Lesson Nine

Competing Hypotheses of Dinosaur Extinction: Argumentation from Evidence

Learning Target
Argumentation is a critical practice of science. In this lesson, students will engage in argumentation using evidence from the competing hypotheses and evidence of non-avian dinosaur extinction (~66 million years ago). Debate over the causes of dinosaur extinction continues today and this presents an authentic opportunity for students to develop their argumentation skills. Using this case study, students will construct, present, and evaluate arguments supported by evidence of change at the Cretaceous-Paleogene boundary (~66 mya) to explain the sudden and gradual causes of (non-avian) dinosaur extinction.

Next Generation Science Standards

- **MS-ESS2-o.** Use arguments supported by evidence from the rock and fossil records to explain how past changes in Earth's conditions have caused major extinctions of some life forms and allowed others to flourish.
- **MS-ESS2-p.** Ask questions from evidence found in the geologic record to determine relationships between the evolution and proliferation of living things and changes in the geosphere, atmosphere and hydrosphere over geologic time.

At the end of the lesson, students who demonstrate mastery will be able to:

- use evidence to **construct an explanation (hypothesis)** for the cause(s) of dinosaur extinction, *and* present their explanation to their peers.
- **argue for and defend a hypothesis for dinosaur extinction**, which should include making a claim, providing supporting evidence, and providing counterevidence to a rebuttal from their peers
- **ask questions** about the causal hypotheses of other groups and **evaluate the hypotheses** posed by their peers based on the given evidence
- describe the evidence for both **sudden and gradual changes** at the Cretaceous-Paleogene mass extinction boundary.

Summary
What caused the extinction of the dinosaurs? Was it a massive meteor? Was it the result of tremendous volcanic activity that covered the globe in volcanic ash? Was it the effects of gradual climate change? Was it the result of plate tectonics? Students are given a set of cards that explain 1) scientific discoveries about rocks from ~66 million years ago, and 2) predictions that would follow given these different events and discoveries (such as a meteor impact, a rise in carbon dioxide levels, and plate tectonics). This lesson has two components, which could be split into two class periods. **In part 1**, teams will brainstorm causes of non-avian dinosaur extinction that they have heard of before, will learn to provide supporting evidence for these claims, and will learn to transform their claim into a scientific hypothesis**. In part 2**, teams will be given actual scientific evidence and will come up with a hypothesis supported by evidence, an alternative hypothesis, and counterarguments to this new hypothesis that would support their original hypothesis. Throughout the activity teams will present their hypothesis and supporting evidence to their peers, and towards the end

teams with competing hypotheses will argue (including engaging in rebuttal and providing counterevidence). The class should ultimately try to derive an overarching hypothesis that best explains the evidence at hand.

(*This plan is adapted by David Williams, Greg Wilson, and Lauren DeBey from a lesson originally created by Irene Salter, www.mysciencebox.org*).

Estimated teaching time

- 10 minutes – introduction and discussion of SUDDEN versus GRADUAL events, mass extinction, and handout
- **Part 1:** ~45 min, or more for younger students
  - 5 minutes – brainstorm causes of extinction
  - 10 minutes – present causes to the class and discuss which are SUDDEN versus GRADUAL
  - 10 minutes – come up with 3 pieces of supporting evidence
  - 5 minutes – model writing a hypothesis as a class
  - 10 minutes – teams transform their cause into a hypothesis statement
- **Part 2:** ~55 minutes
  - 20 minutes – write a hypothesis and list the supporting evidence
  - 8 minutes – teams present their hypothesis to the class; class discussion of various hypotheses (are some competing?)
  - 5 minutes – model ARGUMENT, REBUTTAL, and COUNTERARGUMENT process together as a class
  - 10 minutes – write an alternative hypothesis and formulate a counterargument
  - 12 minutes – debate as a class the competing hypotheses using the claims (hypotheses), rebuttals (alternative hypotheses), and counterarguments
- 10 minutes – wrap up discussion on the state of the debate, and what questions we asked, evidence we used, and conclusions we came to

Groups

Groups of 4 students

Materials

- 1 set of evidence cards per team
- 1 envelope per team
- 1 "Dinosaur Extinction" worksheet per team

Student background

- Students should have an understanding of how fossils form and have experience with the geologic time scale.
- It is helpful to have a good foundation in the rock cycle and stratigraphy so as to better understand how the evidence provided may have been gathered.

Set up

1. Make a copy of the "Dinosaur Extinction" handout for each team of students.
2. Copy and cut out a set of extinction cards for each team of students. Putting the cards on cardstock paper allows you to use the same cards year after year.
3. Put a set of extinction cards into each envelope.

Part 1

1. Introduce the activity in the context of sudden versus gradual change, and explanations supported by evidence, and allow students to explore the specifics of dinosaur extinction during the lesson. Have students brainstorm gradual versus sudden changes they see in their world (e.g., hair growth is gradual, but a drastic haircut or color is a sudden change). Then ask students to provide examples of gradual and sudden change they have seen in earth history.

2. Read through the first page of the handout together, stopping to answer any questions and define any vocabulary the students may be unfamiliar with (mass extinction, hypothesis, etc.) using the glossary.

3. Have student teams (3-4 per team) brainstorm in their groups all the different causes for dinosaur extinction they have heard about.
   i. *Students should fill in the box on their handout with their theories.*

4. Bring students back and have them share-out their theories; teacher should write these on butcher paper, overhead, or white board. Discuss which of these would be the result of **SUDDEN** or **GRADUAL** processes (or a combination of both).

5. Emphasize that any scientific explanation must be supportable by evidence. Have student teams select a cause of dinosaur extinction to work with (if possible, make sure each cause is assigned to a group). Brainstorm three pieces of **EVIDENCE** that would support this theory. It is fine if students are unaware of real evidence, but they should be able to reason that if, for example, they selected global warming (or climate change in general) as a cause for dinosaur extinction, then the rock record should show evidence of this change (plant community change, isotopic change in invertebrate shells, or simply “rock record would show evidence of climate change”).
   i. *Students should fill in the box on their handout with their pieces of evidence.*

6. Explain that students will transform their causal statements and supporting evidence into a **HYPOTHESIS**. Review the components of a hypothesis, particularly, the way a hypothesis is composed of a series of logically linked statements, often with the format “if…, then…” For instance, a hypothesis might say “If a new virus evolved and caused the extinction of all non-avian dinosaurs, then we might expect to see evidence of viral disease/infection in the cellular structure of dinosaur bones but not in the bones of those animals that survived the K-Pg extinction.”
   i. *Students should fill in their handout with their group’s hypothesis and supporting evidence.*

7. Introduce the evidence activity to the class. Explain that we are scientists and we will **ASK THE SCIENTIFIC QUESTION** “Why did the non-avian dinosaurs go extinct?” We will use actual scientific **EVIDENCE** to answer this question. Teams will be given a set of evidence and must come up with an explanation for the cause of the non-avian dinosaur extinction.
   i. The evidence is not equal in importance, so it is not the number of evidence cards that matters but the conclusiveness of the evidence that matters. Thus,

discourage students from using the strategy of the hypothesis with the most number of evidence cards must be true.

Part 2

1. Give each student team an envelope of evidence cards and allow them to discuss possible causes for dinosaur extinction. Circulate around the room and help groups that get stuck or cannot agree on a hypothesis that best explains the evidence. Remind students to make their hypothesis as clear as possible.
    i. Make sure that students do not let their previous assumptions interfere with the process and keep students focused on the evidence cards.
    ii. *Have students write their hypothesis on their handout.*

2. Remind students to think their ideas through completely and explain why they favor some evidence more than others.
    i. *Students should list all the pieces of evidence that support their hypothesis on their handout AND the pieces of evidence that go against (refute) their hypothesis.*

3. Students present their **HYPOTHESIS** and **SUPPORTING EVIDENCE** to the class. List on the board the hypotheses that all groups came up with. Are there competing hypotheses? Explain to the students that professional scientists are still undecided as to the causes of dinosaur extinction, and that scientists go about coming to a conclusion by engaging in a scientific debate. The scientists in the class will do the same to determine the cause(s) of dinosaur extinction.

4. Model the **ARGUMENT**, **REBUTTAL**, **and COUNTERARGUMENT** process for the students. Choose one team's hypothesis (Team A), and ask those students to list their supporting evidence. Ask whether any other teams had these pieces of evidence as conflicting with their own hypothesis (Team B). What was the hypothesis of Team B? What was the conflicting evidence of Team B? Was it the same evidence used to support Team A's hypothesis? What additional evidence or argumentation would Team A use to support their hypothesis of Team B? Have students give one or two examples to the class.

5. Explain that students will defend their causal hypothesis from peer critique and counterarguments. Students should return to their groups and write a hypothesis that explains the evidence that is not supportive of their original hypothesis. Students should formulate a **REBUTTAL** with **COUNTERARGUMENTS** to this new hypothesis that is in support of their original hypothesis.
    i. *Write the alternative hypothesis and their rebuttal to this (including counterarguments) on their handout.*

6. Facilitate a scientific debate where teams present their hypotheses and supporting evidence again and teams with competing hypotheses ask questions (**REBUTTAL**) that require additional support (**COUNTERARGUMENTS**) from groups with competing hypotheses. Allow a question and answer period following each group's presentation. Make sure that questions from other students are also grounded in the evidence. Encourage students to use the counterevidence the came up with in their groups and come up with new relevant evidence as the debate continues.

7. Facilitate an open discussion about the causes of the dinosaur extinction, the competing theories, and try to arrive at a consensus theory. Use this opportunity to discuss what pieces of evidence are stronger than others and why. Always come back to the evidence cards and keep the discussion focused on looking for a hypothesis that best explains the evidence at hand. If teams are still divided after advocating for their theory and discussing the evidence, that's ok, that is still the case today with scientists' hypothetical explanations as well!
    i. *Have students write their reflections on the debate on their handouts. Including:*
        1. *Does the evidence and arguments support a single causal hypothesis? Why or why not?*
        2. *Does the evidence support a GRADUAL cause or a SUDDEN cause? Why or why not?*

8. ~20 minutes before the end of the activity, close the debate and describe the current state of affairs is in the scientific community – that scientists are still very divided into the single cause and multiple cause camps. Allow students to suggest areas of research that could help settle the debate: more conclusive information about how quickly or slowly the extinctions occurred, more clear evidence of asteroid or meteor impacts, more detailed radioactive dating information, fossil evidence from different parts of the world, etc. → There's lots more science to be done!

9. ~10 minutes before the end of the activity, wrap up by asking students reflective questions:
    i. What are some of the questions we asked?
    ii. What are the answers we came to?
    iii. What evidence did we use?

Assessment
Use the students' answers on the handout as well as the content of their group discussions to determine if students were able to meet the learning goals and statements for mastery outlined above.

Going further
1. Have students research other mass extinctions and compare them to the rate of extinction today. Have students write a position paper arguing whether we are currently in a period of mass extinction or not.
2. Have students investigate the conflicting hypotheses explaining the end-Permian (also called Permo-Triassic) extinction, the largest mass extinction known. As they did in this activity, have them summarize one theory about the causes of the Permian extinction and the evidence that supports that idea.

Teacher background

There have been five mass extinctions throughout the history of the Earth. A mass extinction may be defined as an episode in geologic history where over half of the species in existence become extinct in a relatively short amount of time (just a few million years). The worst mass extinction came at the end of the Paleozoic Era 251 million years ago when nearly 95% of plant and animal life in the seas disappeared. Another mass extinction may be happening today. Some estimates show that current rates of extinction are as high as 27,000 species per year, which is significantly higher than the 10–100 species extinctions (also known as ‘background extinction’) per year indicated by the fossil record.

Probably the most famous mass extinction happened ~66 million years ago, when all of the dinosaurs but birds (referred to as non-avian dinosaurs) disappeared. This is generally called the K-T, or K-Pg, extinction. [Until recently geologists used the term K-T to refer to the boundary between the Cretaceous (K) and Tertiary (T) periods. Now, however, geologists have eliminated the Tertiary and replaced it with two periods, known as the Paleogene and Neogene, so that the K-Pg refers to the Cretaceous-Paleogene boundary. You will still see both K-T and K-Pg. To keep up with the science, we are using K-Pg.]

Whatever triggered the extinction of the dinosaurs also caused the death of nearly 60-70% of all the other species on Earth. Interestingly, not all groups of organisms were affected equally. Marine species were hit harder than land species, with 90% of marine species becoming extinct. Birds were the only survivors of the dinosaur lineage. Interestingly, some mammals, lizards, snakes, salamanders, and frogs that would seem to be vulnerable to such an event were less affected. Some groups even benefited from the event. For example, ferns actually expanded and thrived immediately after the event, and mammals underwent a long-term diversification.

So what caused the dinosaur extinction? Clues to the cause of this mass extinction event can be found in the rocks that date from ~66 million years ago. Some pieces of evidence are accepted by nearly all scientists:

1. Around the time of the K-Pg extinctions, there was global climate change. What was once a warm, mild climate changed to one that was more varied (sometimes very hot, sometimes very cold).
2. In India, there was extensive volcanic activity, known as the Deccan Traps. Rocks that date from 67–64 million years ago in southern India are almost entirely igneous (volcanic). Almost 200,000 square miles was covered in lava over a period of 3 million years (an area equivalent to the entire mid-western United States). In some places, the lava beds are a mile deep.
3. Geologist Alan Hildebrand found evidence of what is most likely an enormous asteroid impact site in the Yucatan region of Mexico. He named the 110 mile-wide crater after a nearby town, Chicxulub, which means devil’s tail. The crater has been dated and is coincident with the K-Pg boundary (~66 million years ago). The size of the crater has been used to estimate the size of the asteroid. Estimates vary but the asteroid may have been as large as 6 miles wide.
4. High levels of the rare earth element iridium have been found in a thin ~ 2 cm-thick layer dated to around 66 million years ago. This iridium anomaly has been found in many places around the world at the same rock level. The iridium levels contained in the rocks from this time period are up to 30 times the normal levels on Earth. The most likely sources of high levels of iridium are from:

   i. outer space in the form of cosmic dust from a nearby exploding supernova
   ii. outer space carried to Earth by an asteroid or meteor
   iii. eruptions of massive volcanoes.
5. Shocked quartz and glassy spherules have been found associated in the same layer with the iridium anomaly. The shocked quartz grains are metamorphically transformed quartz with crosshatch patterning that resulted from intense shock waves produced from a high-energy impact event. The glassy spherules are small droplets of melted rock. Both were produced at the impact site and thrown up into the atmosphere and circulated globally before falling to Earth as impact debris and forming a sedimentary layer that we can analyze in the geologic record.
6. Major changes in the oceans and landscape were occurring around 66 million years ago due to plate tectonics. There is evidence that the oceans were receding. For example, a shallow sea once covered what is now the mid-western United States, which ran from the Gulf of Mexico up through Canada, and separated North America in two. This seaway drained away over several million years around the time of the dinosaur extinctions, as the Colorado Plateau rose.

Although there is an abundance of evidence detailing the environmental disturbances that occurred at this time, there is no consensus among scientists whether one or all of these caused the mass extinction. Generally speaking, scientists are divided into two camps:

Single Cause (Asteroid impact) – These scientists argue that the fossil record indicates that ecosystems were "healthy" in the millions of years leading up to the K-Pg boundary until a sudden catastrophic event, namely the asteroid impact, caused massive extinctions. This hypothesis was first proposed in 1980 by Walter Alvarez, a geologist, and his physicist father, Luis Alvarez, and is often referred to as the "Alvarez Theory". Although there is ample evidence in the form of high iridium levels and presence of shocked quartz and glassy spherules in the rocks of that age, it is unclear what the outcome of this impact would have been and how it would have affected the biota. Some have hypothesized that the resulting blast would have destroyed everything within 250–300 miles, including the impact object itself. Trillions of tons of debris (like dust, smoke, and steam) would have been thrown into the atmosphere when the object vaporized, darkening the sky around the globe in just a few weeks. The darkness may have only persisted for a few years but the effects on plant life would have been devastating and caused a chain reaction through the ecosystem. Earthquakes would almost certainly have been triggered, and so might have tsunamis and wildfires.

Multiple Causes – These scientists argue that the fossil record indicates that ecosystems were of declining "health" in the last few millions of years before the K-Pg boundary as the result of accumulating environmental disturbances, culminating in the asteroid impact at the Cretaceous-Paleogene boundary. The time frame is consistent with several major long-term events such as dropping sea level, massive volcanic activity, and climate change. For example, these scientists argue that extensive volcanic activity in India (called the Deccan Traps) would have released massive amounts of sulfuric acid and carbon dioxide into the atmosphere, resulting in climate changes and possibly acid rain, which would have strongly affected ecosystems.

This ongoing debate offers an exciting opportunity for students to sort through the clues and propose a hypothesis to explain the extinction of the dinosaurs. The key to this activity is for students to begin by organizing the evidence into sets of related information and then use the evidence to support a logical theory. Since there is no right answer students have an opportunity to engage in a true scientific debate over the same set of data that paleontologists, geologists, and physicists argue over. Furthermore, there are endless directions in which the debate may travel, opening endless opportunities for further exploration.

Glossary

- Extinction – The total disappearance of a species or higher taxon, so that it no longer exists anywhere.*
- Iridium – A naturally occurring chemical element with the atomic number 77. Iridium is found in much higher concentrations in meteorites than in the Earth's crust.
- K-Pg boundary – Sixty-six million years ago. This boundary marks the end of the Mesozoic and beginning of the Cenozoic eras. The boundary is when one of five mass extinction events in Earth's history took place. Groups that went extinct at the K-Pg boundary include mosasaurs, plesiosaurs, ammonites, pterosaurs, and non-avian dinosaurs.
- Mass extinction – The worldwide extinction of a large number of species.
- Theory – A concept or proposition, developed from an hypothesis, that is supported by experimental or factual evidence but is not so conclusively proved as to be accepted as a law.*

* = Definition directly from Dictionary of Geological Terms, prepared by the American Geological Institute

References

There are many excellent websites that discuss the K-Pg extinction:

- The University of California Museum of Paleontology has a superb discussion of the ongoing scientific debate. (http://www.ucmp.berkeley.edu/diapsids/extinction.html)
- Wikipedia offers a great deal of information about both of the major theories and the evidence in favor of each. (http://en.wikipedia.org/wiki/K-T_extinction)
- PBS also provides a balanced discussion of the major theories. (http://www.pbs.org/wgbh/evolution/extinction/dinosaurs/asteroid.html)
- Finally, the BBC has a good article about the dating of the Chicxulub crater. http://news.bbc.co.uk/2/hi/science/nature/3520837.stm

Next Generation Science Standards – DIG Box Lesson 9
Middle School – Earth Sciences – Earth's Systems

Next Generation Science Standards	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-ESS2-o. Use arguments supported by evidence from the rock and fossil records to explain how past changes in Earth's conditions have caused major extinctions of some life forms and allowed others to flourish.	**Engaging in Argument from Evidence.** *(Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.)* Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. **(MS-ESS2-o)**	**ESS2.E: Biogeology:** Evolution is shaped by Earth's varying geologic conditions. Sudden changes in conditions (e.g., meteor impacts, major volcanic eruptions) have caused mass extinctions, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. **(MS-ESS2-o)**	**Stability and Change:** Stability might be disturbed either by sudden events or gradual changes that accumulate over time. **(MS-ESS2-o)**
MS-ESS2-p. Ask questions from evidence found in the geologic record to determine relationships between the evolution and proliferation of living things and changes in the geosphere, atmosphere and hydrosphere over geologic time.	**Asking Questions and Defining Problems.** *(Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems.)* Ask questions to determine relationships between independent and dependent variables. **(MS-ESS2-p)** **Developing and Using Models** *(Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems.)* Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-ESS2-a), (MS-ESS2-e),(MS-ESS2-h),(MS-ESS2-n),**(MS-ESS2-p)**		**Cause and Effect:** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. **(MS-ESS2-p)**