Glow in the Dark: Bioluminescence in the Animal and Human World

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

Keywords: animals, adaptations, bioluminescence, biomimicry, communication, counter-illumination, aposematism, enzymes

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

Synopsis: This unit will begin an exploration of animals and the adaptations they use to survive, specifically bioluminescence. Students will learn about animals that use bioluminescence and how it is used (communication, aposematism, counter-illumination, aggressive mimicry). Students will begin by studying various types of animals that employ bioluminescence. They will analyze the purpose of bioluminescence in each animal in their environment. The class will then learn about the concept of biomimicry. Students will then use light to create a device for communication across a distance inspired from nature.

I plan to teach this unit during the coming year to 16 first grade students in Science and Literacy in the Spring of 2021. *This unit will be shared with the other grade level appropriate teachers at my school. I would like the opportunity to teach each class the lab activity in our school science lab if possible.*

Glow in the Dark: Bioluminescence in the Animal and Human World

Elizabeth Kerr

Introduction

As a teacher of young elementary students, I realized early on the best way to excite students about reading was to integrate reading strategies with science instruction. Nothing excites students more than discovering their world and science experiments. I find those qualities mirrored in my own experiences as an adult learner.

This particular topic interested me because of its STEAM (science, technology, engineering, math and art) applications. The district that I teach in has also made a move toward more STEM/STEAM integrated learning. Bioluminescence is a concept that works well with state and national standards, as well as topics in the mandated curriculum.

In my experience, all students love to learn about animals. Animals that use bioluminescence are particularly interesting. These animals are not the most beautiful, but they create some beautiful images. Their use of light in their environment is key to their survival and that is even more interesting (especially to a seven-year-old).

Rationale

Bioluminescence is a tool employed by many animal species, mostly marine species, but including bacteria and fungi. In each species, bioluminescence serves a different purpose, which may include: aposematism, counter-illumination, communication, aggressive mimicry, defense, deception and reproduction. These species create their bioluminescence in different ways, from having a symbiotic relationship with bioluminescent bacteria to having photophores strategically placed on their bodies. In each instance, the use of bioluminescence is critical to the animal's survival.

In this first-grade specific unit, students will learn about the uses of bioluminescence in nature and analyze its uses. This meets North Carolina Essential Science Standards 1.L.1 and 1.L.2 with living organisms. Throughout this unit, students will be participating in writing activities, reading supporting texts and participating in hands-on lab activities.

Students will participate in a study of nonfiction text and text features. Students will learn about text features and their purpose. Students will then use text features and informative writing strategies to present their final projects: a device using light to communicate over a long distance.

School Demographics

Bain Elementary School is in the Charlotte-Mecklenburg School System. This system is one of the largest in North Carolina, serving approximately 146,000 students. Bain Elementary, located in the district's Southeastern Learning Community, serves

approximately 928 students in grades Kindergarten through Fifth, the fourth largest elementary school in the district. Approximately 64% of the student body is Caucasian, approximately 15% African-American with approximately 20% of students as Hispanic, Asian, Pacific-Islander and other races.

According to the 2017-2018 NC Schools Report Card for Bain Elementary, approximately 21% of students are economically disadvantaged. The school received an "A" grade in math with growth met and a "B" grade in reading with growth exceeded.[1]

I currently teach in a first grade classroom with 16 students. This unit will be an integrated literacy and science unit and taught in the spring. Standards are based on the NC ELA standards, NC Social Studies and NC Science Standards. This unit will teach students to follow the scientific process and to think about literature critically.

Content

Bioluminescence has been observed in nature as early as 500 B. C. by the Greek philosopher Anaximenes. He noticed the light coming from the sea when he hit the water with his oar.[2] Aristotle also wrote about this phenomenon in *De Anima:*

> "Not everything is visible in light, but only the colour proper to each thing; for some things are not seen in the light but bring about perception in the dark, e.g. those things which appear fiery and shining (and there is no one name for them), such as fungus, horn, the heads, scales, and eyes of fish; but in none of these is the proper colour seen."[3]

Here Aristotle is noting that some animals make themselves known at night by shining or glowing. Even in ancient times, these philosophers made careful observations of their environment and saw something fascinating.

Bioluminescence ("bio" meaning life or living; "luminescence" meaning light)[4] is a fascinating idea to young children. Seeing fireflies in the summer evening is a prime example. Fireflies are easily observable and are a great way to begin this conversation.

Bioluminescence occurs in mainly in protists, bacteria, fungi, insects, marine invertebrates and fish. It has not been discovered in birds, mammals, amphibians, reptiles and true plants.[5] This can happen either through a hormonal response, such as what occurs in the velvet belly lanternshark,[6] or through symbiosis, such as the relationship between bioluminescent bacteria and the anglerfish.[7]

What is present in every bioluminescent organism are three ingredients: luciferin, luciferase and oxygen. Luciferin ("lucifer" meaning "bringer of light") may have a strange name, but it includes any chemical compound that can emit light. Some animals can produce this chemical themselves and others have to take it in from their environment.[8]

Luciferase is an enzyme that combines luciferin with oxygen. Oxygen is the element that begins this chemical reaction. Sometimes another chemical, or co-factor, is needed. Fireflies need ATP (adenosine triphosphate).[9] Lanternsharks use melatonin.[10]

Amazingly, bioluminescence is virtually one-hundred per cent efficient. An average incandescent light bulb can give off up to ninety per cent heat and ten per cent light. Bioluminescence produces almost one-hundred per cent light and no heat. Therefore, bioluminescence is often called "cold light." Even more interesting is that tiny dinoflagellates can generate about 1,010 photons per second. Photons are units of measure for emitted light. That is why when millions of these organisms are packed together in a body of water, it can be so bright.[11]

Bioluminescence in Action

Aposematism (ap·o·sem·a·tism)

- the use of a signal and especially a visual signal of conspicuous markings or bright colors by an animal to warn predators that it is toxic or distasteful **:** WARNING COLORATION[12]

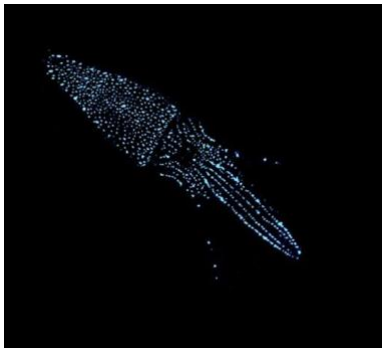
Some species use bioluminescence as a warning sign to other species. This is very prominent in glow-worms. Studies have been conducted that show toads learn to avoid luminescent species of glow-worms. Results showed that toads would stay away from the bioluminescent glow-worms and eat the non-luminescent meal worms.[13]

Another study on the concept shows that members of the milliepede family *Motyxia* emit a greenish-blue light at night to discourage their predators. This millipede generates cyanide through its pores, which of course is very dangerous. Members of this family are also proven to be blind, so their bioluminescence would serve no purpose in communication.[14]

Counter-Illumination

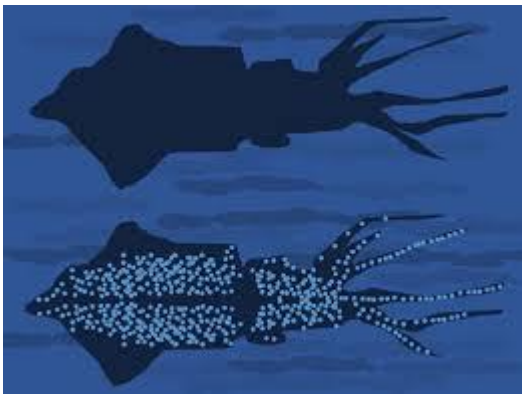
- (biology) A behaviour, found in some cephalopods etc., in which bioluminescence is used to provide camouflage when viewed from below.

Many marine species use bioluminescence to counter-illuminate. These animals often have their lower sides covered with photophores. This is to match the light that is coming down through the water above. When done correctly, the animal can appear to be invisible.[15]



*E. Widder, ORCA, **www.teamorca.org***

This midwater squid, Abralia veranyi, is native to the Atlantic Ocean. It participates in a daily vertical migration. During the day, the squid swims deeper into the water to hide from predators such as birds, salmon and tuna. In the evening, the squid moves to more shallow water and uses its counter-illumination technique to both hide from predators and seek its own prey.[16]

 [17]

These firefly squid are native to the western Pacific Ocean. They also participate in the massive daily migration that takes places in our oceans every day. Firefly squid spend their days in deeper waters and the nights in more shallow waters, using their bioluminescence to both hide them from predators and attract other prey.[18]

Communication

It would be impossible to write about bioluminescence and not mention fireflies. Fireflies use their bioluminescence to communicate for mating purposes and to warn off predators. But be careful, some female fireflies use their flashes to lure in a male insects and eat them!

Fireflies produce a chemical reaction to create their bioluminescence. When luciferin with luciferase comes into contact with oxygen, adenosine triphosphate and calcium, light is produced. This is also a good example of how efficient bioluminescence is. If this reaction produced that much heat, the firefly would not survive.[19]

Male fireflies flash a signal, trying to attract a female. Then, when a female chooses to respond she flashes her own pattern back to the male. The fireflies will continue communicating in this fashion until they mate.[20] Scientists have learned that fireflies that are more flashy and have a little more "bling" are more attractive to the females (their flash is brighter and longer).[21]

In two sub-species of fireflies, *Photinus* and *Photuris*, the females mimic the flashing pattern of the males. Once the male is caught, the female ingests it. The males produce a toxin that protects the females and their offspring from predators. The female is able to pass the toxins, or lucibufagins, through her blood to her offspring. Predators who capture the firefly will find a bitter nasty treat waiting for them![22]

Aggressive Mimicry

- A form of mimicry in which a predator (the mimic) closely resembles another organism (the model) that is attractive to a third organism (the dupe) on which the mimic preys. The anglerfish is an example of aggressive mimicry, having a modified dorsal spine that mimics a worm or small shrimp and serves as a lure to attract its prey. [23]

One of the more popular species that uses bioluminescence as a way to lure in prey is the anglerfish. The anglerfish resides in the Midnight Zone of the ocean. The **esca**, the fleshy growth that protrudes from a pointy spine at the end of its dorsal fin, acts as a lure to prey in deep, dark ocean. The esca actually cultures bacteria that cause the luminescence. The method of how the anglerfish controls the light is still unknown, however, it is effective at drawing in dinner. Other adaptations enable the anglerfish fish to consume prey up to two times its size. What is the most interesting, though, is that only the female anglerfish use this lure. [24]

25

Another newly discovered species that scientists think may use bioluminescence to lure prey is the pocket shark. Only two pocket sharks have been discovered ever. The latest discovery was made in the Gulf of Mexico in 2010 (species was identified in July 2019). The pocket shark is so named due to the glands, or "pockets," above its pectoral fins. These glands house bioluminescent liquid that scientists think the shark may shoot out to attract prey. No one has ever seen a pocket shark eat, so this is all speculation.[26]

Photo by Tulane Researcher Michael Doosey[27]

Defense and Deception

One animal that uses its bioluminescence as its escape plan is the Green Bomber worm (Swima bombiviridis). This species of sea worm, discovered August 20, 2009, was found in the Pacific Ocean off the coasts of California and Oregon. This worm has sacs filled with bioluminescent fluid that scientists posit are dropped when the worm senses danger. The "bombs" draw the predator's attention away from the worm, allowing it to escape.

S. H. D. Haddock/MBARI[28]

Another deep sea animal that uses its bioluminescence to distract predators is the *Acanthephyra purpurea*, or deep sea shrimp. This shrimp emits a luminescent blue cloud in the presence of predators. This cloud, scientists think, serves to distract or confuse predators. When looking at pictures, it does look like the shrimp is vomiting at its predators. Luckily for them, scientists do know that the cloud it not the shrimp's stomach contents. Much is still unknown about this shrimp, such as how the cloud is produced and if the luminescent material comes from what the shrimp eats or not. However, one thing remains the same. Luciferin is involved. When the luciferin interacts with the oxygen in the water, we have a blue glowing cloud and a way to escape.[29]

Reproduction

Animals are not the only things that glow in the dark. Some types of mushrooms do too. There are actually over 80 species of bioluminescent mushrooms on Earth. These mushrooms produce luciferins, which when met with luciferase and oxygen, glow. Note these are same compounds found in other bioluminescent animal species.[30]

Scientists think the mushrooms glow to help with their reproduction. The glowing fungi attracts swarms of insects, which help to spread their spores to different areas. This in turn helps to create more mushrooms.[31]

 [32]

Glowing Genetics

I had previously stated that bioluminescence has yet to be observed in true plants and mammals. However, amazing things are happening with genetic engineering. Plants are being crossbred with bioluminescent fungi DNA and mammals are injected with Green Fluorescent Protein (GFP) that enables cells to glow.

Researchers at MIT are trying to create plants to replace indoor and outdoor lighting. Prior to this experiment, scientists were able to create glowing tobacco plants. Now, using the MIT method, scientists were able to reproduce these results in arugula, kale, watercress and spinach. Imagine, pulling a plant over when you want to read at night instead of flipping a switch.[33]

GFP is a protein found in North American jellyfish. This protein absorbs blue light, then is able to emit green light. Osamu Shimomura was able to extract the genes with the directions for making GFP in the 1960's. Scientists later were able to introduce the gene into other species, making certain parts of their bodies glow. This has opened the door for studies in cellular development.[34]

Where genetic engineering and bioluminescence will lead in the future? The possibilities are endless. That is why using the techniques of biomimicry are so important. Studying nature is a great way to find solutions to problems we are facing now. These species have had to survive some pretty incredible obstacles. Why wouldn't we refer to them for our solutions now?

Biomimicry

- the imitation of natural biological designs or processes in engineering or invention **:** BIOMIMETICS[35]

The advances made with genetic engineering show that bioluminescence can help us solve real world problems. Biomimicry is just this field of study. Let's ask our students to think like engineers and use what they have learned to just that.

The Next Generation Science Standards for First Grade is already encouraging students to explore this idea to create a communications device:

> **1-PS4-4 Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.[36]**

This standard makes studying the communication aspect of bioluminescence applicable to the real world. What can students learn from studying species that use bioluminescence to communicate? How can they use that information to solve this problem? That is what I hope to find out.

Begin with the End in Mind: Goals and Outcomes

While teaching this unit, students will:

- compare and analyze how different species use bioluminescence
- research species that use bioluminescence for communication
- read nonfiction texts to research bioluminescent species
- read nonfiction texts on biomimicry
- create a design using recyclable items to communicate across a long distance.

After teaching this unit, students should be able to:

- explain the purpose of bioluminescence (how it helps the animal to survive)
- explain the purpose of text features in non-fiction texts
- create an informative presentation to explain their engineering design.

The Plan: Instructional Implementation

Materials needed to implement this unit are:

- *Glow in the Dark Creatures* by Natalie Hyde (available for free for educators on Epic! Online Library)
- *Glow-in-the-Dark Animals* by Natalie Lunis (available for free for educators on Epic! Online Library)
- *Fireflies* by Christina Leaf (available for free for educators on Epic! Online Library)
- *Glowworms Are Not Worms!* by Daisy Allyn (available for free for educators on Epic! Online Library)
- *Fireflies* by Emily K. Green (available for free for educators on Epic! Online Library)
- chart paper
- student science journals
- baking soda
- vinegar
- flasks or cups used to observe baking soda and vinegar reactions
- balloons
- cards with light patterns (2 cards should match as a set, located in Appendix 2)
- flashlights

- cellophane film, various colors
- empty water bottles
- glow sticks
- googly eyes
- die cut shark (or other animal) shapes out of construction paper
- newspapers or other printed papers
- cardboard for use in final project (i.e. recycled boxes)

Day One, Introduction to Unit

Tell students they are getting ready to study a special group of animals that have a very special ability. These animals are able to create their own light! Introduce the term "bioluminescence" and define it with students, breaking it down into parts (bio – life, luminescence – light). Make an anchor chart with students with bioluminescence at the top.

Read the introduction of *Glow-in-the-Dark Creatures* by Natalie Hyde.

Use the familiar example of fireflies. Ask for other examples that students may already know. Explain that fireflies use a chemical reaction to create their light. Fireflies use some different ingredients to create their light. When the ingredients are mixed properly, fireflies make their own light.

Next, we will work to model a chemical reaction. Show students baking soda and vinegar and explain what each part is. Note that nothing is happening to each ingredient right now. However, the students will need to watch what is happening when the two are mixed. Model the experiment and have students take notes. With the balloon on top of the flask, the students should see that the chemical reaction gives off gas. Each ingredient can no longer be separated. The same reaction occurs with luciferin, luciferase and oxygen only light is given off instead.

Have students draw a diagram in their journals of the experiment, labeling each part and the result of the experiment. Review activities from today.

Use Exit Ticket in Appendix 2 to gauge students' understanding.

Day 2, Bioluminescence to Communicate

Revisit your definition of bioluminescence and chemical reactions. Today, the focus will be on using bioluminescence to communicate.

Read *Fireflies* by Christina Leaf. Discuss how fireflies use bioluminescence. Have student look carefully at book. Begin pointing out text features seen in book. Record on an anchor chart. Be sure to describe the purpose of each text feature.

Tell students that they are going to pretend to be fireflies. Pass out cards with light patterns, making sure that students are paired up. Give each student a flashlight. Students should

practice making the pattern on their card with flashlight (long flashes, short flashes). After students practice using the flashlights, they will move around the classroom looking for the student that is flashing the same pattern they are. If they think they have found their partner, they can check each other's card. You will probably only be able to let half of the class go at a time.

At the conclusion of the experiment, call students together to discuss experiment. Was it difficult or easy?

Have students write a reflection in their science journals.

Use the Day 2 Exit Ticket in Appendix 2 to gauge students' understanding.

Day 3, Bioluminescence as a Lure

Review previous concepts, including text features. Today, students are going to learn about an animal that uses bioluminescence as a trap for prey.

Read *Glowworms Are Not Worms!* by Daisy Allyn. Be sure to discuss the text features present in the story (see sample anchor chart in Appendix 3).

Discuss with students why glowworms glow (as a way to attract prey). Now, students will use the water bottles. glow sticks, construction paper and other recyclable items to create their own glow in the dark bug. This bug must have a way to trap prey like the glowworm.

Show students the parts of an insect. Students must include these parts in their model. Next, students must sketch their design in their science journal, labeling all the important parts of the insect.

Use Exit Ticket for Day 3 in Appendix 2 to gauge student understanding.

Day 4, Bioluminescence as a Warning

Review previous concepts, including text features. Today, students are going to reread *Glowworms Are Not Worms!* by Daisy Allyn and discover a different way that glowworms use bioluminescence.

Reread pages 12 and 13 of text. Discuss how in the previous lesson students learned how glowworms use bioluminescence as a lure. Glowworms also use bioluminescence as a warning to possible predators.

What are some ways that people use light as a warning in the human world? (railroad crossing, brake lights in cars, lights on emergency vehicles, etc.)

Now have students think about warning lights. If they could design their own, what would it look like? What would it do? What would it serve to warn others about?

Have students draw a diagram and design their own warning light. Think about introducing the idea of biomimicry, how people take inspiration from nature to find solutions to their problems.

Use Exit Ticket for Day 4 in Appendix 2 to gauge student understanding.

Day 5, Bioluminescence as Defense (Distraction and Camouflage)

Review all previous concepts listed for bioluminescence. Today, students will learn about how lantern sharks use bioluminescence to disguise themselves.

See Day 5 in Appendix 2 for Reading Passage on Lantern Sharks. Read with students and discuss "photophores" and the purpose of bioluminescence in lantern sharks.

As counter-illumination is a type of camouflage, students will now "hide" a die-cut shark shape using paper as a background.

Students will be given a shark die cut shape. One side should be out of colorful construction paper. The flip side of the shape should be another type of paper, such as newspaper, or other printed paper. Students will make a background to "camouflage" one side of their shark.

Use Exit Ticket for Day 5 in Appendix 2 to gauge student understanding.

Day 6, Biomimicry

Review all previous concepts and uses of bioluminescence.

Now, have students think about all of the ways that we use light in our world. We are going to use light to explore an idea called biomimicry. Biomimicry is using an idea from nature to solve a real-world problem (see Teacher Resources for several short, kid-friendly videos on this topic).

Read one of the suggested books on biomimicry (see Teacher Resources, Appendix 3).

Now, using the pictures from this website (Treehugger, 8 Amazing Examples of Biomimicry or other examples that you can find), have the students work to match the real-life solution to the idea found in nature. This can be done with partners or as a matching game.

Encourage students to start looking in nature for creative ideas to solve problems.

Days 7-9, Creating a Communication Device

Review biomimicry from previous day. Tell students that they are going to use fireflies to help inspire them to create a communication device using light.

Think about fireflies. What are important aspects of what they do to communicate? Are there other animals that use their light to communicate?

The students' communication device needs to go over a distance. For the purpose of evaluation, from one end of the hall to another. It will need to flicker or turn off and on to convey a message. The students will have to come up with the meaning of the sequence of lights. This will need to be written down. The observers of the message will need to be able to determine to message for the device to be a success. See the Rubric for Days 7-9 in Appendix 2 for parameters of project.

Students should have Days 7-9 to work on device.

Day 10, Sharing Final Projects

Allow students to invite in administration or family members to see their presentations. Students may present in any format you are familiar with (digital, handwritten, video, etc.)

Appendix 1: Implementing Teaching Standards

NC Essential Science Standard 1.L.1.1
Recognize that plants and animals need air, water, light (plants only), space food and shelter and that these may be found in their environment.
This standard focuses on a plant or animal's habitat providing what it needs to survive. Bioluminescence plays a factor in this by helping the plant or animal get what it needs in its own environment.

NC Essential Science Standard 1.L.1.2
Give examples of how the needs of different plants and animals can be met by their environments in North Carolina or different places throughout the world.
This standard focuses on how different animals live in different habitats and ecosystems. The needs of animals in each are different. Students will look at how bioluminescence is used differently in each environment.

NC Essential Science Standard 1.L.2.2
Summarize the basic needs of a variety of different animals (including air, water, and food) for energy and growth.
Students will learn how bioluminescence helps animals get what they need to survive.

NCSCOS RI.1.1 Ask and answer questions about key details in a text.
Students will be able to explore non-fiction text about animals that use bioluminescence.

NCSCOS RI.1.5 Know and use various text features to locate key facts or information in a text.
Students will use text features in their research to better understand non-fiction text.

NCSCOS W.1.2 Write informative/explanatory texts in which they name a topic, supply some facts about the topic and provide closure.

- **a. With guidance and support from adults, organize information and ideas around a topic to plan and prepare to write.**
- **b. With guidance and support from adults, focus on a topic, respond to questions and suggestions from peers, and add details to strengthen writing as needed.**

Students will complete a research project on an animal that uses bioluminescence with their theory why and provide reasons for their thoughts.

1-PS4-4 Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.
This is the final project for the students, incorporating the idea of biomimicry. Students will study how bioluminescence is used to communicate and create their own device using light to communicate across a distance.

Appendix 2: Implementing the Unit

Day 1 Exit Ticket

What does bioluminescence mean?

____

____

What is a chemical reaction?

____

____

Day 2 Light Pattern Cards (Make 2 copies)

0 0 0__________0 0 0__________0 0 0__________0 0 0__________0 0 0__________

0__________0__________0__________0__________0__________0__________0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

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0 0_____0 0_____0 0_____0 0_____0 0_____0 0

0 0 0 0_____0 0 0 0_____0 0 0 0_____0 0 0 0_____0 0 0 0

Day 2 Exit Ticket

Why do fireflies use bioluminescence?

_____

_____

Think about the story we read. What is one text feature from the story today that helped you understand the text better?

_____

_____

Day 3 Exit Ticket

Why do glowworms use bioluminescence?

_____

_____

What text features from the story help you to understand the text better?

_____

_____

Day 4 Exit Ticket

What are two ways that glowworms use bioluminescence?

_____

_____

Describe your warning light.

_____

_____

Day 5

Lantern Shark Reading Passage[37]

Lantern Sharks

Lantern sharks are small. They feed on small fish, squid, and crustaceans. What makes them so special? They glow!

Lantern sharks have special organs in their bodies, called photophores, that produce light. Scientists are not even sure how the sharks produce light, but they know it is used for camouflage.

Lantern Sharks can control the amount of light their bodies produce to match the light coming through the ocean water above. This helps the sharks to blend in with the water and makes them very difficult to see. So, these sharks cast no shadow below!

How do you think this would be helpful in the deep, dark ocean?

Day 5 Exit Ticket

What is one special thing about lantern sharks?

_____

_____

How does this ability keep lantern sharks safe?

_____

_____

Days 7-9 Rubric for Assessing Success of Final Project

Device can be seen from a distance.			
Device can clearly communicate message to viewers.			
Students came up with a simple method for communicating a message.			
Message can be understood by viewer.			
Device has a protective covering that will allow it to be used out of doors.			

Emojis copied from Emojipedia.[38]

Appendix 3: Annotated Teacher Resources

Chart of Recommended Text Features to Teach to First Graders

Text Feature	Purpose
Table of Contents	tells reader where to look in a book for specific information
Photographs	shows the reader what something looks like in real life
Illustrations	pictures that are drawn and explain ideas in the book
Diagrams	labels the important parts of an object
Maps	shows where things can be located in the world
Captions	tells the reader more information about the photos or illustrations
Headings	titles a section of the book that is about a certain topic
Bold Print Words	special words that the author wants the reader to know
Glossary	defines important words from that book only
Index	tells the reader where in the book special words are mentioned

Biomimicry[39]
This video shows children exploring the concepts of biomimicry in nature.

Plagiarizing Nature by Tinyverse[40]
This animated video shows several real-life instances where biomimicry was used to create something new or solve a real-world problem.

Biomimicry for Kids: Activities and Resources (K-3)[41]
This is a website designed for anyone preparing to teach a unit on biomimicry.

Supplemental Texts on Biomimicry (all texts available for free to educators on Epic! Online Library)
Everyday Inventions Inspired by Nature by Samantha S. Bell[42]
Clothing Inspired by Nature by Wendy Hinote Lanier[43]
Energy Technology Inspired by Nature by James Bow[44]
Medical Technology Inspired by Nature by Venessa Bellido Schwarz[45]
Burrs to Velcro by Jennifer Colby[46]
Cat Claws to Thumb Tacks by Jennifer Colby[47]
Cat's Eyes to Reflectors by Jennifer Colby[48]

Kingfishers to Bullet Trains by Jennifer Colby[49]
Lampreys to Robots by Jennifer Colby[50]

These books go through several inventions that were inspired by nature.

Lesson Ideas for NGSS 1-PS4-4 (Final Project Standard)

Better Lesson[51]
This website lists several other ideas for implementing this standard if you wish to follow up.

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