



Grade Level: Grades 6-8

Preparation Time: less than 5 minutes

Activity Duration: up to five classroom sessions

Concepts Addressed

- Science is a process by which we learn about the natural world using our senses and extensions of our senses.
- Science follows a process guided by certain parameters.
- Science relies on the observation of physical evidence from the natural world.
- Physical evidence is examined and interpreted through logic.
- An observation is a description of physical evidence based on what we see, feel, hear, smell, or taste.
- An inference is a logical conclusion based on observation of physical evidence.
- A hypothesis is a scientific idea supported by physical evidence.
- Science advances as scientific theories are supported, modified, or replaced as new evidence is found.

Objectives

The student will:

- Develop hypotheses based on observations from provided evidence.
- Revise hypotheses based on introduction of new evidence.
- Create new hypotheses based on introduction of new evidence.
- Participate in and discuss the process and advancement of science.

Materials Included

- Laminated Dino-Data Card #1 (one for each group of four students)
- Laminated Dino-Data Card #2 (one for each group of four students)
- One set of 14 laminated Dino-Data cards (one for each group of four students)
- Dino-Data Dinosaur Images (transparency, lamination or PowerPoint slide on CD-ROM)

Background

Part I--for use in steps 1–12 of the Procedure

Through the work of paleontologist Jack Horner and other scientists, we have learned that

several different dinosaurs lived at the same time (roughly 80 million years ago) and place in Montana. Three of these dinosaurs were *Orodromeus* (mountain runner), a swift plant eater; *Troodon* (wounding teeth), a small but fierce predator (carnivore); and *Maiasaura* (good mother lizard), a larger herbivore. There is good fossil evidence to show that all three laid eggs in nests. The nesting sites included two islands surrounded by a shallow lake. The environment at that time included volcanoes and a few mountains to the west (not the Rockies as they were in the process of uplifting) and to the east, a warm interior seaway which divided North America from north to south.

Part II--for use in steps 13–15 of the Procedure

For thirteen years, evidence found by Horner and colleagues confirmed that there were two types of nests found at this locality and that they belonged to two different dinosaurs. Skeletal and embryonic evidence supported the hypothesis that one type of nest belonged to the dinosaur *Maiasaura*. An abundance of *Orodromeus* skeletons and the rarity of *Troodon* bones at the Egg Mountain supported the hypothesis that the second type of nests was that of *Orodromeus*. And when embryonic remains were discovered in a clutch of eggs at the Egg Island site, preliminary studies suggested that these were most likely those of *Orodromeus*. However, there were two discoveries that would lead to the falsification of this hypothesis.

1. In 1993 paleontologist David Varricchio discovered the hind end of an adult skeleton of *Troodon* on top of what was thought to be a clutch of *Orodromeus* eggs.
2. In 1995, paleontologist Mark Norell and others published a paper on a skeleton of another dinosaur, *Oviraptor*, from Mongolia. This skeleton was found squatting over what was assumed to be a nest of *Protoceratops* due to the numerous skeletons of *Protoceratops* in the area. However, it was found that one of the eggs contained an embryo of *Oviraptor*, thus overturning the previous hypothesis. Most likely *Oviraptor* was sitting on its own eggs, not feeding on those of another!

As the *Oviraptor* was squatting in much the same position as the *Troodon* found by Varricchio, the Egg Island embryos were further prepared and more thoroughly studied. The examination revealed that the embryos were in fact *Troodon*, falsifying the long held hypothesis that *Orodromeus* had been the egg layer.

So, if the nests were those of *Troodon*, why all the bones of *Orodromeus*? The current hypothesis is that *Troodon* dragged the carcasses of *Orodromeus* to the nesting area for their hatchlings to feed on.

Reference: Horner, J.H. 2002. *Evidence of dinosaur social behavior*, pp. 71–78. In Scotchmoor, J., D. Springer, B. Breithaupt, and A. Fiorillo (eds). *Dinosaurs: the Science Behind the Stories*. American Geological Institute.

Explore these links for additional information on the topics covered in this lesson:

Fossils—http://evolution.berkeley.edu/evosite/lines/lfossil_ev.shtml

Nature of Science—<http://evolution.berkeley.edu/evosite/nature/index.shtml>

Procedure

Part I—Hypotheses based on evidence

1. Tell the class that they are about to participate in an investigation about dinosaurs in which information is revealed to them in much the same way evidence is revealed to scientists. They will be asked to explain what they think one can learn about the dinosaurs from the evidence they have. Then, as they receive additional information, they will be asked to re-explain what they think went on.
2. Distribute Dino-Data Card #1 to groups of students and read through it with them (you can also show it with an overhead PowerPoint projector). Show the illustrations of the three dinosaurs discussed on the card.
3. Distribute Dino-Data Card #2 to each group. Read through the data card with the whole class and ask the class to brainstorm about what we can learn about the Montana dinosaurs *from the evidence on the cards*. Example: #1 states that *Maiasaura* probably ate nearly 200 lb. of vegetation each day. #4 states that they have been found in herds up to 10,000 in number. A class discussion around these two points might result in a hypothesis such as, *Because each Maiasauara consume 200 lb. of vegetation per day and herds numbered as large as 10,000, the Maiasaura must have migrated because they would need to find new food sources.*
4. Record the proposed “hypotheses” on the board or on a sheet of paper to be saved.
5. Conduct a whole-class discussion: which of the hypotheses are supported by the data that have been given? “Is this hypothesis supported by the data?” Note that some students may bring prior knowledge to the discussion or make inferences that go beyond what is contained in the given Data. Remind the class to focus only on the given data as you briefly discuss the various hypotheses. Leave the hypotheses posted for future reference.

Part II—Revision of hypotheses based on new evidence

6. Redistribute Dino-Data Card #1 to each group, along with a Dino-Data card set (containing 14 data points—the points from Dino-Data Card #2 are the same as points 1-4). Briefly review what transpired before. Read through each of the new pieces of data to make sure that students understand the terminology.
7. Ask the groups to lay out all the data they now have (new and old) and to brainstorm with one another what the data might reveal about the dinosaurs. Each group should write at least three hypotheses based on the evidence.
8. Have the groups write their hypotheses with the information that provides evidence to support each hypothesis. Also ask them to list what additional information they would need to further support or eliminate each hypothesis.
9. After each group has completed work on the three hypotheses, ask them to select one hypothesis that they find particularly interesting and to prepare a presentation for the class. Each presentation should clearly state the hypothesis, the evidence for the hypothesis, possible weaknesses of the hypothesis, and what additional information they would need to further test the hypothesis.

10. Allow the rest of the period for groups to prepare their presentations.

Part III—Peer review

11. Groups present their hypotheses. Encourage students to respectfully “challenge” proposed hypotheses if they think there is evidence that would disprove those hypotheses.
12. Conduct a discussion regarding which hypotheses seemed the best supported by the evidence. Ask for specifics.

Part IV—New discovery

13. Tell the class that you have just received some breaking news: Further study indicates that what were thought to be *Orodromeus* nests have turned out to be *Troodon* nests. Ask students to discuss and write what effect this new information has on their hypotheses. Ask also what additional information they now need to make sense of what happened with the dinosaurs. (Note: This new information is likely to upset many of the students’ hypotheses. See Background, Part II for details.)
14. At this point, you might ask the groups to further modify their hypotheses based on the new information, with consequent discussion, or go on to step 15.

Part V—Process of Science

15. Conduct a large group discussion. “What have we learned about how science works from this experience?” Establish with the group at least these points: Scientists work from evidence. Scientists formulate multiple hypotheses. Scientists eliminate or modify hypotheses as evidence comes in. New evidence is always changing our ideas about how things work. In science, we often learn more from being wrong than from being right.

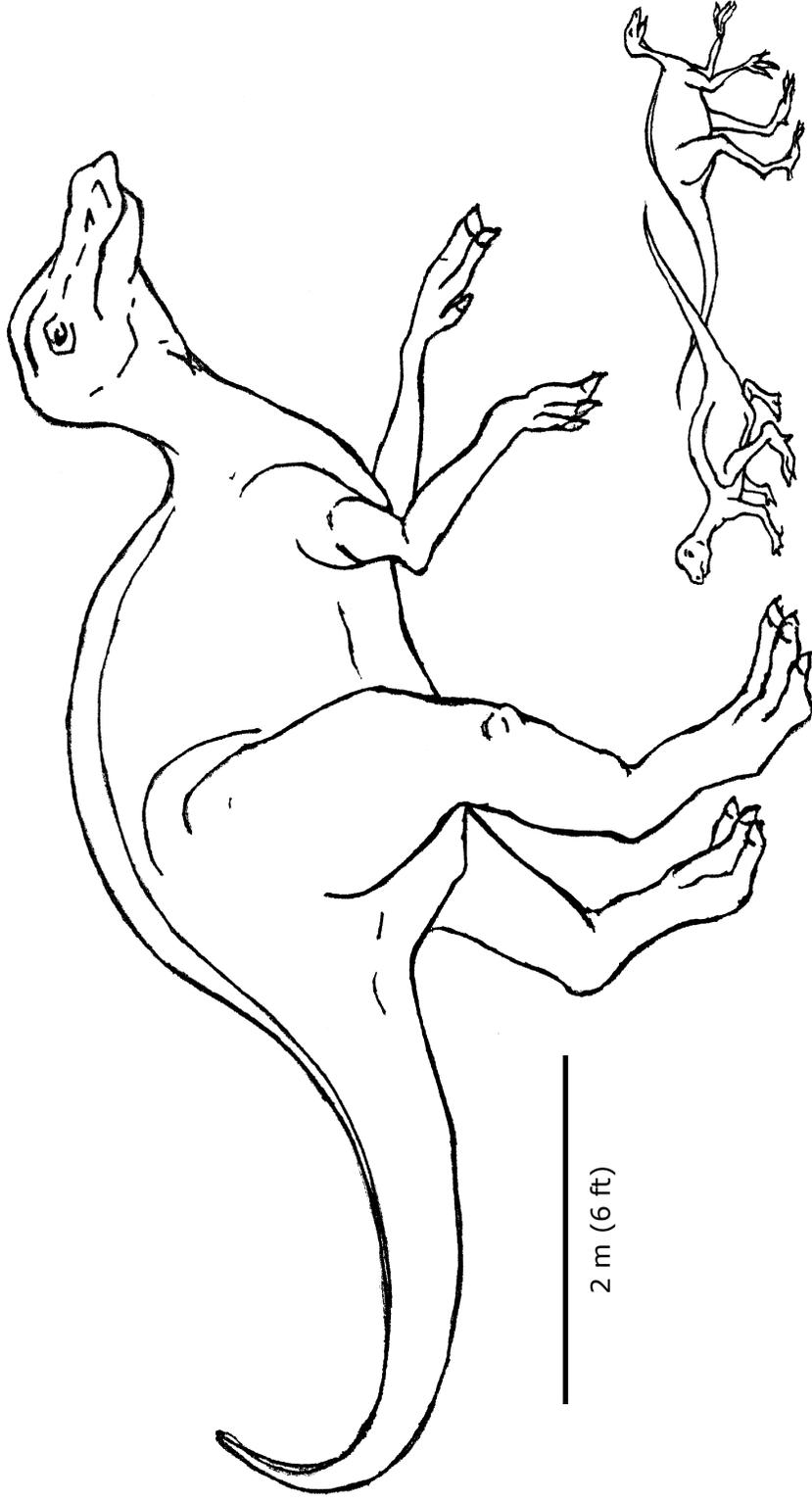
Dino-Data Card # 1

Through the work of Jack Horner and other scientists, it has been learned that several different dinosaurs lived at the same time (roughly 80 million years ago) in Montana. Three of these dinosaurs were *Orodromeus* (mountain runner), a swift plant eater; *Troodon* (wounding teeth), a small but fierce predator (carnivore); and *Maiasaura* (good mother lizard), a larger herbivore. There is good fossil evidence to show that all three laid eggs in nests. The nesting sites included two islands surrounded by a shallow alkaline lake.

The environment at that time included volcanoes and a few mountains to the west (not the Rockies, as they were in the process of uplifting) and to the east, a warm interior seaway, which divided North America from north to south.

Dino-Data Card # 2

1. *Maiasaura* were herbivorous. They weighed roughly 3 to 4 tons as adults. They probably ate 200 lb. of food each day.
2. Many *Maiasaura* nests have been found at two sites, Egg Mountain and Egg Island. At the time of the dinosaurs, each of these sites was an island. Although islands are rather limiting in space, the nests were usually found 20 to 30 feet apart.
3. The sharp serrated teeth of a small dinosaur called *Troodon* have been found in the nesting area of *Maiasaura*.
4. Large numbers of bones in some areas of Montana indicate that there existed a herd of *Maiasaura* of nearly 10,000 individuals. These individuals varied in size from 9 to 25 feet in length.



Maiasaura

Orodromeus

Troödon

1. Maiasaurs were herbivorous. They weighed roughly 3–4 tons as adults. They probably ate 200 lb. of food each day.

2. Many Maiasaur nests have been found at two sites, Egg Mountain and Egg Island. At the time of the dinosaurs, each of these sites was an island. Although islands are limited in space, the nests were usually found 20–30 feet apart.

3. The sharp serrated teeth of a small dinosaur called *Troödon* have been found in the nesting area of Maiasaurs.

4. Large numbers of bones in some areas of Montana indicate that there existed a herd of Maiasaurs of nearly 10,000 individuals. These individuals varied in size from 9 to 25 feet in length.

5. The dinosaur nests at both of the Egg Mountain locations have been found at three different depths. Several layers of sandstone were deposited between the depths.

6. The bones of most newborn birds are not fully ossified (hardened into bone). The ends are still relatively soft and spongy and made of cartilage. As a result, newborn birds can stand up only momentarily. Their bones will not support them.

7. The adult Maiasaur reached a size of 25–30 feet in length.

8. The egg shells found in the nests of the Maiasaurs are all broken up.

9. The front teeth of many dinosaurs like Maiasaurs are very interesting. There is a heavy enamel layer on the outside of the upper teeth, but that very same layer is on the inside of the lower teeth. Therefore, as the teeth come together, a self-sharpening effect takes place. The teeth become like scissors.

10. The shells found in nests of *Orodromeus* are not all broken up. The lower egg shell is usually intact.

11. The bones of the hatchlings of Maiasaurs are not fully ossified. The ends are still relatively soft and spongy and cartilaginous.

12. Examination of the embryos of Maiasaurs show wear on the front teeth. This has occurred before hatching.

13. At birth, Maiasaurs are about 20 inches in length. Bones have been found in the nests of Maiasaurs that belonged to individuals that were over 4 feet in length. This is very common.

14. The bones of the hatchlings of *Orodromeus* are fully ossified. That means that the ends of the bones are well developed and very strong.