The Unsinkable Horseshoe Crab

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Introduction

"How inappropriate to call this planet Earth when it is quite clearly Ocean"[1].

The ocean is a vast, complex world. It regulates our climate, it sustains us, and its force is profound. Experts agree that there are 326 million gallons of ocean water, but most of it is off limits to humans and fellow air breathing creatures. Its underwater landscape is more varied than ours, with mountains, valleys and even volcanos. It is also home to over half the species on Earth. These often strange and amazing creatures all have one thing in common: they have perfectly adapted for their watery environment. In fact, one could say that virtually all ocean life exhibits adaptations that have allowed them to survive, despite a myriad of challenges.

One such ocean dweller is the horseshoe crab. Sometimes referred to as a "living fossil", the horseshoe crab's ancestors have been traced over 450 million years. That is 200 million years before the dinosaurs! Each spring, Delaware's beaches are inundated with them, as they come ashore to lay their eggs and ensure their continued legacy on Earth. They have survived despite climate change, human harvesting and natural predators. Today, their existence is crucial to the east coast ecosystem and to the modern biomedical community. This unit extends the 5th grade Ecosystems unit and explores this astonishing ocean inhabitant, its place in history and the important roles it plays in our ecosystem.

Background

My district is currently facing great change in the face of urban strife and administration shifts. As one of the largest districts in our state, we cover both urban and suburban areas. In the near future, the state plans to make some changes. Presently there are three districts that have schools in the city of Wilmington, Delaware. The state will consolidate them into one as of the next school year. This will drastically change my district. Looking ahead, the Christina school district has decided to increase the services available to our brightest students, in an effort to stem their flow to private and charter schools, particularly at the middle school level.

This is wonderful news for me, since I am a Talented and Gifted teacher at the elementary level and have been advocating for more services since I began in my present role, ten years ago. My school is a large suburban elementary school serving grades kindergarten through fifth. This year's enrollment is currently 753 students, with little transience throughout the year. Our population is quite ethnically diverse, with thirty five percent identifying as White students, thirty five percent as African American, seven percent as Latino, fifteen percent as Asian, and the rest are considered Multi Racial. Family involvement is strong as evidenced by membership in the PTA and attendance at school functions and events.

Academically, we are consistently rated a "superior" school in terms of meeting the state standards. Twenty six percent of students are identified as low income, nine percent are English Language learners and just over seven percent are identified as having Special Education needs. We have a full time Educational Diagnostician and school Psychologist, a Counsellor, and a part time Speech and Language Pathologist to support student and family needs. We have also recently become a school where several visually impaired students attend and there is a great deal of support for them as well.

Last year, a committee was formed of teachers, administrators, parents and community members to evaluate the current services for academically advanced students across the District. This committee met regularly to listen, research and finally put together a new plan for high ability learners. This plan includes the Cambridge program being brought to all middle schools to increase the rigor in core subjects and for each of our high schools to offer a unique program at the secondary level. At the elementary level, there will now be 4 levels of service available to high ability students. All students will be taught a series of higher level thinking lessons in the classroom and all students will be assessed at the end of second grade with the COGAT test to identify the highest learners. Those identified will then be provided levels of service including differentiated instruction in the classroom and/or advanced curriculum taught by the certified gifted teacher.

Rationale:

My goal is always to provide my students with educational opportunities that expand their worlds. As they are considered the "best and brightest," I feel responsible to help them see that they can make a difference in the world. They have the potential to become our future policy makers, scientists and scholars. Even though they are young, inspiration can come at any time, and I try to empower my students despite their tender age.

Additionally, with the changes in my current role, I am looking for new, enriching curriculum opportunities. This unit is aimed at the highest learners in the fifth grade, as

an extension of the 5th grade core science curriculum on Ecosystems. Presently this Ecosystems unit focusses on the food chain and the delicate balance necessary for a healthy ecosystem. I plan to begin with the basic vocabulary and background knowledge about the environment, ecosystems and biomes, implications of climate change and then take an in-depth look at the Horseshoe crab. Its roles in the Delaware coastal ecosystem will be carefully examined, along with its importance to medicine, as it is used widely for its very unique characteristics. This unit has the potential to be widely cross curricular, incorporating Common Core Standards including ELA, Reading, Science, Social Studies, Technology and Math. Students will make use of critical thinking skills as they evaluate evidence, consider a variety of points of view, follow historical timelines, assess data and debate ethical issues. A field trip to experience the horseshoe crab's natural habitat will provide authentic learning and application of new knowledge.

The Basic Vocabulary of Organisms

Our seminar group began with the basic question: "What is an organism?" In order to answer that, we discussed the levels of organization within an organism:
CELL>TISSUE (group of cells)>ORGAN (each performing different functions) >Systems (Organs working together)> AN ORGANISM!
According to the Biology Online Dictionary, an organism can be defined as

"*An individual living thing that can react to stimuli, reproduce, grow, and maintain homeostasis. It can be a virus, bacterium, protist, fungus, plant or an animal.*"[2]

Thus, evolution is not a belief, it is a fact! The way that it happens might be up for debate, but organisms do evolve. What causes evolution? One cause is natural selection. In a very long, slow process, the gene pool frequency is changed by removing some genes. Commonly known as "survival of the fittest," it refers to genetic traits that help an individual survive, reproduce and then are passed along to the offspring. Another cause is artificial selection: This occurs when species are intentionally paired for particular traits and functions. Think of a "labradoodle" - a Labrador retriever bred with a poodle to produce a smart, loveable, non-shedding canine! Kin selection refers to the old saying "blood is thicker than water", whereby an animal risks its own well-being for that of its offspring. An example of this is the way that a quail might feign injury when a fox comes lurking, to draw him away from her chicks.

Just what makes an organism successful in its environment? ADAPTATIONS! They are genetic and can take a long time and can be the result of gene combinations or mutations. An adaptation can be defined as a genetic characteristic, such as feather color or nest building that helps an organism survive and reproduce in its environment. Other important definitions that students will need are the following:

Biodiversity: This refers to the variety of species and the number of individuals in a given area.
Community: All of the plants, animals and other organisms that live in an area and interact with each other.
Ecosystem: An ecosystem includes the community of organisms in an area, their interactions with each other, and the environmental factors that affect them. For example, trees, birds, insects, fungi, soil type and rainfall are all parts of a forest ecosystem.
Environment: An environment is all that surrounds an organism and has an impact on it, including plants, animals, microbes, soils and weather.
Evolution: Evolution is change in the genetic makeup of populations, not individuals, over time. It can proceed through natural selection and by random events. Over time, population changes may result in new species.
Extinction: This comes from a Latin word meaning "no longer burning". Extinction is the death of all individuals of a species and is permanent.
Species: A species is a group of interbreeding organisms that are different from another group in one or more characteristics. Different species usually do not breed together in nature.

More about Adaptation

"The study of adaptation is central to the understanding of biology. All organisms are subject to environmental pressures, such as cold or heat and the need to escape predators and find food. Adaptations are a response to these pressures."[3]

A feature or trait may be an adaptation if it has a genetic basis, has been shaped by the organism's environment and if it contributes to an organism's ability to survive long enough to reproduce. However, not all features of an organism are adaptations! Scientists determine whether a feature is an adaptation by considering the following: Adaptations are usually complex, such as the eyes of the organism. Also adaptive features often appear in unrelated organisms: they have independent evolutionary origins. A good example of this would be the development of white fur and feathers of Arctic animals. Although they are different species, all share the same environment and have made adaptations for their survival. This is sometimes called "convergent evolution."

There are several different types of adaptation that can contribute to the success of an organism. Genetic adaptations are the presence or absence of a given trait that has evolved over time that serves a particular function, in response to the organism's environment.

There are three basic types of genetic adaptations. Morphological adaptation referring to body form, like skin color or camouflage. Physiological adaptations would be chemical

and metabolic qualities specific to that organism, such as venom. Behavioral adaptations are just that: the way that the creature behaves. Each of these adaptations allow the organism to acclimate to its environment and each relies on one another for survival of the creature.

Let's consider a rattlesnake as an example. Morphologically, it has fangs that are hollow, curved and able to retract. Physiologically, it has slow digestion, so that it doesn't have to eat very often, and deadly venom with a solid delivery system to kill its prey. It has developed behaviors that increase its chances of survival such as clustering in cold climates, coiling its body for attack and striking quickly with its fangs. These adaptations have created a very worthy killing machine that is highly likely to survive long enough to reproduce in the wild.

Adaptation and Climate Change

There is little doubt today that climate change is real. On the surface, the increases seem incremental, but viewed across time, the facts are startling. The month of July 2015 had an average temperature that broke the previous records set in 1998 and 2010 by about one seventh of a degree. That is a large margin compared to the previous monthly temperature records that were broken by a twentieth of a degree or less. The Earth is warming and it seems that there is no end in sight. And it's not just in North America. While U.S. weather officials said that July 2015 was Earth's warmest month on record, the trend is clear across the globe. Substantial effects of severe heat were seen in Europe and the Middle East, with Austria, France and even the Netherlands smashing heat records as well. All indications point to this year being marked as the warmest year on record—EVER! [4]

Just this past summer, California experienced its driest four years on record. This resulted in devastating wildfires that indicate a very bleak future if nothing is done to deal with the drought. A recent report by the Public Policy Institute of California predict more widespread wildfires, tumbling wildlife populations and even poor rural communities running out of water entirely.[5] Apparently drought is the new normal, and there are several new native species on track for extinction as a result.

According to this report, California's fresh-water habitats and forests are hardest hit. Eighteen native California fish species, including most native salmon and steelhead trout, are facing serious threats of extinction. It also threatens the 5 million migratory birds and other wildlife in the stricken forests. This will mean significant changes for this area of the country.

Closer to my home, on the east coast, the ocean waters are experiencing increasingly warm temperatures in recent years. One documented effect is being felt up the coast in

southern New England, where the lobster population is now at its lowest level on record. This is having a huge impact on the lobstermen in Connecticut and Rhode Island, as many are being forced to give up their way of life. Lobster numbers aside, the temperature rise is indisputable, as evidenced at a power plant in Long Island Sound, where there were more than 75 days with a recorded average water temperature above 68 degrees from 2012-2014. Considering that this happened only twice in the years between 1976 and 2010,[6] it is quite noteworthy.

Another species that has certainly been affected by climate change, and one that has drawn some mainstream attention, is the bee population. In an analysis of the major northern shifts in territorial boundaries and severe decline in numbers, many scientists ruled out human causes such as pesticides. The only explanation that is clear seemed to be that the weather has just gotten too hot for them, forcing the bees to move their habitats northward. And because bees play such a vital role in the pollination of many of our crops and food sources, it's time to take notice. [7]

One amazing adaptation was recently discovered by researchers at Rutgers University who were studying the black sea bass population.[8] There is an apparent decline in the number of male fish available for mating, (perhaps due to over fishing?) and so the female fish seem to change their sex. Exactly how this happens is unclear but it seems that nature has found a way to correct the imbalance. Fish were tagged with a code and contact information, along with the promise of a reward if fishermen reported their catches. Of the 269 reported catches, 126 had begun their lives as females, but only 106 remained so. Nine were male and nine were considered to be in transition, showing evidence of both male and female sex organs. Although researchers aren't blaming climate change per se, it seems probable that some significant change in the ocean environment has initiated the need for this unique animal behavior.

Recently President Obama visited Alaska to see first-hand the effects of environmental change there. Scientists have long been trying to draw attention to the major changes happening there due to global warming. Consider this: more than 3.5 trillion tons of water has disappeared from Alaska's glaciers since 1959[9], the very year that Alaska was made an official state. To put these numbers in perspective, that is enough water to fill more than one billion Olympic swimming pools! The melting of this sea ice severely impacts those who live there, most notably 26 villages that are on the verge of disappearing, according to the army Core of Engineers. Rising temperatures have caused the creation of raging wildfires there as well; just last year an area the size of Connecticut and Rhode Island combined burned out of control. Compare this fact with the evidence that from 1959-1969 there were scarcely a quarter square mile of fires annually, and the last ten years have had averages closer to 1.2 million acres. While Alaska and its problems may seem far away, we cannot ignore them because they influence the rest of North America. Arctic weather changes influence the jet stream and

cause a ripple effect as it travels southward, including the polar vortex that has brought severe winter storms over the past couple of years.

The wildlife of the Arctic has been forced to adapt as well. There is evidence that the warming has been responsible for new patterns of insect outbreaks and the discovery of new pest species affecting trees. Reproductive and laying cycles of birds are also changing, and many other shifts disrupt the natural way of life there. Animals like the trumpeter swans, caribou and pink salmon are suffering because the change in birthing time might not be in sync with their food supply.

The melting of the glaciers and ocean warming are also contributing to the rise in sea level. This also can cause changes in the salinity of the water. In Delaware, it has been estimated that we are losing as much as an acre of tidal marsh a day.[10] These tidal marshes are crucial to the shelter and protection of species like the horseshoe crab, weakfish and striped bass. Literally dozens of juvenile fish species grow and develop there. Without them, these species will be in jeopardy. In addition the rising temperatures can mean less oxygen in the water and a higher salt content. This combination can lead to outbreaks of disease like Dermo, a disease that is devastating to the oyster population.

There are those who are listening to Mother Nature and are trying to counteract some of these environmental disasters. For example in Washington State, there is an effort to bring the grizzly bear back from the brink of extinction. It was declared a threatened species there over forty years ago. One of the options being explored is the transplanting of grizzlies from other areas of the country. Farmers and ranchers are not so keen on the idea. However, when one considers the overall ecosystem, the bears have an important role to play to keep things in balance. Ranchers are already struggling with a rising number of wolf packs, but could the reintroduction of grizzlies help to keep the wolf population in check? That will be left to be seen, if the recovery plan passes legislation and is acted upon.

Climate Change and Fish Migration in the Eastern Atlantic Ocean

Here in Delaware, we continue to take notice of the effects of a warmer climate. Like the lobsters mentioned earlier, our fish populations are changing as they seek out their optimum environments. Fishermen have been noticing the changes and now it has the attention of many others. In a special feature this past summer, the News Journal cited some glaring facts to support their claims of imbalance in our delicate coastal ecosystem.[11] For instance, in 2013 a Virginia bass fishing competition had hundreds of participants, but just a single bass was caught. And the blue crab, once so unique to the Chesapeake and Delmarva Peninsula, has also begun to seek out new habitats, moving up the coast to Maine. This front page article discussed nine aquatic species that were once commonplace here that seem to be looking for new homes. These species include the

Black Sea Bass (moved north to New England), Summer Flounder (now more commonly found off the coasts of New Jersey and New York), the American Lobster (as mentioned earlier, this species in now more commonly found off the northern coasts of Maine), the Striped Bass (heading to deeper waters during their fall migration), Oysters (now are actually coming back to the Delaware Bay after it had previously been too cold), the Tarpon (previously known as a Florida Sportfish, is now being sighted off the Virginia coast) and the Brown Shrimp (now being caught off the Delaware coast but were never sighted here before). Undoubtedly these are just a few of the changes caused by climate change, with many more to follow.

Ecosystems: A delicate balance

My students have been taught the District fifth grade Ecosystems unit in the regular classroom. It is always a favorite, because it includes the creation of an aquatic environment in a soda bottle. Its key learning point is that living and nonliving things are interdependent and that living things impact the ecosystem as they satisfy their basic needs for survival.

My unit will pick up there and extend their knowledge to the local, unique environment that is the Delaware Bay and coast. In particular, it will examine the role of the horseshoe crab, an organism that has been present on the earth for millions of years, despite climate change and it's only major predator: man.

The Delaware Bay sets a unique stage for exploring a delicate balance between species and the environment. Each spring, during the full and new moon events in May and June, thousands of horseshoe crabs come ashore to spawn. The beaches are literally covered with these prehistoric looking creatures as they drag themselves onto the sand to reproduce. It is also during this time when migrating shorebirds descend upon the beaches to rest and feed on the horseshoe crab eggs before continuing onto their breeding grounds in the far north. This interaction between horseshoe crab, shorebird and humans is the focus of this unit.

A Fascination or Nuisance?

Ask native Delawareans who frequent the local beaches and you will undoubtedly find people who are less than enthusiastic about these prehistoric, hubcap-looking creatures using the beaches for spawning grounds during high tides each late spring. They leave behind carcasses and molted shells which are rather unattractive. But considering the fact that the earliest horseshoe crabs had already inhabited the Earth for at least 100 million years before the dinosaurs arrived about 200 million years ago, I say they are fascinating!

Today there are four species of horseshoe crab in the world, but only one lives here in North America. *Limulous polyphemus* can be found along the Atlantic coast from Maine to Florida, the Yucatan peninsula, and several places along the Gulf of Mexico. But the largest concentration in the world is right here in the Delaware Bay: between Delaware and New Jersey.

The Anatomy of the Horseshoe Crab

First, is it really a crab? Actually, the horseshoe crab is in a class by itself. It is really closer to relatives like spiders, ticks and scorpions. True crabs have one pair of claws, but the horseshoe crab actually has five! They do not have antennae or mandibles (jaws) like true crabs. However, they do have a similar mouth structure to spiders and scorpions: chelicerae are the first two small claws found in the front of a horseshoe crab's mouth. These small claws are used to find food and move it into the mouth.

The body of this amazing creature is divided into three parts. The prosoma is the large semicircular part of the horseshoe crab that houses the head and thorax under a hard exoskeleton. The opisthosoma is attached to the prosoma with a hinge-like structure that protects the gills and genital pores. There are two large compound eyes found on the prosoma and eight other simple eyes and light receptors on the top and bottom of the shell. The third part is the telson, or tail. While it looks like a deadly weapon, it is used for righting itself when flipped by waves. They do not bite or sting.

Under the shell, there are seven pairs of appendages. Six of them have gnathobases or "shoulders of the leg." Five of the pairs have claws. The second pair are modified on mature males for grasping the female during reproduction. The sixth pair assist with movement and the seventh pair are remnants.

Habitat

The horseshoe crab lives in salt water on bay or shallow coastal ocean bottoms. They search, dig and burrow for food, using claws and pusher appendages to move along. It pushes sediment like a farmer plows a field, seeking out prey such as clams or worms. It does not have a nose structure but uses tiny hairs on the gnathobases to "smell." When food is discovered, one of the claws picks it up and moves it toward the gnathobases, which are equipped with tiny bristles that grind it, then it is pushed upward by the tiny pair of claws in front of the mouth. They are scavengers and predators and eat just about anything. They feed on small clams, crustaceans, worms and even algae. In environments that stay warm year-round, the horseshoe crab will stay active. However, if waters are cooler in the winter, it will become dormant, burrowing down in the mud until things warm up again in the spring.

Reproduction at the Shore

Live horseshoe crabs emerge from the ocean in the late spring with high tides. The smaller males follow the females ashore use their modified claws called pedipalps to hook onto the female's abdomen, basically hitching a ride. When she finds the best spot above the high tide line, the female will then hollow out a series of five to seven shallow nests in the sand as the tide recedes. Each nest will hold a deposit of about 4,000 eggs and the attached male (and any others that are in her vicinity) will all fertilize the eggs as she lays them, thus decreasing the chances of any being missed.

These pastel green eggs may hatch in two weeks or even many months later, looking like mini adults. The only thing missing is the telson, which appears after the first molt. Over the next decade or so, the horseshoe crab will go through the process of molting, shedding their shells to allow for growth of about thirty percent each time. It takes about seventeen or eighteen molts until they reach adulthood, roughly nine or ten years, at which most are seven to twelve inches in width. The largest recorded horseshoe crab was seventeen inches wide. Males and females look similar, although the females are generally larger, and the males don't get their claws for attaching to the females until eight or nine years old.

Overharvesting and Environmental Threat

Horseshoe crabs have historically been harvested for fertilizer, minnow and eel bait, largely because they seem to be so abundant and easy to collect. Since the early 1900s, they have been routinely scooped up from their spawning grounds for other uses by man. In fact it was quite a lucrative and easy business. For instance, in just five years between 1992 and 1997, the number of reported crabs harvested went from about 100,000 to more than two million, with an estimated value of between eleven and seventeen million dollars![12] Considering there was no mandatory reporting system, it is difficult to ascertain exact numbers.

Another threat to the horseshoe crab population is the biomedical industry. Somehow over the millions of years it has inhabited the earth, the horseshoe crab has developed a unique defense mechanism to protect itself from infection. A cut on a horseshoe crab is quickly sealed naturally, blocking out the dangerous bacteria in the murky waters. A chemical found only in the amoebocytes of the crab blood cells can detect the smallest traces of bacterial presence and encapsulate them in inescapable clots. This amazing fact was discovered by scientist Fred Bang in his 1956 paper. He created a test that used the crab substance to detect bacterial contamination and named it the "LAL" test (or Limulus amebocyte lysate (after the species name of the crab).[13] Bang theorizes that the horseshoe crab's bacteria rich habitat is responsible for the evolution of this miraculous chemical defense and what has kept them alive on the planet for so long.

Today, over 600,000 crabs are captured to be “bled:” the tissue around the heart is pierced and 30 percent of the crab’s blood is extracted. Currently only five labs in the world are licensed to do the procedure. Afterwards, the crabs are set free in a different place than their capture, to avoid their recapture in the future. The whole process is quick, only twenty four to seventy two hours. Of course, the industry minimizes the cost to the crab populations, saying that there is a casualty rate of about ten to thirty percent. It is estimated that the blood of this ancient creature is worth $60,000 a gallon in a global industry valued at $50 million a year. It is said that we all have been touched by horseshoe crab blood. In fact, the FDA requires the use of this special clotting agent to test all injectable and intravenous drugs produced in the U.S. today, along with surgical implants such as pacemakers and prosthetics.

Interdependence in the Delaware Ecosystem

The horseshoe crab plays yet another important role: its eggs provide crucial energy as the primary food source to the Red Knot. The Red Knot is a tiny migratory bird that has one of the longest migratory routes of any species in the world. This little dynamo flies from the tip of South America where it spends the winter to the arctic regions of Canada to breed, covering over 30,000 kilometers. Obviously it must stop along the way for rest and refueling and the Delaware beaches are the crucial last stop on its trip. The horseshoe crab eggs are a rich source of quick protein that the Red Knots count on to fatten them up and provide the necessary fuel to continue northward. By the time these birds reach Delaware, they are weak and unable to even digest their usual prey. Horseshoe crab eggs are soft, easily digested and by gorging themselves on these energy rich eggs, the Red Knots are able to literally rebuild their organs and muscles over just a couple of weeks.

When the horseshoe crab population is healthy and there is little room on the beach to spawn, the females inadvertently unearth the eggs of others as they dig their own nests, exposing them for the birds. The action of the ocean waves also assists in serving up eggs to the Red Knot diners. On the other hand, if the numbers are not nearly as high, the eggs stay buried and inaccessible to the starving birds. Watchers have noted that the number of Red Knots declined drastically when they were deprived of their feedings on the horseshoe crab spawning grounds. The overharvesting and loss of sandy spawning beaches (resulting from human development, erosion and the rising sea level) not only affected the horseshoe crab, but the entire coastal ecosystem when their numbers were weakened.

In response to the drastic decline that was noted around 1997, intensive shorebird studies were begun to monitor the weight and numbers of the birds. Monitoring of the horseshoe crab numbers and health of the red knot population are closely intertwined, and the results have shown that in times of unrestricted crab harvesting (like in the ‘90s when

it was estimated that the horseshoe crab and egg population went down by 80%), the red knot weights began to decline as well. Despite the reduction of horseshoe crab harvesting, the Red Knots have not completely recovered. In order to have healthy, economically important horseshoe crab and Red Knot populations, there must be restoration of the crab populations to levels similar to the 1990s. Current efforts have shown promise but will certainly require continued work to restore the balance that nature intended.

Strategies

Because this unit is an extension of the fifth grade Ecosystems unit, it will be important to assess the students' prior knowledge. I recently attended a professional development with LeAnn Nickelson[14] about prepping the brain for learning. She presented some powerful evidence that when students activate prior knowledge, new learning is more effective and efficient. By priming the brain before presenting new information, it helps students integrate and preserve the new information. Thus my first activity will be an Activating Prior Knowledge activity, which will also serve as a pre-assessment, allowing the teacher to scaffold if necessary.

This unit also integrates the arts, with an activity that provides the opportunity to express student learning in a creative way. Integrating the arts is a differentiation strategy that taps into a variety of student interests, abilities and learning styles. After participating in a past DTI seminar with Dr. Lynnette Overby, I have used this strategy often and I can honestly say that my students love it.

Socratic Seminars offer excellent opportunities to teach students all four essential Language Arts skills — reading, speaking and listening, and writing — along with critical thinking. This teaching strategy requires students to thoughtfully engage with a text, first observing, then analyzing what it says. To participate, they must then listen attentively and express themselves clearly. Post seminar writing assignments provide the opportunity to further consider and develop the ideas expressed in the seminar.

Activity One:

Activating Prior Knowledge

Before being introduced to the video "Crash: A Tale of Two Species", students will participate in a "Super Sleuth" activity to activate their prior knowledge and to give them

an idea of the topic we will be exploring. This Super Sleuth (see appendix A) has 9 boxes that have 9 questions about the topic of Horseshoe crabs and their relationship with the shorebirds. Students move about, asking their questions until they are all answered, with a signature of each of the peers that they have shared with. While being fun and engaging, this activity also builds on existing neural pathways.

After this activity, show the video, or a clip of it (depending on time) and have students complete Crash Film Worksheet (Appendix B). The full video is 50 minutes but can be edited to suit your needs. A written assignment will follow with the prompt: "What do you think the future holds for the Horseshoe crab? Include evidence to support your opinion."

Activity 2

Saving the Red Knot: An Introduction to Pantomime
This activity integrates science standards with Theater and Dance.

Objectives:

Students will understand the importance of body language in self-expression, demonstrate mime techniques as a means of communication, sequence scenes into a dramatic study with a beginning, middle and an end and demonstrate their understanding of the connectedness of an ecosystem.

Students will collaborate as they work together to create and perform in small groups.

Materials: "Horseshoe Crabs and Shorebirds: the Story of a Food Web" or use one of several You Tube videos available from the Delaware Bay Shore Bird Project
Introduction and warm up.

Begin by showing students a few silent film clips. Draw their attention to the use of body movement and facial expression. A great introductory activity is called the "Imaginary Object Pass." Arrange students in a circle and pretend to pass an object around the circle, using different levels of movement, facial expressions, etc. to convey the identity of the object. It might be a soft and cuddly kitten, a heavy rock, or a dirty diaper! Focus on the way that we use our hands and expressions to show feelings and emotions. Then have students try acting out several situations, such as being stuck in traffic, eating an apple, getting a haircut or grocery shopping. Have others observe and provide feedback about their observations.

Next read and discuss “Horseshoe Crabs and Shore Birds: the Story of a Food Web” or show Red Knot video found on YouTube (see teacher resources). Students will then pantomime, in small groups, scenes from the beginning, middle and end of the shorebirds journey. In the beginning, the birds start out strong and fat, happy but as time goes on they get weaker, hungry, more desperate. In the middle, they stop at the Delaware Bay, where there are lots of horseshoe crab eggs to feast on (or not, if you want to show the endangered aspect), and the birds become fat, happy and strong. In the end the birds arrive at their breeding grounds in the Arctic.

Assessment: Students can be evaluated based on their participation and demonstrated understanding of the migration cycle and the importance of the food web to these local species.

Activity 3: “I Have, Who Has” Game
See Appendix C for cards

This is a game that is a great way to check for understanding. It addresses the Science standards from the unit, but necessitates careful listening and solid communication skills. Students match up the answers on their cards with questions on other students’ cards. Distribute all the cards in the set.

The student who has the card that says “I have the first card” goes first. He/she reads it aloud, including the question that follows. The student with the correct answer on their card reads the response: “I have _____”. This student will then read the question at the bottom of his card, “Who has____?” Then the student with the card that answers the question responds. Every card in the set is connected to a card before it and a card after it. To keep the game moving at a quick pace, all students need to pay attention to every question that is asked.

Play continues in this fashion until all of the cards have been played. The game will end with the same student who started the game. This game can serve as an informal formative assessment and play can be paused if concepts require discussion or clarification.

Activity 4: Socratic Seminar

There are many, many articles and videos online that would be appropriate for a Socratic Seminar about the horseshoe crab. I chose “How Horseshoe Crabs May Have Saved Your Life” (http://www.deepseanews.com/2013/08/how-horseshoe-crabs-may-have-saved-your-life/). Students will read the article and complete a pre-seminar worksheet that will help them come to the seminar prepared for the discussion. See Appendix D for the worksheet. Socratic seminar will follow using established rules. This can be used as a

formative assessment in terms of student participation, preparedness, and communication of opinion and content.

Activity 4: Final Project

Students will choose from the following possibilities:

1. Create an advertisement to educate people about the wonders of the horseshoe crab. You may use art mediums and/or technology.
2. Write a journal for a Red Knot's migration, including as many facts as possible.
3. Write a song or rap from the perspective of the Horseshoe crab or Red Knot.
4. Create a trivia game to be shared with others, based on what you have learned about the horseshoe crab

Standards to be addressed in this unit

This unit will be cross curricular in nature and cover a variety of standards.

Science

Standard 1: Unifying Concepts and Processes—Evolution; organization and anatomy
Standard 2: Science as Inquiry—"How we know"; fossils; eyes; natural history
Standard 3: Physical Science—Forces and motion in swimming
Standard 4: Life Science—Anatomical structure and function; reproduction; life cycles
Standard 5: Earth and Space—Earth's history
Standard 6: Science and Technology—products derived from the horseshoe crab
Standard 7: Science in Personal and Social Perspectives—status of world's horseshoe crab population; science; technology and society
Delaware Science Standard 8: Organisms are linked to one another in an ecosystem by the flow of energy and the cycling of materials. Humans are an integral part of the natural system and human activities can alter the stability of ecosystems.

Arts

National Theater Standard 2: Acting by developing acting skills to portray characters who interact in improvised and scripted scenes.
National Dance Standard 1: Identifying and demonstrating movement elements and skills in performing dance.

National Dance Standard 3: Understanding dance as a way to create and communicate meaning.
National Dance Standard 4: Applying and demonstrating critical and creative thinking skills in dance.
National Dance Standard 7: Making connections between dance and other disciplines.

Reading: Literature:
Rl5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.
Rl5.2 Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.
Rl5.3 Explain the relationships or interactions between two or more individuals, events, ideas or concepts in a historical, scientific, or technical text based on specific information in the text.
Rl5.4 Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a grade 5 topic or subject area.
Rl5.5 Compare and contrast the overall structure (e.g. chronology, comparison, cause/effect, problem/solution) of events, ideas, concepts, or information in two or more texts.
Rl5.6 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.

CCSS.ELA-LITERACY.SL.5.1.A
Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.
CCSS.ELA-LITERACY.SL.5.1.B
Follow agreed-upon rules for discussions and carry out assigned roles.
CCSS.ELA-LITERACY.SL.5.1.C
Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.
CCSS.ELA-LITERACY.SL.5.1.D
Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

Presentation of Knowledge and Ideas:
CCSS.ELA-LITERACY.SL.5.4
Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

CCSS.ELA-LITERACY.SL.5.5
Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.
CCSS.ELA-LITERACY.SL.5.6
Adapt speech to a variety of contexts and tasks, using formal English when appropriate to task and situation.

Resources for Teachers

Crenson, Victoria, and Annie Cannon. *Horseshoe Crabs and Shorebirds: The Story of a Food Web*. New York: Marshall Cavendish Children, 2009. Nicely illustrated, this picture book gives good details about the co-dependence of the Horseshoe Crab and the coastal shorebirds.

"Crash: A Tale of Two Species." PBS. Accessed December 8, 2015. http://www.pbs.org/wnet/nature/crash-a-tale-of-two-species-video-full-episode/4772/. Great video to explain the synchronicity of the Horseshoe Crab and Red Knot bird.

Fredericks, Anthony D. *Horseshoe Crab: Biography of a Survivor*. Washington, D.C.: Ruka Press, 2012.
A great introduction to the major topics about the Horseshoe crab and the challenges it faces to survive.

Horowitz, Ruth, and Kate Kiesler. *Crab Moon*. Cambridge, Mass.: Candlewick Press, 2004.

"How Integrating Arts Into Other Subjects Makes Learning Come Alive." MindShift. Accessed December 9, 2015. http://ww2.kqed.org/mindshift/2015/01/13/how-integrating-arts-into-other-subjects-makes-learning-come-alive/.
Interesting article about the reasons for integrating the arts across subject areas

Jensen, Eric. *Bringing the Common Core to Life in K-8 Classrooms: 30 Strategies to Build Literacy Skills*.
Practical ideas to teach smarter!

Jensen, Eric, and LeAnn Nickelsen. *Deeper Learning: 7 Powerful Strategies for In-depth and Longer-lasting Learning*. Thousand Oaks, CA: Corwin Press, 2008.
Another wonderful resource for brain based learning.

"Horseshoe Crab Count Under Way on East Coast." National Geographic. Accessed December 10, 2015. http://news.nationalgeographic.com/news/2014/05/140516-

horseshoe-crabs-long-island-blood-coagulant-conch-bait-quadrat-protocol-red-knots-science-world/.

Bibliography

Huxley, Thomas Henry. "The Struggle for Existence in Human Society." In *Collected Essays*, 199. Vol. 9. 1894.

"July Was Hottest Month Recorded Worldwide -U.S. Scientists." *Saudi Press Agency*, August 20, 2015. Accessed September 23, 2015. http://www.highbeam.com/doc/1G1-426186649.html?

Madrigal, Alexis. "The Blood Harvest." The Atlantic. February 26, 2014. Accessed October 25, 2015.

Murray, Molly. "Climate Change Forces New Great Migration." *The News Journal*, September 6, 2015.

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Niles, Lawrence, Jonathan Bart, and Humphrey Sitters. "Effects of Horseshoe Crab Harvest in Delaware Bay on Red Knots: Are Harvest Restrictions Working?" *BioScience* 59, no. 2 (2009): 153-64. Accessed October 24, 2015. www.biosciencemag.org.

"Organism." - Biology-Online Dictionary. Accessed October 13, 2015. http://www.biology-online.org/dictionary/Organism.

"Seeking Mates, Fish Switch Sex." Philly-archives. July 10, 2015. Accessed October 23, 2015.

Seth, Borenstein, and Joling Dan. "Alaska amid a Great Thaw - Philly.com." Accessed October 23, 2015.

"Study Sees Dying Wildlife, Bigger Fires If Drought Lasts." *AP Online*, August 20, 2015. Accessed October 22, 2015. http://www.highbeam.com/doc/1A1-63b943b397e143ca89f1e7df8e62887f.html?

"Study: American, European Bumblebees Feeling Climate Sting." *AP Worldstream*, July 9, 2015. Accessed October 22, 2015. http://www.highbeam.com/doc/1A1-dc83e07fe77f44daaedd26598e8d828a.html?

Whittle, Patrick. "As Ocean Warms, New England Lobsters Are Heading North." *The Seattle Times*, August 19, 2015. Accessed October 22, 2015. http://www.highbeam.com/doc/1G1-426015040.html?

Appendix A

Name: _____ Date: _____

Super Sleuth

DIRECTIONS:

1. *Walk around the room and find someone who can respond to one of the statements below. After responding verbally to your question, the person should initial within the square. Make notes if you would like to in the square as well.*
2. *A person can only answer and initial one square on your card. Feel free to discuss the answer too.*
3. *The goals of Super Sleuth are to activate participants' prior knowledge and to meet new people with new ideas.*

What do you think is meant by "the call of the moon"?	Do all animals have red blood?	What are the uses of a tail? Give examples.
Name a creature(s) that sheds its shell.	Can you think of an animal with more (or less!) than two eyes?	Can you name a coastal bird?
What is "synchronicity"?	Where do most of the world's horseshoe crabs	Can you name two animals that are interdependent?

	live?	

Appendix B

Crash: A Tale of Two Species

Read the questions before you watch the film so that you will know what to look for while you watch.

All responses should be in complete sentences using proper spelling, grammar and punctuation.

1. Briefly describe what the film is about.

Notes:

_____

_____

_____

_____

_____

_____

2. Identify the people, places, events, or environment that are the focus of this film.

Notes:

_____

3. List six facts described in the film that impressed you.

Notes:

4. Did this film show you something you hadn't seen before, caused you to think in a new way, or helped you understand something more clearly? Explain.

Notes:

_____

_____

_____

_____

_____

_____

_____

_____

Appendix D

Socratic Seminar Prep Sheet

Read your article and don't forget to annotate and make connections!

!- I love this!

?-I don't quite understand this

??-I need to talk about this

Write 3 of the most important phrases or sentences from the article.

1._____

2. _____

3._____

Focus: Write 3 higher order thinking questions for discussion.

1._____

2._____

3._____

Possible responses:

1._____

2._____

3._____

Notes:

[1] "Arthur C. Clarke Quote." BrainyQuote. Accessed August 20, 2015

[2] "Organism." - *Biology-Online Dictionary*. Web. 13 Oct. 2015. <http://www.biology-online.org/dictionary/Organism>.

[3] Delaware Museum of Natural History mural

[4] "July Was Hottest Month Recorded Worldwide -U.S. Scientists." *Saudi Press Agency* 20 Aug. 2015. Web. 23 Sept. 2015.

[5] "Study Sees Dying Wildlife, Bigger Fires If Drought Lasts." *AP Online*, August 20, 2015. Accessed October 22, 2015. http://www.highbeam.com/doc/1A1-63b943b397e143ca89f1e7df8e62887f.html?

[6] Whittle, Patrick. "As Ocean Warms, New England Lobsters Are Heading North." *The Seattle Times*, August 19, 2015. Accessed October 22, 2015. http://www.highbeam.com/doc/1G1-426015040.html?

[7] "Study: American, European Bumblebees Feeling Climate Sting." *AP Worldstream*, July 9, 2015. Accessed October 22, 2015. http://www.highbeam.com/doc/1A1-dc83e07fe77f44daaedd26598e8d828a.html?

[8] "Seeking Mates, Fish Switch Sex." *Philly-archives*. 10 July 2015. Web. 23 Oct. 2015.

[9] Seth, Borenstein, and Joling Dan. "Alaska amid a Great Thaw - Philly.com." Web. 23 Oct. 2015.

[10] Murray, Molly. "Wetland Loss the Issue in Delaware Bay." *The News Journal*, September 6, 2015.

[11] Murray, Molly. "Climate Change Forces New Great Migration." *The News Journal*, September 6, 2015.

[12] Niles, Lawrence, Jonathan Bart, and Humphrey Sitters. "Effects of Horseshoe Crab Harvest in Delaware Bay on Red Knots: Are Harvest Restrictions Working?" *BioScience* 59.2 (2009): 153-64. *BioScience*. University of California Press. Web. 24 Oct. 2015.

[13] Madrigal, Alexis. "The Blood Harvest." The Atlantic. February 26, 2014. Accessed October 25, 2015.
[14] Jensen, Eric and LeeAnn Nickelsen."Bringing the Common Core to Life", Solution Tree, 2014

Curriculum Unit Title	The Unsinkable Horseshoe Crab	**Author**	Nancy Ventresca

KEY LEARNING, ENDURING UNDERSTANDING, ETC.

Living and nonliving things are interdependent.

Living things impact the ecosystem as they satisfy their basic needs for survival

ESSENTIAL QUESTION(S) for the UNIT

How do organisms interact with the living and nonliving parts of the environment?

How have the actions and needs of humans impacted the delicate balance of the eastern coastline ecosystems?

CONCEPT A	CONCEPT B	CONCEPT C
Ecosystems and Adaptation	Interdependence of species	Role of the Horseshoe crab in biotechnology
ESSENTIAL QUESTIONS A	**ESSENTIAL QUESTIONS B**	**ESSENTIAL QUESTIONS C**
How are Horseshoe Crabs well suited to live in their environment? How have the structures of the horseshoe crab enabled it to survive for millions of years?	How does a change in one part of an ecosystem affect the other parts of the ecosystem? Why is the horseshoe crab essential to migratory birds such as the Red Knot?	What role has the horseshoe crab played in biotechnology and modern medicine?
VOCABULARY A	**VOCABULARY A**	**VOCABULARY A**
Estuary, anatomical structure, ecosystems, biomes, Limulus polyhemus, prosome, opisthosoma, exoskeleton, median eyes, telson, pusher legs, biodiversity, climate change, genetic adaptation, morphological adaptation, physiological adaptation	Interdependence, dependent, food chain, shorebirds, spawning, migration, overharvesting, biodiversity, Red Knot, fertilizer	Copper, resight tags, immunology, intravenous, coagulogen, “bleeding”,biotechnology

ADDITIONAL INFORMATION/MATERIAL/TEXT/FILM/RESOURCES

Crenson, Victoria, and Annie Cannon. *Horseshoe Crabs and Shorebirds: The Story of a Food Web*. New York: Marshall Cavendish Children, 2009.

"Crash: A Tale of Two Species." PBS. http://www.pbs.org/wnet/nature/crash-a-tale-of-two-species-video-full-episode/4772/.

Fredericks, Anthony D. *Horseshoe Crab: Biography of a Survivor*. Washington, D.C.: Ruka Press, 2012

Horowitz, Ruth, and Kate Kiesler. *Crab Moon*. Cambridge, Mass.: Candlewick Press, 2004.