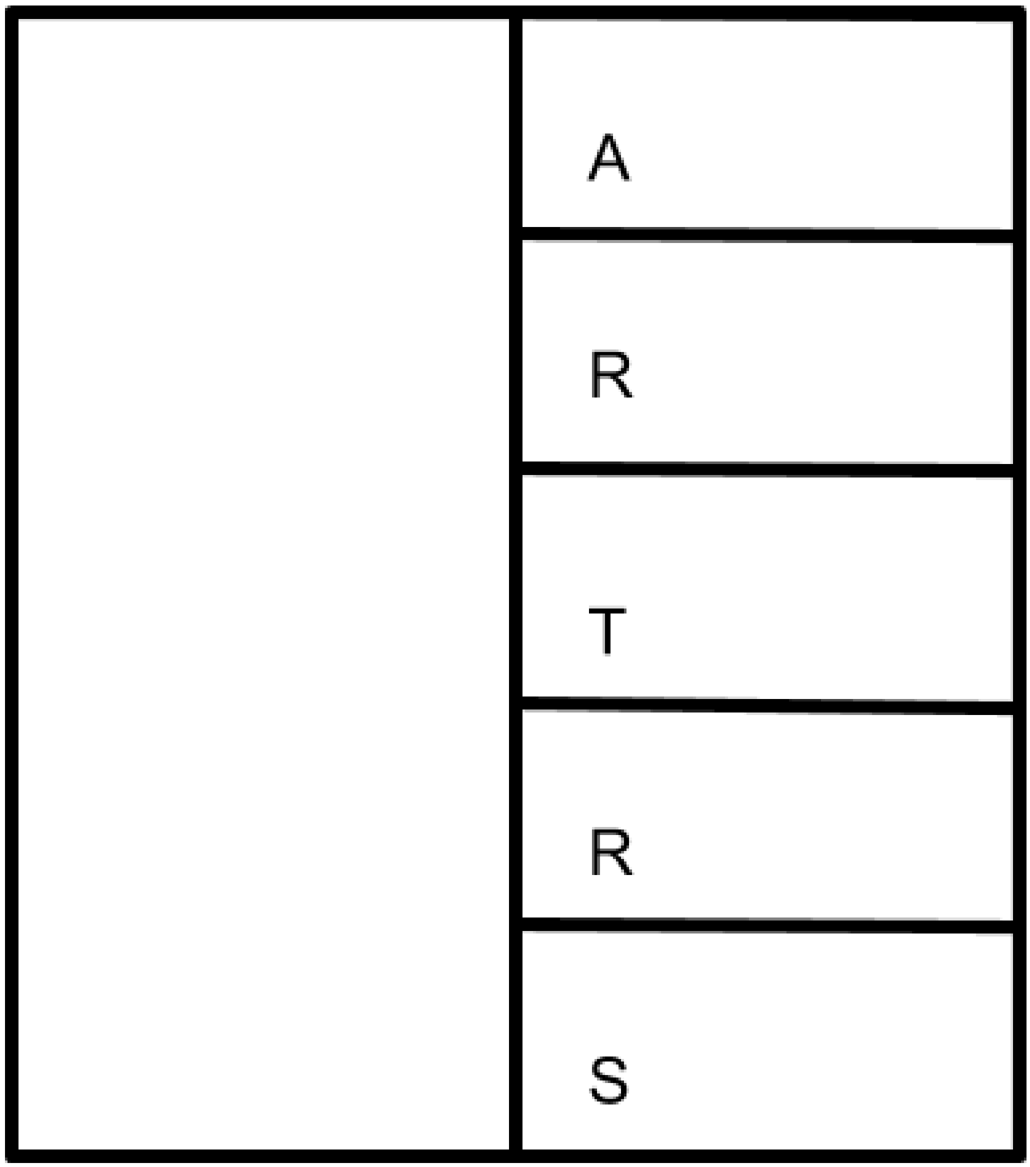
Appendix 4: KWLQ Chart

K	W	L	Q
What do I Know?	What do I Want to know?	What have I Learned?	What Questions do I still have?

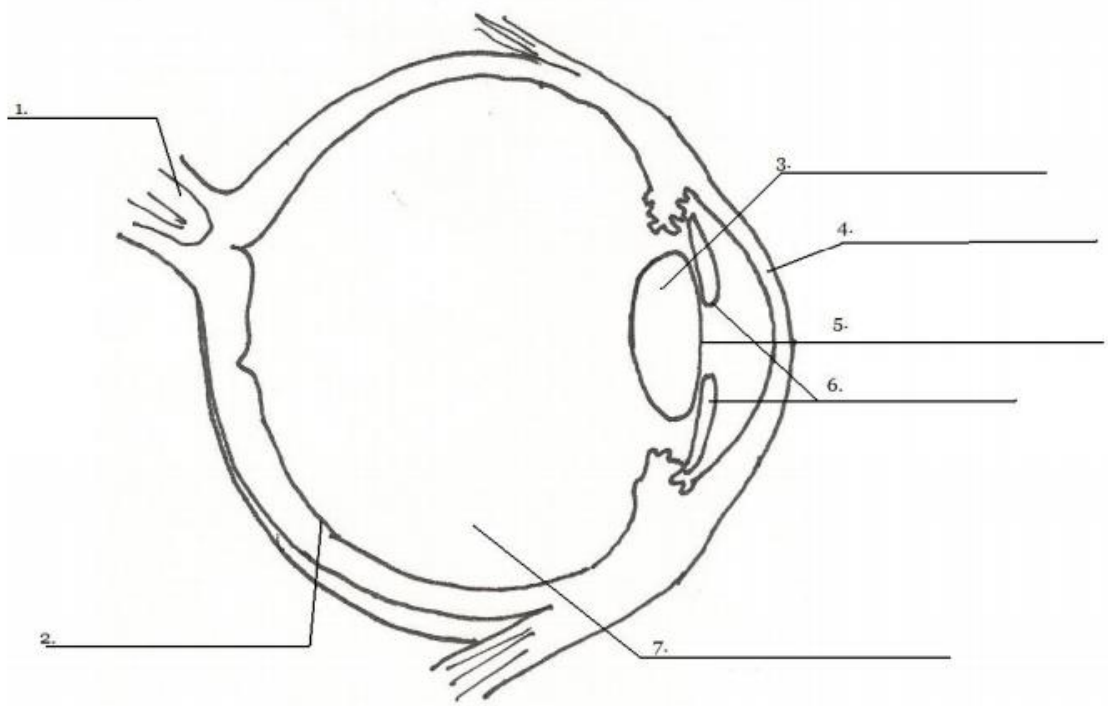
Appendix 5: Electromagnetic Spectrum



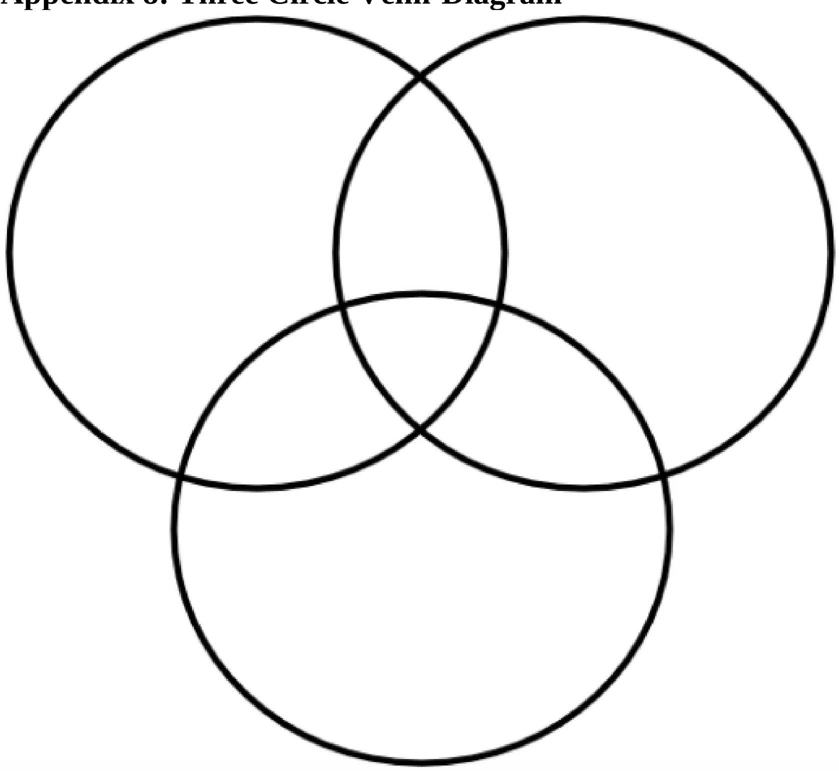
Appendix 6: Example Reflection/Absorption/ Transmission/ Refraction/ Scattering Foldable



Appendix 7: Eye Diagram



Appendix 8: Three Circle Venn-Diagram



Appendix 9: Popcorn Energy Activity

Activity Preparation
The class will be divided into groups of 4.
Each group will need a bag with 16 pieces of popcorn, 4 paper towels, and a pencil and paper.
Teacher will need the bag with leftover popcorn to replenish the "used resources."

Part 1: Renewable Resources Activity

1. Each team begins with 16 pieces of popcorn. Each student must take at least 1 piece of popcorn per round to survive, and may take as many as he/she likes.
2. One student per team records the number of pieces each team member takes per round, and the number of pieces remaining for the team.
3. The resource is then "renewed" by half (if there are 8 remaining pieces after round 1, the teacher will add 4 more pieces to the bag for round 2).
4. 6 rounds are played in this manner. The object of the game is to have the most pieces of popcorn per team member after the final round.

At the end of the game, discuss different strategies used by teams:

- Some may die because they'll consume too much of the resource early on
- Others may take one piece at a time and build up a store by the end
- Others may take more throughout but will always keep enough in reserve to be sufficiently renewed

Part 2: Non-Renewable Resources Activity

1. Students each pick up a slip of paper from a bag (there are about 10% "1st generation", about 15% "2nd generation", 25% "3rd generation," and 50% "4th generation" slips – numbers will depend on how many students are in class)
2. Teacher goes to the front of the classroom with a bag of popcorn, and leads a brief discussion of what it means when one generation finds a resource and how future generations are affected by it.
3. 1st generation students then come up and take as much popcorn as they want back to their seats. 2nd generation students then do the same, followed by 3rd and 4th generations.

Teacher and students should then discuss:

- how the students acted in "using" the resource
- any waste that occurred (popcorn dropped on the floor)
- whether any thought was given to students coming afterwards
- if there were protests from other students
- the degraded quality of popcorn towards the end (everyone's hands were in it before, and it's been crushed into smaller, less desirable pieces.

Appendix 10: Luminescence Jigsaw

Name ______________________________ Date______________

Luminescence Jigsaw

Topic: Luminescence

Reading assignments for Jigsaw: "Luminescence in Nature and in the Education"
1. Photoluminescence
2. Chemiluminescence
3. Bioluminescence

My notes for assigned selection # ___

Main Idea 1:

Supporting Detail A:

Supporting Detail B:

Supporting Detail C:

Main Idea 2:

Supporting Detail D:

Supporting Detail E:

Supporting Detail F:

Other important information:

Important Terms and Definitions:

Term 1:

Term 2:

Notes from Group# _____:
Topic: ___________________

Notes from Group# _____:
Topic: ___________________

Materials List

For the lab: 1x1" FTO glasses, small Ziploc bags, blackberries- fresh or frozen, plastic pipettes, tweezers, paper towels, multimeter alligator clips, golf pencils, 1" Binder clips, water cups/beakers, TiO_2 paste, iodide/triiodide electrolyte, scotch tape, hotplate (one or two for whole class)

Student Resources

YouTube, Khan Academy, Ducksters, Quizlet, Quizizz, DiscoveryEd, BrainPop

Teacher Resources

Canvas, YouTube, Khan Academy, Ducksters, Quizlet, Quizizz, DiscoveryEd, BrainPop, EdPuzzle, PearDeck

Notes

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