

Students Explore Fossil Creatures of the Cambrian Period Burgess Shale through Model-Making

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Abstract

This practical article features an arts-integrated science unit on fossils of the Burgess Shale for fourteen elementary/ middle school students at a weeklong summer day camp. The day camp had a theme of recycling, reduction and reuse; all of the fossil models had substantial recycled components to support this theme. Next Generation Science Standards were supported by the course activities in which students examined fossil specimens, images, and comparative modern relatives to determine the anatomy and lifestyles of Burgess Shale Cambrian Period fossil animals (e.g., *Olenoides* trilobites, *Anomalocaris*, *Canadaspis*, *Opabinia*, *Wiwaxia*, *Hallucigenia*) through making scientific drawings and craft models (3-LS4-1), interpreting the environments in which they thrived by creating a diorama (3-LS4-3), considering how populations change as the environment changes (3-LS4-4), and creating a model of a fossil animal using only recycled plastic bottles, lids, pipe cleaners, beads, and sheet foam (3-5 ETS1-1). Students greeted the activities with great enthusiasm, demonstrating their learning of science content by eventually excelling at a fossil hunter game in which people related to paleontology were connected with their fossil finds or products and through responses to oral questions. Plans, results, and example student products document this effective arts-integrated science and engineering unit. Students expressed pride and excitement regarding their creations. Students engaged socially as they excitedly showed one another their creations and discussed their design choices.

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Key Words

Fossils, Cambrian Period, STEM, STEAM, Burgess Shale, elementary students, science models, elementary students, middle school students.

Introduction

A summer day camp elementary student on the second class day reported to the teachers:

I was disappointed yesterday when I found out that I didn't get into the art class and was put into this science class. I like science, but I wanted to do *art*. But now, I see how I get to do them *both* and it is *so much better* than just art! I love this class!

Art Integration into Environmental Education.

The theme of the annual weeklong music day camp of which this instructional unit was part was "Think outside the trash." Through music and the arts, classes emphasized reducing trash, reusing items or materials, and recycling. Song (2008) highlighted the importance of art integration for students to expand their environmental education: "art makes environmental education more experiential and helps to build appreciation, awareness, and a sense of shared responsibility for nature that students may carry throughout their lives" (Song, 2008, pg. 1).

Song (2008) discussed three problems of current environmental education that may be alleviated through arts integration: an emotionally detached perspective, a reactive, problem-focused approach rather a proactive, preventive view, and a very narrow scope that does not include reflection on the beauty of nature and its balance. The instructional unit on fossils of the Burgess Shale addressed these problem areas by encouraging students to develop an emotional connection to an ancient seafloor community through making appealing craft models of the organisms, by being proactive in making the models of recycled materials, and by appreciating the balance in nature by learning about the interrelationships of a fossil ecosystem.

Why Focus on the Burgess Shale? The Burgess Shale, an unusual seafloor ecosystem from half a billion years ago, was chosen as a focus for a strand of one-hour-a-day lessons at the day camp for two reasons: to assist students in considering how environmental changes can have devastating effects on a population and to use this population of animals to explore interdependence in a fossil ecosystem. Because animal populations on our planet are facing increasing pressures from global climate change, loss of habitat because of human encroachment (often through appropriation of land for natural resources to manufacture more products and sometimes through acquisition of land for landfills), pollution (some stemming from human trash), and other factors, it is important to understand and generate solutions for protecting ecosystems. The surprising and mysterious Burgess Shale fauna also provides an effective setting for considering interactions among fossil organisms and their relationships with the environment. In this unit, problem-solving and inquiry were used to teach science and engineering concepts to elementary and middle school students.

Literature Review

The following brief literature review first explains affective, thinking skill, and career benefits of arts integration into science. Then, information about how the Burgess Shale was discovered and some of the unusual creatures it contained are described.

The Benefits of Arts Integration into Science

Arts integration involves combining an academic subject with an art discipline such as music, visual arts, dance, and/or theater (Chicago Public Schools Office of Arts Integration, 2013). There are numerous benefits of integration of the arts with other subjects, and science in particular. Integration of art with other subjects promotes student curiosity and use of creative and analytical skills in other subject areas (Ceschini, 2014; Land, 2013; & Zeidler, 2014). Science and art complement each other: the sciences provide an analytical component, and art provides the associative (creative) component resulting in increased levels of creativity, curiosity, empathy, self-confidence, and collaboration (Nichols & Stephens, 2013).

Specific skills vital for science careers that can be developed through art include observation, visual thinking, the ability to recognize and form patterns, and manipulative ability (Root-Bernstein & Root-Bernstein, 2013). Moreover, the scientific method and creative process include many components that are similar and based on inquiry (Nichols & Stephens, 2013). Both of these processes employ creative problem solving and higher order thinking skills. Therefore, Nichols and Stephens, in an essay comparing the processes with model integrated lessons (2013), concluded that integrating arts into science lessons enhances student understanding of both artistic and scientific concepts.

The need for highly qualified professionals in STEM careers is growing quickly, but a significant lack of US-born undergraduates enroll in STEM programs (Land, 2013, p. 548). Arts integration increases student motivation to learn and enhances student ability to retain information, in addition to making STEM education more appealing to students (Land, 2013; Ceschini, 2014; Zeidler, 2014; & Chicago Public Schools Office of Arts Integration, 2013). Unfortunately, curriculum and instruction in current US schools focuses on addressing the needs of students primarily with verbal-linguistic and logical-mathematical intelligences (Ross, 2008). There is strong research-based evidence that arts integration benefits students and positively impacts their learning: Deasy (2002) compiled 62 research studies that showed an increase in student achievement as well as positive social effects of arts integration. Additionally, according to Ceschini (2014),

over a decade of implementing arts integration at a public school provides evidence that integration of art with other subjects equips teachers with a powerful tool for differentiating instruction and making curriculum more accessible to all students.

The Importance of the Burgess Shale

This section describes the discovery of two different nearby fossil-bearing formations and the unique creatures they contain.

Richard McConnell's Discovery. In 1886, while Canada was building a transnational railroad through the Rocky Mountains in British Columbia near the town of Field, a carpenter working on the hotel near the railway told geologist Richard McConnell about some stone bugs he had found nearby (Collins, 2009). This led to the discovery of the trilobite beds of the Stephen Formation on Mount Stephen.

Trilobites. Trilobites are interesting marine arthropods that, at first glance, look somewhat like beetles, but with many more pairs of legs. Besides using these legs for walking, crawling, or swimming, several types of trilobites use the spines or stiff hairs on their upper legs to capture and process worms. Trilobites straddle their prey, spearing the worm with leg spines. The worm is pushed to the middle of the underside of the body into the medial groove and, as the worm is moved forward to the toothless mouth, it is chopped into pieces by the upper legs (Fortey, & Owens, 1999).

Anomalocaris, the First Mystery Animal. A mystery animal was found in the trilobite beds along with the trilobites by Joseph Whiteaves in 1892 (Daley & Paterson, 2012). The creature's fossil impression looked like a headless shrimp and was named *Anomalocaris*, which means "odd shrimp" (Gould, 2000, p.194). These fossils, it was later discovered, were not shrimp, but the front grasping appendages of a large swimming predator of the Cambrian seas that may have preyed on trilobites and certainly ate other softer-bodied creatures (Daley, 2013). Several trilobite fossils with healed bite marks attest to close calls (Fatka, Budil, & Grigar, 2015), but some scientists dispute whether the mouthparts of *Anomalocaris* were strong enough to pierce a trilobite's carapace (Daley & Paterson, 2012).

Charles Wolcott. Another geologist named Charles D. Wolcott worked near Field in 1907, studying the Cambrian rocks (Royal Ontario Museum, 2011a). Toward the end of the summer, he located some soft-bodied fossils near Fossil Ridge. As he and his wife were descending the mountain, a horse stumbled on a rock in the trail. Wolcott struck the rock with a hammer to break it up, discovering some beautiful fossils; unfortunately, it was snowing and time to head for home at the end of the summer season.

The Burgess Shale. Two years later, Wolcott returned to find the source of those marvelous fossils and discovered the Burgess Shale nearby, across from Mount Burgess (Briggs, Erwin, & Collier, 1994). This deposit was a unique treasure trove of fossils with their soft parts preserved. This fossil find was so extensive and contained so many creatures that were new to science that Wolcott, the Director of the Smithsonian Institution, returned year after year to gather specimens. The most common fossil was *Marrella*, which Wolcott called the "lace crab" (Briggs, et al., 1994, p. 142). The second-most common fossil in the deposit was the crustacean *Canadaspis*, which looked something like a modern mole crab that lives off detritus, tunneling in wet sand. *Canadaspis* also likely churned sediment with its legs to find food.

A Giant Mudslide Deposit. Most of the animals of the Burgess Shale were seafloor dwellers who were caught up in a giant mudslide on the sloping Cambrian seafloor and were swept over a submarine cliff to be deposited in jumbled positions in a pile of sediment (Briggs, et al., 1994). These dead organisms were buried by layers of mud, then rapidly de-watered and compressed to preserve their fleshy parts in shale, a type of hardened, layered mudstone.

Five-Eyed *Opabinia*. Although many of the Burgess Shale fauna, such as *Canadaspis*, trilobites, sponges, and various seaweeds were easily classified, this ecosystem yielded some very surprising, unusual creatures. One of them was *Opabinia*, a small (4 to 7 centimeters in length) creature with a trunk-like appendage on the front of its five-eyed head that ended in grabber claws (Royal Ontario Museum, 2011b). This animal swam near the seafloor and probably hunted worms, plunging its trunk into holes to capture the creatures and then bending its trunk around to

feed them to its mouth on the underside of the head (Conway Morris, 1998). *Opabinia* was so bizarre that when paleontologist Harry B. Whittington showed his drawing of it during his presentation at a professional geology conference in 1972, the audience burst into laughter, thinking it was a joke (Royal Ontario Museum, 2011b).

Slug-like *Wiwaxia*. Another strange creature was *Wiwaxia*. This animal was slug-like with no eyes, but a mouth with teeth on the front underside of the body, presumably used to graze on algae. *Wiwaxia* was unusual because it had two rows of sclerite spikes on its back and many rounded sclerite armor plates for protection. The sclerite material (tough chitin, like the material of fingernails, with a striated microstructure inserted directly through the body wall; Conway Morris, 1998) suggests an affinity with polychaete annelid worms, although the soft muscular underbelly and pattern of teeth are reminiscent of mollusks (Smith, 2014).

Dreamlike *Hallucigenia*. A final creature to mention is *Hallucigenia*, so named for its weird, dreamlike appearance (Shipman, 2012). This animal had a wormlike main trunk with many pairs of spindly legs ending in pointed claws. Along its back were two rows of giant spines for protection.

Highly-Specialized Fauna. The Burgess Shale is not only notable for its unique preservation of anatomical details of its fauna that allow better interpretation of animal lifestyles and interrelationships in the environment. The greatest contribution of this find may be the discovery that Cambrian animals were not generalized, primitive organisms, but often highly specialized creatures with body parts well-adapted to specific roles in the ecosystem (Gould, 2000).

National Standards Addressed

This exciting fossil life unit addressed national standards from science, engineering and art. These are detailed in the following two sections.

Next Generation Science Standards

Science Standards. Three science-focused Next Generation Science Standards (NGSS Lead States, 2013) were supported by the rich set of lessons described in this

practical article. The first was NGSS Standard #3-LS4-1: “Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.” This standard was addressed as students discovered the unique preservation of the soft parts of Burgess Shale fossils. Students learned how scientists examine fossils and interpret them to unravel exactly how the organism looked and the features it had. They heard about mistakes paleontologists made such as misidentification of parts of *Anomalocaris* as separate organisms and of *Hallucigenia* being first portrayed as upside-down.

The second standard addressed was NGSS Standard #3-LS4-3: “Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. Students learned of the lifestyles of various fossil organisms and the evidence that verifies these ideas. Students found out how scientists often compare a fossil organism to a modern organism with similar body parts and features to generate ideas about how it may have lived. In particular, the crab *Canadaspis* has been compared to the modern mole crab and *Wiwaxia* has been compared to a sea slug.

A third standard was also supported through the lessons; NGSS Standard #3-LS4-4: “Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.” After students learned of several different organisms of the Burgess Shale fauna, they considered the changes occurring to our modern oceans of pollution, temperature rise, and overfishing. They considered different solutions to these problems and their merits.

Engineering Standards. The fossil unit also employed engineering practices as these have been recognized as important. As students engage in engineering practices they take on a proactive perspective for problem-solving and prevention. Song (2008) observed that students’ attitudes towards environmental issues evidenced “emotional detachment from nature; an emphasis on a reactive, rather than a preventive, approach” (Song, 2008, p. 1). Creating models from plastic lids, bottles, and other items that might have become trash prevents landfills from taking over the landscape. The fourth standard addressed was NGSS Standard #3-5 ETS1-1: “Define a simple design problem

reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.” This engineering standard was implemented as students made various models of the fossil organisms using given materials. In particular, student work supported this standard when they made a fossil organism with the recycled bottles, plastic lids, pipe cleaners, pony beads, and pieces of glittered foam. The animal, through the use of recycled items, had to be constructed so that all attachments were engineered with pipe cleaners and beads.

National Core Arts Standards

Several National Core Arts Standards (State Education Agency Directors of Arts Education, 2014) were supported by the project. Anchor Standard #10 states that students will synthesize and relate knowledge and personal experiences to make art. This standard was addressed as students created their organisms using information they were acquiring at camp. Students learned about fossils daily and used this knowledge to create models of fossil organisms. Arts integration offers a multi-dimensional solution for students to engage in problem-solving from varying perspectives. Encouraging students to engage in activities aimed at multiple perspectives allows the students to gain deeper connections and understanding of the task at hand. Anchor Standard #11: Relate artistic ideas and works with societal, cultural and historical context to deepen understanding. This standard was addressed daily as students created models of the fossil organisms and environmental dioramas where these organisms lived during their lifetime. Students made connections with the extinct organisms and their sea habitats from their historical period.

The Lessons

This section details the context and students with which the lessons were implemented; the inquiry structure of the lessons; the model-making activities; some engineering concepts taught during the pipe cleaner, bead, and plastic recycled item model-making activities; and the fossil-making work on natural stones.

Summer Camp Students

The lessons took place at a one-week summer music camp at a university with the green theme of “think outside the trash.” Over 200 students from preschool through ninth grade attended the summer day camp; fourteen of the upper elementary to middle school-aged students attended the one-hour-a-day strand of lessons described here that focused on learning about Burgess Shale fossil creatures and making models of them from recycled materials. During the weeklong camp, students took music lessons, singing lessons, danced, and practiced their parts in an hour-and-half musical production that was presented to families and community members on the afternoon of the last day of the camp.

The students who took part in this unit constituted a diverse group. Fourteen students (7 female, 7 male) of different racial and ethnic backgrounds (2 African American, 4 Hispanic, and 8 White) and of different ages entering grades 4 through 9 participated. Signed parent and student consent was obtained for photographs of students and their products to be included in this practical article.

Organization of the Lessons

The lessons were presented as 5E Learning Cycles. Research from Bransford, Brown, and Cocking (2000) along with Abdi (2014) supports learning processes that have emerged from inquiry-based teaching approaches. These researchers found that “in inquiry-based science education, children become engaged in many of the activities and thinking processes that scientists use to produce new knowledge” (Bransford, Brown, & Cocking, 2000, pg. 37).

The one-week unit had five approximately one-hour lessons as shown in Table 1. On several days, students played a Fossil Hunter Game. This game used a set of large, illustrated color cards with a ribbon attached so that each card could be worn over the chest suspended by a ribbon that went around the back of the neck. The set consisted of pairs of cards, one a fossil hunter or person related to fossils and the other card of each pair a fossil find or product related to fossils. The object of the game was to find the card that corresponded to the one you were wearing. See Table 2 for the information used in this game.

Table 1. *The 5E's Learning Cycle Lesson Structures for the Five Day, One-Hour-a-Day Class* (Table extends across three pages)

Day and Standard	5E's Learning Cycle Part	Activity
Day 1 NGSS Standard 3- LS4-1	Engage	Gain attention by showing a picture of the original fossil part of <i>Anomalocaris</i> , called "odd shrimp" because it seemed shrimplike, but had no head. Tell students scientists were puzzled by this fossil – what do they think it represents?
	Explore	Ask students to tell a person nearby what they think the fossil could be. Have volunteers report their ideas and their reasoning.
	Explain	<u>Finding and Interpreting Fossils</u> . Show a slideshow about the fossil trilobites of the Stephen Formation near Field, British Columbia, how they were found by railroad workers who called them "stone bugs," and the odd <i>Anomalocaris</i> fossils found there. Images in the slide show explain how trilobites used spines on their inner legs next to a medial groove on their underside to capture and chop worms that they then passed to the mouth for eating. The slide show also describes how <i>Anomalocaris</i> was misidentified, how the creature was made of many parts, and it's lifestyle of preying upon smaller organisms, including trilobites. Trilobites with bite marks on them are shown as evidence of predation.
	Expand	Students practice the skill of scientific drawing by using a fine-tipped black ink pen to draw dots and lines on a life-size painted cardboard trilobite model. They also add glitter glue highlights, jewel eyes, and a pin back to complete a trilobite badge.
	Evaluate	Students place <i>Olenoides</i> trilobites on or near the seafloor in their Burgess Shale Cambrian sea diorama. Questions: Why did railroad workers call trilobites "stone bugs"? What is similar between a trilobite and an insect? Why did scientists have a hard time identifying the real <i>Anomalocaris</i> animal? What evidence is there that <i>Anomalocaris</i> ate trilobites? How did trilobites eat worms?
Day 2 NGSS Standard 3- LS4-3.	Engage	Play the Fossil Hunter Game in which each person receives a printed sheet that is supported by a ribbon hung around the neck. Half of the sheets describe a "Fossil Hunter" or a person connected to fossils. The other sheets describe a "Fossil Find" or a product connected to fossils. The object of the game is to find the person whose placard is a partner to yours. As students locate their partners, freeze players and explain their connections, then resume play. Show a photo of a fossil of the crustacean <i>Canadaspis</i> to gain student attention and to focus them on the fossil they will encounter today. Ask: What kind of animal was this? How did it live?
	Explore	Ask students to tell a person nearby what they think the fossil could be. Have volunteers report their ideas and their reasoning.
	Explain	Comparison of a Fossil Organism to a Modern Organism to Generate Ideas for Survival in an Environment. Show a slideshow that explains how Charles Wolcott discovered the Burgess shale with the crustacean <i>Canadaspis</i> being the most common fossil. The slide show compares <i>Canadaspis</i> to modern mole crabs in general anatomy and in lifestyle. <i>Canadaspis</i> ate detritus and worms by stirring the sediment with its legs; mole crabs have a special digging apparatus to quickly dig into the sediment; they eat detritus.



	Expand	<p>Students practice the skill of scientific drawing by using a fine-tipped black ink pen to draw dots and lines on a life-size painted cardboard <i>Canadaspis</i> model. They also add glitter glue highlights, jewel eyes, and a pin back to complete a crustacean pin.</p> <p>Students search through fossil books and choose a fossil organism to make. They use several sets of a commercial toy by Zolo, Inc. (2016) called Curious Bonz, Sea Bonz, and Dragon Bonz to construct the organism. This toy has organic-shaped snap-together parts such as claws, trunks, wings and bodies, etc. They present their construction and explain its features.</p>
	Evaluate	<p>Students place <i>Canadaspis</i> crabs on or near the seafloor in their Burgess Shale Cambrian sea diorama. Questions: Explain why scientists often compare fossil and modern organisms that seem similar. What might be learned from this? How can comparison to a modern organism help explain how the animal survives in an environment?</p>
Day 3 NGSS Standard 3- LS4-3	Engage	<p>Play the Fossil Hunter Game.</p> <p>Show a photo of a <i>Wiwaxia</i> fossil. Ask: What kind of animal is this fossil? How did it live? What is your reasoning?</p>
	Explore	<p>Ask students to tell a person nearby what they think the fossil could be. Have volunteers report their ideas and their reasoning.</p>
	Explain	<p>A slideshow gives facts about <i>Wiwaxia</i>'s lifestyle similar to a slug that eats algal mats on the ocean floor.</p>
	Expand	<p>Students make a felt and glittered sheet foam model of <i>Wiwaxia</i>. They cut the sclerite blades and round sclerite disks from glitter-covered foam and glue them on an ellipsoidal felt model stuffed with fiberfill.</p> <p>Students search through fossil books and choose a fossil organism to make. They construct the fossil organism from plastic lids and small bottles with holes drilled into them, pipe cleaners or chenille stems, plastic pony beads, and pieces of glittered sheet foam cut with scissors and pierced with a hole punch for attachment tomorrow. They present their model and explain its features for survival.</p>
	Evaluate	<p>Students place <i>Wiwaxia</i> on or near the seafloor in their Burgess Shale Cambrian sea diorama. Questions: What could be a predator of <i>Wiwaxia</i>? How did comparing <i>Wiwaxia</i> to a mollusk or snail help in determining its lifestyle? What does <i>Wiwaxia</i> need to survive in its environment? What did <i>Wiwaxia</i> use for protection from predators?</p>
Day 4 NGSS Standard 3- LS4-1	Engage	<p>Play the Fossil Hunter Game again, this time, students are divided into two teams (girls and boys) that must choose the correct match for given fossil hunters. Winning students are allowed first choice of drilled plastic bottles for their pipe cleaner and bead organism constructions.</p> <p>Show an image of a drawing of <i>Opabinia</i> by an artist. Ask if it is real. Ask what would have to be changed to make it a real creature.</p>
	Explore	<p>Ask students to tell a person nearby whether they think the animal in the drawing could be real and what might have to be changed to make it real. Explain reasoning. Call on volunteers to tell their thoughts.</p>

NGSS Standard #3-5 ETS1-1	Explain	Show a slideshow about <i>Opabinia</i> and its lifestyle. Show photographs of <i>Opabinia</i> fossils and point out the evidence that it had a trunk, grabber claws, and five eyes. Show also a slide show on the more recent (Pennsylvanian) fossil from concretions in eastern Illinois from the Mazon Creek Formation called the Tully Monster. This creature also has a trunk that ends in a grabber claw.
	Expand	<p>Students practice the skill of scientific drawing by using a fine-tipped black ink pen to draw dots and lines on a life-size painted cardboard <i>Opabinia</i> model. They also add glitter glue highlights and five jewel eyes.</p> <p>Students begin work on their fossil creature made of recycled plastic bottles, lids, beads, glittered foam, and pipe cleaners or chenille stems.</p>
	Evaluate	Students place <i>Opabinia</i> on or near the seafloor in their Burgess Shale Cambrian sea diorama. Questions: What was <i>Opabinia</i> 's trunk with grabber claw used for? Why did <i>Opabinia</i> have five eyes? We only know about <i>Opabinia</i> because the Burgess Shale preserved soft parts of animals. Do you think other strange animals lived that we don't know about?
Day 5 NGSS Standard 3- LS4-4	Engage	Show a photograph of a <i>Hallucigenia</i> fossil. Ask students what animal the fossil represents.
	Explore	Ask students to tell a person nearby what they think the fossil could be. Have volunteers report their ideas and their reasoning.
NGSS Standard #3-5 ETS1-1	Explain	<p>Present a slideshow about <i>Hallucigenia</i> and how it was misidentified as upside-down until a similar fossil creature was discovered in China. The name <i>Hallucigenia</i> refers to the dreamlike quality of the strange creature.</p> <p>The organisms of the Burgess Shale no longer live on the seafloor in our modern times. Some of these organisms do have some relatives that live in our modern oceans. However, the chemistry and temperature of seawater have changed since a half-billion years ago. Also, new predators have evolved. Currently, the temperature of sea water is rising and that is making the populations of sea animals change. Also, human populations have increased and many parts of the ocean are over-fished. Some sea animals have gone extinct and others are endangered. What solutions might we have to these problems? Explain the merits of your solution.</p>
	Expand	<p>Finish the organism constructed out of recycled plastic lids and bottles, beads, foam, and chenille stems. Explain how its features helped it survive.</p> <p>Create a fossil on a rock. First, locate a fossil in a book that is of interest. Then use a permanent marker pen to draw the fossil on a smooth surface of a rock.</p>
	Evaluate	<p>Students place the <i>Hallucigenia</i> sticker on the seafloor in their Burgess Shale Cambrian sea diorama. They glue the <i>Wiwaxia</i> model on the seafloor of the diorama.</p> <p>Students present their fantasy creatures to the class and these are photographed. Students explain how the body parts help the animals survive.</p>

Table 2. *Ideas for Fossil Hunter Game* (Table extends across two pages)

Text for Fossil Hunter Card	Text for Fossil Find Partner Card	Sources
British fossil hunter, Mary Anning, searched Jurassic marine fossil beds in the cliffs along the English Channel with her faithful dog named Tray.	This fossil hunter recognized that coprolites, called bezoar stones at the time, were really fossilized animal droppings or poop. This fossil hunter found the first fossil plesiosaur in 1824 in the cliffs by the sea.	Information about Mary Anning's life can be found at BBC (2014). Many interesting facts are in the biography by Scott (1996-2016).
Roy Chapman Andrews was the Director of the American Museum of Natural History. He used automobiles and camels to explore Mongolia for fossils.	This fossil hunter was likely the inspiration for Indiana Jones. He found the first nests of dinosaur eggs and discovered specimens of <i>Velociraptor</i> and <i>Oviraptor</i> in East Asia.	Information about Roy Chapman Andrews can be found in a video by (Comic pencil, 2009). Photos of Andrews and his work in excavating dinosaurs can be found in Bausum (2001).
Sue Hendrickson collected insects encased in amber and enjoyed participating in many fossil digs. She worked on a fossil dig in South Dakota led by the Black Hills Institute of Geologic Research that resulted in this incredible find.	This fossil hunter discovered a small trail of bones that led to the largest Tyrannosaurus Rex ever discovered, now in the Chicago Museum of Natural History. The T-Rex was named for this person.	Information about Sue Hendrickson can be found on her website (2016). Information about Sue Hendrickson and other women associated with dinosaur finds is available in Turner, Burek, and Moody (2010).
Barnum Brown was named after the famous circus personality, P. T. Barnum. Barnum Brown was a fossil hunter for the American Museum of Natural History and discovered many fossils out West with some questionable and reckless methods.	This fossil hunter used to dynamite large areas of land, sort through the rubble for bones, and bring them back to camp in horse-drawn carriages. This fossil hunter found the very first Tyrannosaurus Rex skeleton in 1902.	Information about Barnum Brown's life can be found at the Smithsonian website (Switek, 2010) and Discover Magazine website (Dingus & Norrell, 2007).
Joan Wiffen is called the "Dragon Lady" by the press because of her interest in dinosaurs and paleontology. She was a talented amateur paleontologist from New Zealand who made some important discoveries.	This fossil hunter proved that dinosaurs once roamed New Zealand. This person discovered a new genus of mosasaur in New Zealand and some theropods.	Information about Joan Wiffen can be found at Te Papa (Museum of New Zealand, n.d.) and New Zealand Geographic (Molnar, 2009).
Jose F. Bonaparte was a collector of fossils as a child and eventually opened a small museum in his hometown in Argentina. He is a senior scientist at the National Museum of Natural Sciences in Buenos Aires.	This fossil hunter discovered the world's largest dinosaurs (Titanosaurs) and helped to bring Argentina to sixth spot in the world dinosaur charts.	Information about Jose F. Bonaparte can be found at Fundacion Konex (2016) and Strauss (2016).
Luis Alvarez won a Nobel Prize in Physics for his discovery of resonance states. He became interested in geology and fossils because his son was a geologist. He thought of a theory about dinosaurs.	This person theorized that dinosaurs became extinct when a large meteor hit the Earth, threw up dust that blotted out the sun, and killed plants, their food source.	Information about Luis Alvarez can be found at the Famous Scientists website (Stewart, 2014).



Text for Fossil Hunter Card	Text for Fossil Find Partner Card	Sources
Charles D. Walcott was the director of the U.S. Geological Survey, and finally director of the Smithsonian Natural History Museum. He traveled to Canada in search of fossils for the Smithsonian.	This fossil hunter discovered the famous Burgess Shale in the mountains of British Columbia and its well-preserved soft parts of trilobites and unusual Cambrian fauna.	Information about Charles D. Walcott can be found at the Smithsonian Institution Archives (1999).
Michael Crichton, American best-selling author, physician, producer, director, and screenwriter, best known for his work in science fiction.	This person wrote the novel <i>Jurassic Park</i> , which became a thriller movie about scientists who clone dinosaurs from the blood of mosquitoes preserved in amber.	Information about Michael Crichton can be found at the official site of Michael Crichton (CrichtonSun, 1997-2015).
Mignon Talbot was born in Iowa City, Iowa, studied geology at Ohio State University and completed a Ph.D. at Yale. She became a Professor of Geology at Mount Holyoke College in Massachusetts.	This female geologist discovered many Triassic footprints of dinosaurs and created a collection for a university. This fossil hunter discovered the first skeleton of <i>Coelophysis</i> .	Information about Mignon Talbot can be found in Talbot (1911).
Richard McConnell was a geologist for the Canada Geological Survey. Railroad workers told him about "stone bugs" on a mountainside.	In 1886, this geologist discovered the Trilobite Beds of the Stephen Formation in British Columbia in Canada.	Information about Richard McConnell can be found at the Royal Ontario Museum's website (2011c).
Tilly Edinger was a Jewish German paleontologist who moved to the United States in 1940 and worked at the Harvard Museum of Comparative Zoology.	This paleontologist made casts of the inside of fossil skulls (endocasts) to study the brains of horses through time.	Images and information from Freidenreich (1998-2016) and TrowelBlazers (2016).
Lisa White is an African American Paleontologist at the University of California at Berkeley.	This paleontologist unraveled ancient ocean patterns by mapping marine microfossils.	Images and information from the University of California Museum of Paleontology (2016) and in Sharlach (2016).
This child, pretending to be a paleontologist tour guide, was used to introduce a product idea by an American Company.	Mattel's African American Paleontologist Barbie	Screen captures of child playing paleontology museum tour guide from video at Mattel, Inc. (2016).
Mee-mann Chang is a Paleontologist from China	This scientist studies fossil fish.	Information about Mee-mann Chang can be found at her website (Chang, n.d.).
African American David Wilcots has a master's degree in geology from Fort Hays State University in Western Kansas.	This scientist created a fossil news website for young people. He also participates in fossil digs for a museum.	Information about David Wilcots can be found at his Dinosaurs, Fossils & Adventures website (Wilcots, 2014).

The Craft Models

Many different models were made of the fossil animals during the unit. Some were placed inside the diorama, while others were worn as pins/ badges or served as stand-alone models. These exciting projects are described in this section.

Dioramas of Fossil Life. The dioramas were made using recycled blue plastic tubs that originally contained fresh mushrooms and were wrapped in plastic wrap at a grocery store for sale. The fossil scenes (drawn by the last author), shown in Figure 1 and Figure 2, were printed in color on whole-page label or sticker paper so that they would easily adhere to the plastic tubs. Each of these backgrounds was outlined in a cross shape with dotted lines. One page was to be used to cover the inside of the tub; the other was used to cover the outside of the tub. Extra images of the fossil animals were placed on the page to be cut out and applied to the scene in the appropriate areas. Application of fossil animals in their habitats on, above, or within the water column was part of the assessment of student understanding. The white ribbon drawing in Figure 1 was where the student could write his or her name. Full-page fossil scenes are available in the Appendix of this article.

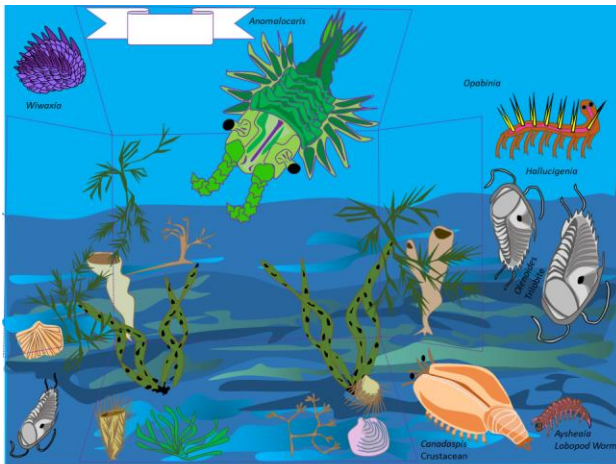


Figure 1. The first of the diorama background scenes



Figure 2. The second background scene

Cardboard Models. Figure 3 shows the patterns of cardboard pieces that were stacked on top of each other to make the trilobite cardboard base. This figure also shows the steps of making the trilobite. First, the cardboard pieces are securely glued on top of each other. Then, the trilobite was covered in white gesso, a stiff paint base. The trilobite was then painted. Students shaded the model with dots and small lines while looking at a scientific drawing of the trilobite. Glitter glue was applied to highlight some areas. The eyes are added with enough white craft glue to form a ring around the edge to hold the acrylic jewel in place. This white glue dried clear. Finally, a pin clasp was added to the back of the trilobite.

Figure 4 shows the pattern of cardboard pieces that were stacked on top of each other to make the *Canadaspis* cardboard base. In a way similar to the trilobite model, the pieces were glued together in order. Two bases were cut out and glued together as shown to make a stiffer, thicker model. This figure does not show the step of painting the cardboard model with white gesso. Also, the last steps are not individually shown. The last image shows the completed *Canadaspis* pin.

Figure 5 shows the cardboard pieces that were stacked on top of each other to make the *Opabinia* cardboard base. The same process was used for each model in terms of stacking and gluing cardboard pieces on top of each other.





Figure 3. Pattern for cutting cardboard pieces and steps in making the *Olenoides* trilobite

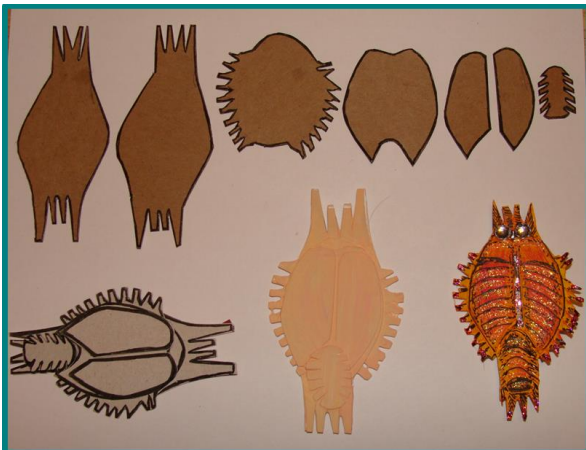


Figure 4. Pattern for cutting cardboard pieces for *Canadaspis*

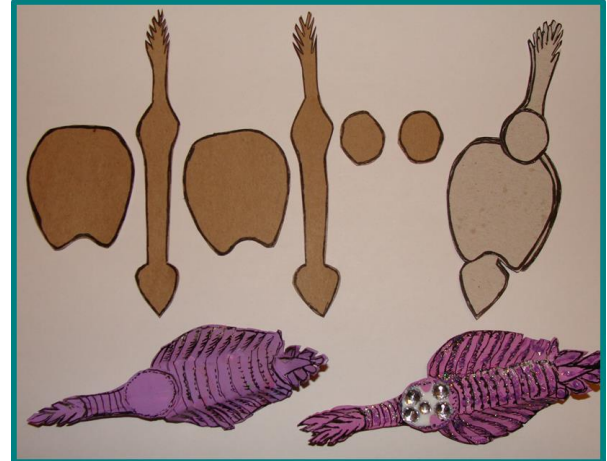


Figure 5. Pattern for cutting cardboard pieces for *Opabinia*

Wiwaxia Felt and Glitter Foam Model. Figure 6 shows the pieces for a *Wiwaxia* model of felt scraps. First, one top and one bottom pattern piece were cut from felt. A piece of cardboard was cut to be the insert that holds the flat shape of the bottom of the organism. Using thread and needle, a line of running stitches was made along the edge of the bottom felt piece. The cardboard insert piece was placed into the middle of the bottom felt oval. The thread was tightened so that the cardboard edges were covered with felt. The thread was knotted so that the gathered felt would stay in place. A line of running stitches was made along the edge of the top felt piece. The thread was tightened so that the shape fit on the top of the felt covered bottom. The top piece was stuffed to pad the *Wiwaxia*. The top and bottom parts were whip-stitched together. Sclerites were cut with scissors or a hole punch from glitter-covered foam and glued to *Wiwaxia*.

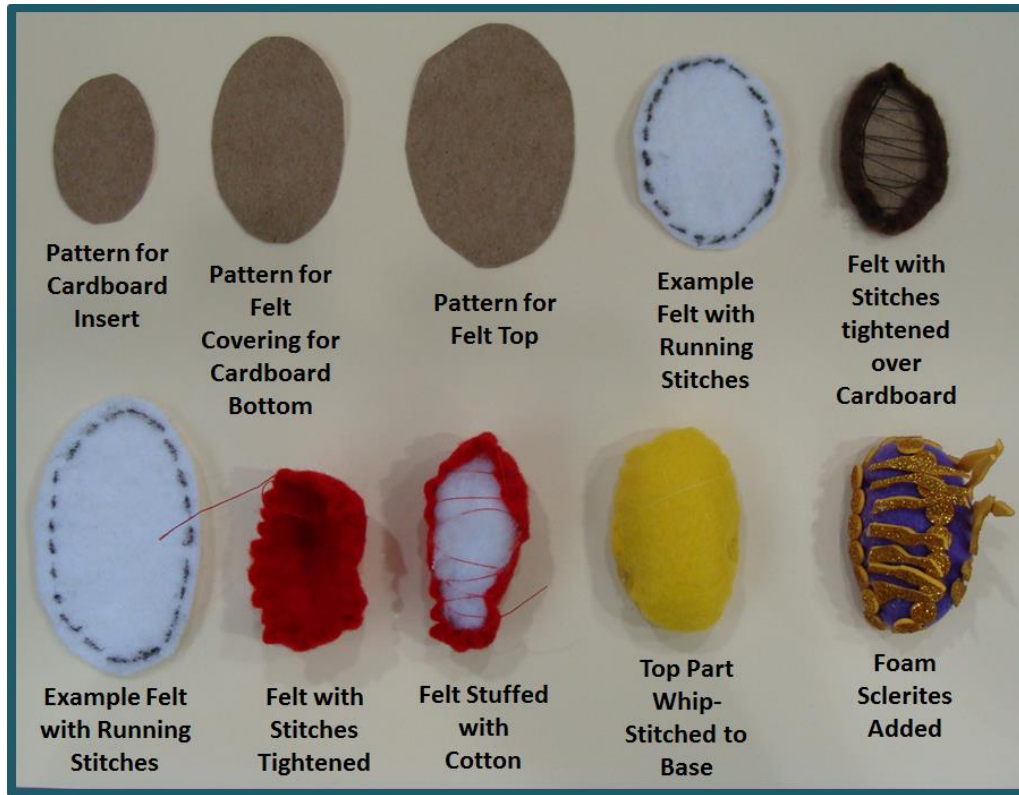


Figure 6. Pattern for *Wiwaxia* felt model

Fossil Animal Models Made from Recycled Plastic Lids and Small Bottles. To match the camp’s theme of recycling “trash” items, students constructed their own fossil models made from plastic lids or various pieces, pipe cleaners, beads, and glitter foam. Prior to the activity, instructors drilled various holes into pieces of recycled plastic such as lids and containers of different sizes. Students decided which fossil they wished to recreate based on the slideshows they had viewed during the week, or from images they found in fossil books. Students attached their various pieces of plastic together using pipe cleaners to loop through the holes in the plastic. For example, as shown in Figure 7a, a bead could be looped onto a pipe cleaner to form a knot for holding the pipe cleaner in place. Figure 7b shows how a leg or antenna might be constructed by stringing a bead endpoint onto a pipe cleaner and then adding beads on both parts of the pipe cleaner to make the linear appendage. Figure 7c shows how a bead might be added and the end of the pipe cleaner could be twisted against the rest of the pipe cleaner to anchor it.

Finally, 7d shows a pipe cleaner being threaded through a piece of foam for attachment.

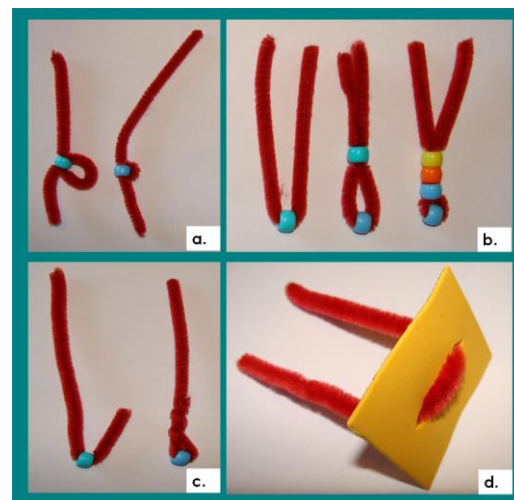


Figure 7. Some engineering techniques for constructing with pipe cleaners and beads.

Simulated Fossils Drawn on Rocks. For an extension of the activities of the week, students who completed the other activities early were given a rock to create a homemade, simulated fossil. Rocks of various shapes and sizes were provided. Using a permanent marker and illustrations from books, students drew a fossil onto the rock.

Results: Student Discussion Ideas

Engagement and Exploration Activity Discussions

The first day began with a discussion in which the students were shown an unmarked fossil (*Anomalocaris*) and asked what they thought the fossil could be; student responses included a caterpillar, lobster, gecko, arthropod, shrimp, water scorpion, centipede, and water parasite. Students based their guesses on the segmented shape of the fossil (caterpillar and centipede) and its similarity to crustacean body parts (arthropod, shrimp, water scorpion). These were appropriate scientific ways to begin the investigation. Students were then informed it was an *Anomalocaris* and proceeded to view a slideshow about this fossil predator.

Day 2 started with the students being shown a very large shell-like fossil photograph and being asked, "What do you think it is?" Student responses included a turtle, water arthropod, snail, hermit crab, salamander, and horseshoe crab. Again, students noticed the shell-like nature of the fossil and guessed appropriately. Students were then informed it was a *Canadaspis*, and they proceeded to view a slideshow about the crustacean.

Day 3 began with a recap of the previous two days. Students were asked to name the previous two fossils they had learned about; student responses included strange shrimp and trilobite. Students were then asked what the railroad workers called the fossils they found; one student responded, "Stone bugs because their skeletons were on the outside of their bodies." Students then engaged in a discussion of what type of organism another fossil photograph might represent. They then viewed the slideshow featuring the lifestyle of *Wiwaxia*.

Day 4 engaged the students in a discussion based on a drawing of a possible fossil animal (the image was of

Opabinia). Students were asked if this animal could be real and if not, what changes would need to be made for it to be a real organism. Students' responses included "I would add two grabber arms like the *Anomalocaris*," "I wouldn't want it to have too many eyes," "this picture looks like part of his tail is missing; he needs more tail," and "I would take an arm off and give him longer legs." Following this discussion, the students watched a slideshow featuring *Opabinia*.

Day 5 involved a class discussion recapping all of the information previously covered throughout the week. Students were shown an unidentified fossil (*Hallucigenia*) and encouraged to think about what it might be based on what they had learned during the week's activities. Student responses included "This is a type of bug that starts with 'h'," "a scorpion," "an underwater creature," and "it starts with 'h' and has a 'u' in it." Students were then informed the fossil picture they were viewing was *Hallucigenia*. Students were then engaged in a slideshow about this unusual organism.

All of these questions about photos of fossils effectively engaged students in enthusiastic speculation and use of scientific inference skills. They were ready to learn more after each discussion.

Factors Causing Current Sea Life Endangerment

The Next Generation Science Standard about environmental changes and their effects on an ecosystem was met as students discussed real-life problems that were occurring in addition to potential solutions. Students identified the following challenges facing sea life in the current oceans: oil spills, pollution, dioxin, oceans turning acidic, global climate change, landfills in the ocean (garbage dumping), hunting of endangered animals, and overfishing. The elementary and middle school students then generated possible solutions to these problems. For overfishing, have laws on the number of fish that can be caught and throw back some. For pollution, don't allow cities to throw garbage here; clean garbage out of ocean water. For endangered species, have laws against hunting and fishing with fines. Several students suggested ideas for solving oil spill problems: put up signs and tell companies not to spill oil into the oceans, stop using oil so boats won't transport it, and stop boats from using oil and require them to use another energy source. Unfortunately,

time was limited and so students could not pursue these issues further.

Results: Student Products

Throughout the course of this instructional unit, students engaged in activities aimed at expanding their creativity through the artsy model construction of fossils they were studying. As the week progressed, students were able to see their creations grow in number and could view and compare their products to one another. This situation allowed students to critique their work, perhaps learning from what went well or did not go well, and then to tackle the new task at hand with this gained knowledge very fresh in their minds.

Recycled Cardboard Models of Burgess Shale Animals

Figure 8 shows example student-made *Olenoides* trilobite models made of layers of recycled cardboard, painted in white gesso, painted in color, with drawn ink details, and with jewel eyes and glitter accents. Students were tasked with drawing the details of their trilobites through the use of shading with pens and markers with fine tips. Some students produced trilobites with great detail in their shading, while other students struggled to achieve fine details in their drawings. This discrepancy in skill and production could be attributed to students' levels of experience and also their large age range.



Figure 8. Example *Olenoides* trilobite models.

Figure 9 presents cardboard models of the most common fossil of the Burgess Shale, the crustacean *Canadaspis*.



Figure 9. Example student-made *Canadaspis* models

Models of the unusual five-eyed *Opabinia* are presented in Figure 10. These models show the trunk-like appendage that ends in grabber claws and the side flaps that enable the animal to breathe and swim. Students further refined their skills when making these models.



Figure 10. Models of *Opabinia*.

Underwater Fossil Scene Dioramas

Photos of two students working on their dioramas are shown in Figure 11. The dioramas and other models students created during the class were put on display the last day for families to view after the musical presentation of this weeklong summer music day camp. A view of the display is shown in Figure 12. The students were excited when they saw an example diorama; they were eager to make one by themselves. However, when they initially received the materials for the diorama, many of them were puzzled.

Teachers gave the students detailed instructions on how to cut and apply stickers onto the plastic blue tub. Despite that, several of the students were confused and hesitant to start working. One of the reasons for such reaction, according to one of the students, was the fear to cut the stickers in an incorrect way and ruin the project. Another student said that she did not understand how to attach a flat rectangular piece of paper to a box so that the whole box would be covered. That student may not have been familiar with using engineering skills and spatial skills, and mentally manipulating objects to create a step-by-step mental plan of

how to achieve a desired result without physically altering the objects. Several other students were not familiar with cutting and folding paper to make it into a 3D object, a box. Some students also seemed to have had difficulties with peeling off the sticker paper. These students had not had a chance to work on projects involving sticker paper before, and, after unsuccessful attempts to peel the stickers off, they decided to use glue. However, their teachers helped them to learn how to cut out the stickers, peel them from the waxy backing packer, and apply them.

This part of the project addressed the standard on interpreting the environment for a fossil organism as students chose the best location in the substrate, sediment surface, or water column for each sticker organism. Felt models of *Wiwaxia* were also glued in the correct locations near algae.

While cutting, folding, ensuring that the edges of the paper aligned with edges and corners of the boxes and applying stickers to the blue plastic boxes, the students practiced their fine motor skills, engineering, and spatial skills. Students learned to use a given pattern to fold and cut paper and make a 3D object out of a 2D object.



Figure 11. Students working on the fossil scene dioramas.



Figure 12. Table display on the last day of student products for families to see

Fossil Toy Models Made by Students

Students had the opportunity to explore sea creature anatomy as they browsed fossil books and snapped together plastic toys to make models. Students made basic science observations of shape, weight and balance as they worked to connect various plastic pieces together. Several students struggled with maintaining a balanced weight of their fossil model and became frustrated when their model was unable to stand up. However, these students exhibited

problem-solving skills as they removed certain pieces of plastic and rearranged them to achieve a model fossil similar to the one they had looked at in their book as their example. Additionally, students engaged in social learning as they worked alongside one another and were able to observe their peers' successes and failures of engineering as they constructed their own models. Figure 13 shows a composite of photographs of students with some of the models they made.

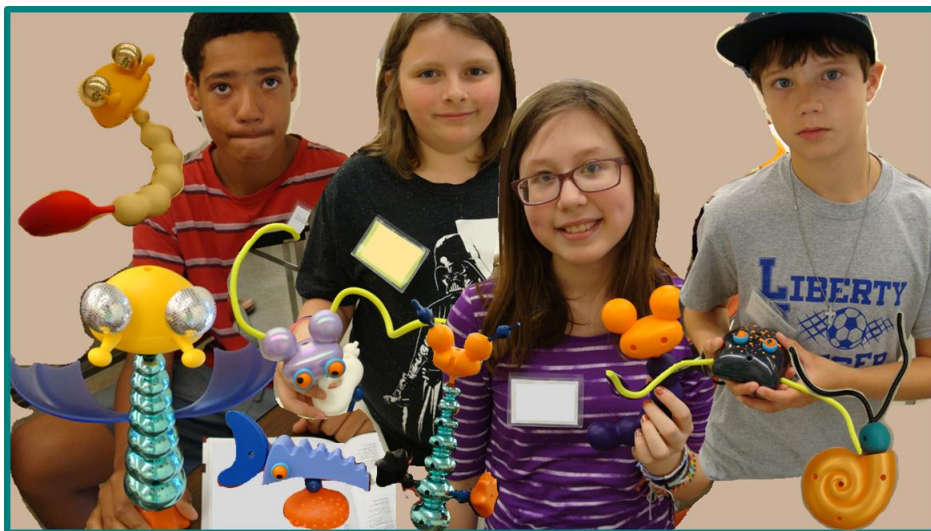


Figure 13. Student models of fossil animals made with a commercial toy

Recycled Felt and Glitter Foam Models of *Wiwaxia*

Students particularly enjoyed armoring their models of *Wiwaxia* with many sclerite spines and plates. The age range and accompanying skill levels of the participating students were particularly evident during this activity. Several instructor-made models of the *Wiwaxia* were available for students to examine. The younger students had difficulty visualizing how their raw materials could be used to create the finished product. Instructor guidance was needed to assist younger students in terms of cutting and hole-punching their foam glitter prior to application. The younger students lacked some of the fine motor skills needed to apply such tiny pieces of foam glitter to their felt *Wiwaxia* body, with several students gluing their foam glitter to themselves instead. However, with instructor guidance and a longer amount of time, the younger students persevered and completed their *Wiwaxia* models. Upon returning the next day, the younger students were very excited and proud to see their finished product after all of their hard work.

The older students had a much easier time creating their *Wiwaxia* models. They took care in cutting out their

materials to create the sclerite spines and plates. Some created more triangular shapes, while others were long and slender. One girl actually cut her spines to increase in height as they went from the front of the *Wiwaxia* to the back. Some also selected specific colors to coordinate with the color of the material that made up the body. See Figures 14 and 15.



Figure 14. Models of *Wiwaxia*



Figure 15. Composite of photos of students working on *Wiwaxia* models.

Recycled Plastic Lids or Bottle Models of Fossil Animals

The Next Generation Science Standard about designing a problem solution that includes criteria and constraints was supported by making models of fossil organisms from recycled plastic pieces, pipe cleaners, and plastic pony beads. Figures 16 through Figure 20 show models made by attaching plastic lids or bottles with pipe cleaners and pony beads. Glitter foam was also allowed in these constructions.

The students who participated in this camp varied in age, in terms of skill set the variation of student's ages was very apparent during the construction of their recycled fossils. Some students produced more than one recycled fossil model with excellent attention to detail that were both structurally sound and creative, while the younger students appeared to struggle with the completion of one. The most pronounced barrier for the younger students in terms of constructing a recycled fossil appeared to be in terms of both motor skills (figuring out how to physically attach their pieces) as well as their spatial skills (visualizing where they needed to place specific pieces in order to obtain the desired outcome), however, the younger students exhibited a high degree of perseverance as they continued to try constructing their recycled fossil in light of several barriers making it difficult.



Figure 17. Student-made models of *Anomalocaris*

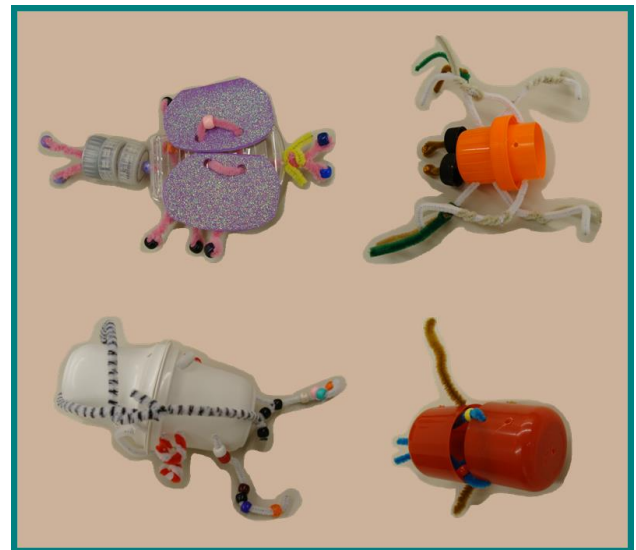


Figure 18. Student models of the crustacean *Canadaspis*

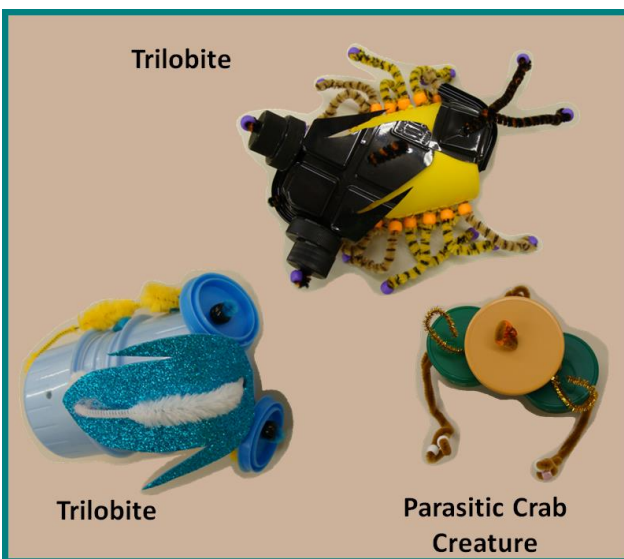


Figure 16. Models of trilobites and an imagined parasitic crab with lures on its front Appendages



Figure 19. Student-made models of *Opabinia* showing trunk-like appendage with grabber claws.

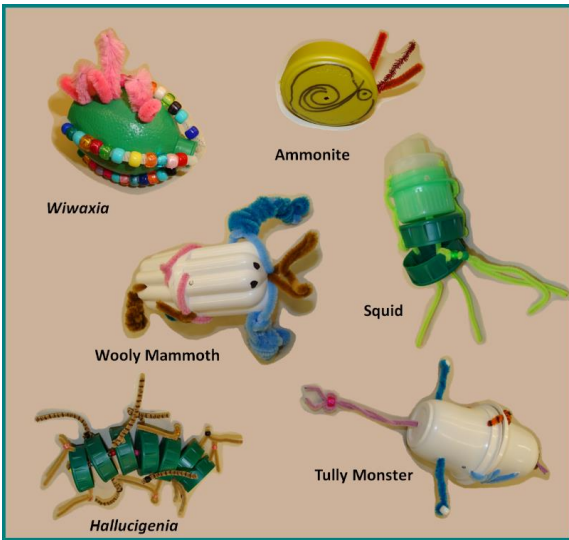


Figure 20. Other fossil organisms

Simulated Fossils Made by Drawing Images on Rocks

Not all students had the time to create their own homemade fossil using the rocks and permanent markers. The eight fossils were all well-made and recognizable as the organisms in the pictures chosen by the students. See Figure 21. One additional student asked to take a rock home to draw his organism there. The simulated-fossil-on-rock activity, which the researchers initiated as an extra activity for students

finishing early, turned out to be popular with students. They clearly enjoyed the opportunity to sketch a fossil of choice.

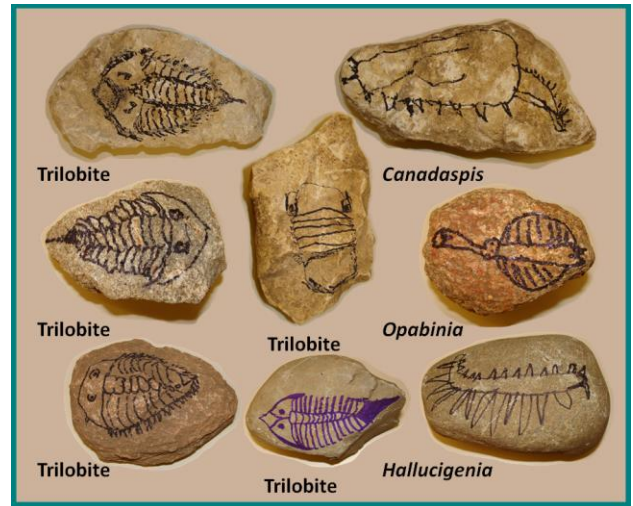


Figure 21. "Fossils" created by permanent marker on rocks

Conclusion

Summary

Overall, the lessons on fossils were very well-received by students. Students were enthusiastic about the lessons with several repeatedly saying how much they loved learning about these fossils and doing the arts and crafts. A lack of experience with craft-making was evident in some students' products and may be a consequence of the focus on standardized tests in some schools to the exclusion of arts and crafts. In general, students produced effective products and evidenced quite a bit of learning about the fossils studied and about the fossil hunters addressed in the Fossil Hunter Game.

Tips and Suggestions

Fossil Hunter Game Variations. The Fossil Hunter Game was played in two ways. The first way is more explorative and is intended to spark student curiosity and facilitate critical thinking. The second set-up is more challenging, and focused more on collaborative learning and critical thinking.



During the first couple of days, the students played the game with each student assuming a role of either a scientist (received a card with information about a scientist) or a role of representing a “discovery” (received a card with information about a discovery that one of the scientists made). Students walked around the room and explored each other’s cards. Students learned the information at their own pace, socialized, analyzed, and discussed the cards with one peer at a time, and, after assessing their ideas, concluded if their cards complemented each other.

Later in the week, when the students started displaying greater knowledge of the scientists and their discoveries, they were offered a more challenging variation of the fossil hunters’ game. The students were divided into two groups: group one “scientists” and group two “discoveries”. Every “scientist” read the clues about him/herself, and the “discoveries” group members were given about a minute to analyze and discuss the clues and make a group conclusion regarding the matching “discovery.” This game set up facilitated team-building and collaborative learning in addition to analytical and critical thinking.

Multiple Teachers and Small Groups. One aspect of our classroom lesson design was separating the students into smaller groups of three to four students. This allowed dispersed work spaces for students and the easy sharing of materials like glitter glue and scissors. The students worked in these groups all week and were very engaged during the activities. A tip for future applications would be to divide the students into small groups with a mix of the students’ ages. Allowing a mix of younger students to work alongside older students could aid in their social learning from one another. The younger students may benefit from having an older student as a mentor as they watch and observe how the older student problem-solves and constructs the models. Additionally, the older students may benefit from being able to coach and assist the younger students through the completion of tasks, thus providing an increase in their self-esteem as they can share their own knowledge. However, older students often feel ill at ease being put into a group of younger students, so it is best to provide a pair of older students in each group.

Possible Extensions and Connections

The topics explored through this instructional unit could be practiced or extended through additional or substitute activities, as listed below.

Fossil Masks. During the fourth lesson, students examined two papier-mâché masks of fossil animals made by the last author. The first mask was of a trilobite and the other mask was of *Opabinia*. See Figure 22. Students expressed interest in making a papier-mâché mask of a fossil animal and the authors are considering doing that in a future summer class.

Increasing Student Ownership of Activities. In regards to the rock fossil activity, future attempts of implementing this activity could benefit from allowing the students to search for their own rock outside of class. This would allow students to continue learning outside of class and allow them to problem solve on their own by answering questions such as: Where can I go to find a rock? Is this rock too heavy to carry back to class? Is this rock flat enough for sketching a fossil upon? Is this the type of rock (sedimentary) in which fossils usually occur?

Similarly, regarding the recycled plastic fossil organism construction, students could search their household recycled items for pieces for their constructions. An adult teacher could drill holes into their plastic pieces while paying close attention to where specifically the student would like their holes to be so as to best construct their fossil. Lastly, assigning responsibility to the students to locate their own pieces of recycled plastic allows for a discussion of the social responsibility we have to protect our planet. As the students are made aware of the plastic they have used, which would typically be designated to trash or recycling, they can become personally responsible for making sure their waste has been turned into a positive.

To better support the students in creating their fossils from scratch, they could receive instructions prior to the beginning of class to bring cereal or other types of food container boxes from which they will cut the pieces of their fossils. To create the fossil pins/badges from recycled cardboard, time must be allocated for the cutting out, gluing, assembling, gesso-coating, painting, doing the shading and scientific drawing on the pieces for the pins/badges. That

amount of time was not available in the short week-long summer camp, but would have benefited students in better appreciating the origins of their models and how they were made from "trash."



Figure 22. Two Papier Mache Fossil Masks: The top image is a trilobite; the lower image shows *Opabinia*

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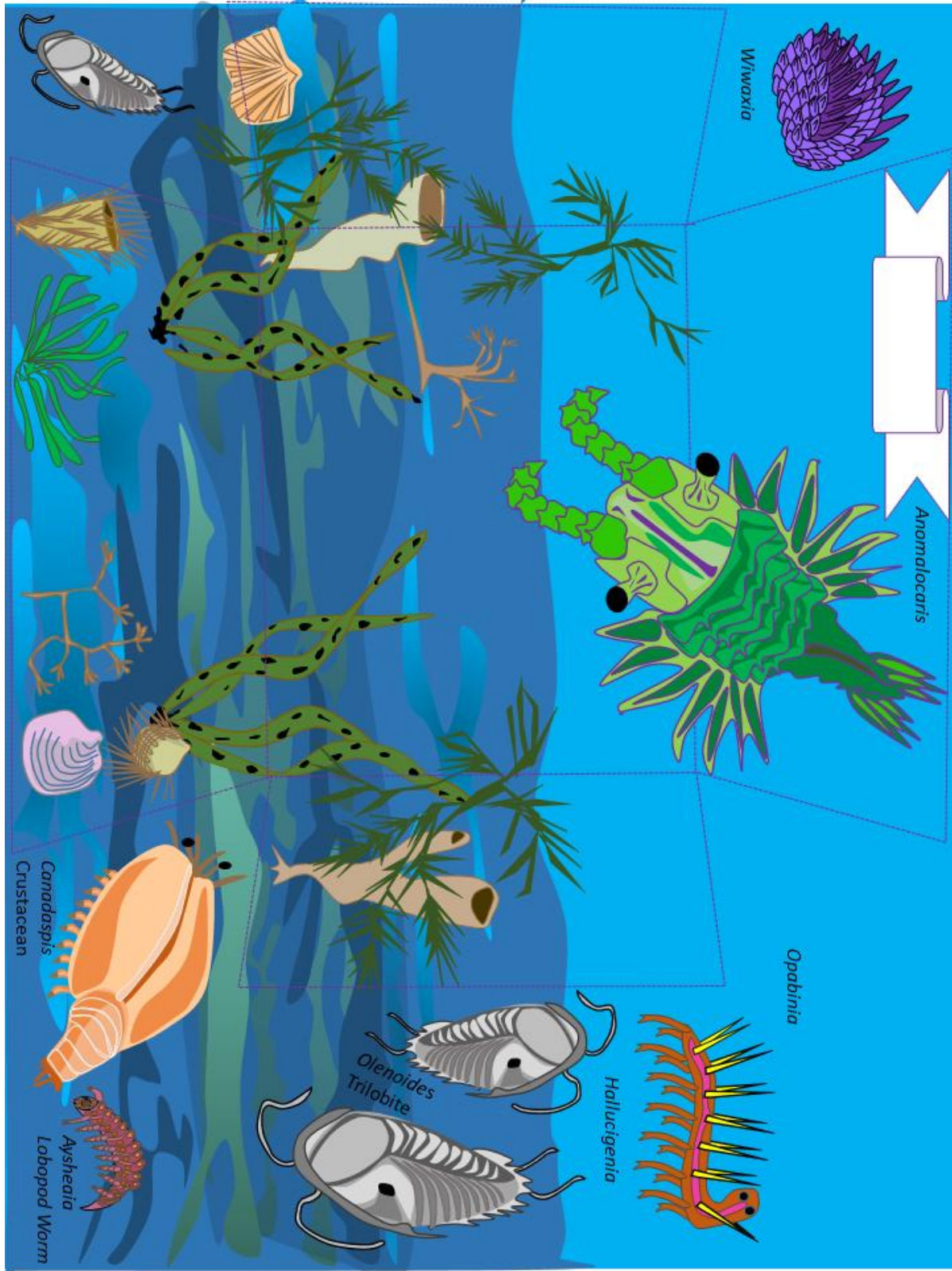
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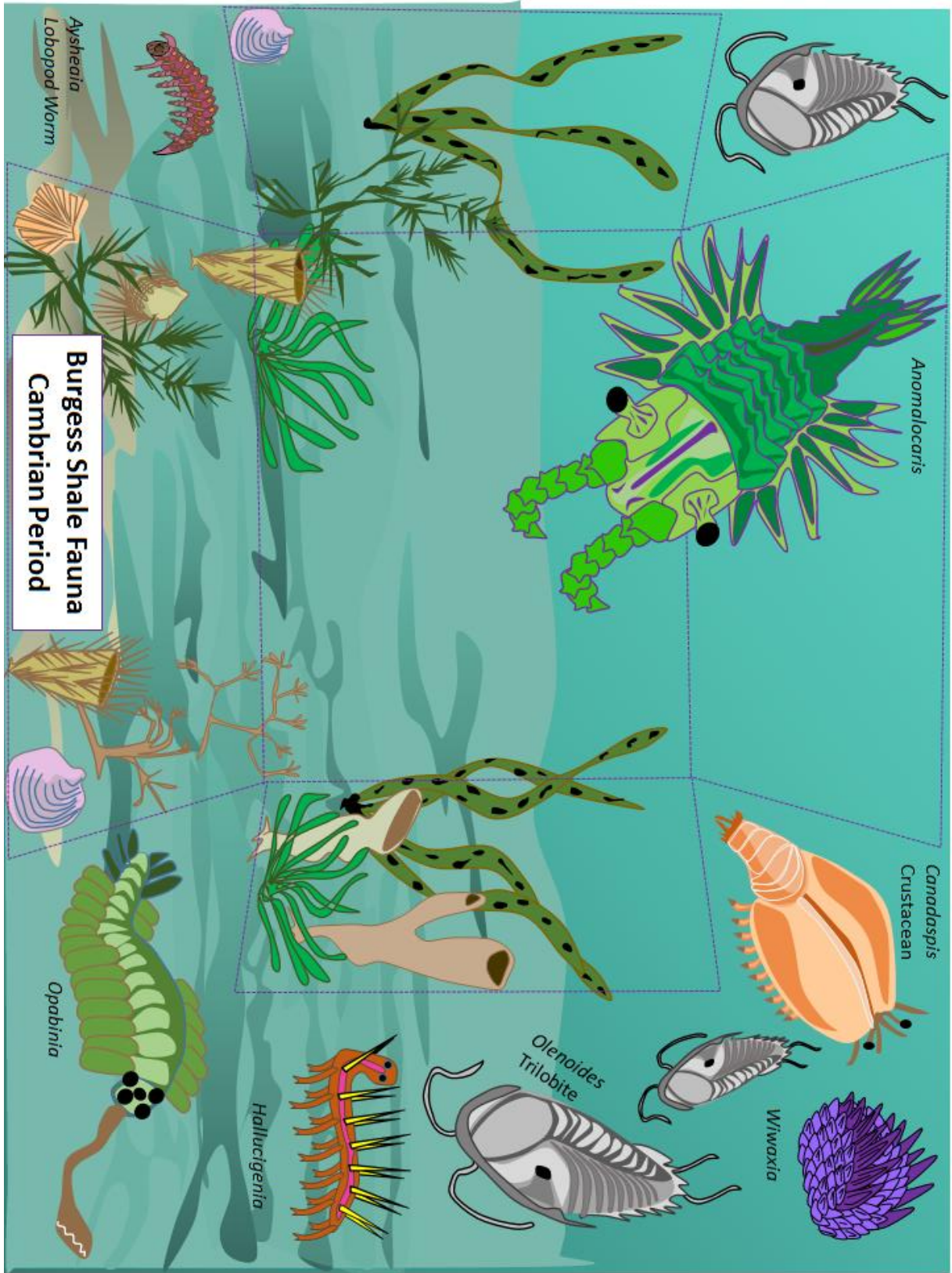


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Appendix on Next Two Pages







**Burgess Shale Fauna
Cambrian Period**