SN EDUCATOR GUIDE

February 4, 2017
Dino Doomsday

Cross-Curricular Discussion

After students have had a chance to review the articles "Devastation detectives" and "The lucky ones," lead a classroom discussion based on the questions that follow. You can copy and paste only the questions that apply to your classroom into a different document for your students. Before starting the discussion, you may want to show this Howard Hughes Medical Institute educational video titled "The day the Mesozoic died." This video is approximately 33 minutes, but shorter clips may be useful for geologic visuals. The video highlights the asteroid impact hypothesis and does not mention the potential impact Deccan volcanism had on Earth or the dinosaurs. NASA has also released images of the Chicxulub crater in "A 'smoking gun' for dinosaur extinction."

BIOLOGICAL SCIENCES

Discussion Questions:

1. What set of features distinguishes modern birds from dinosaurs like *Tyrannosaurus rex*? [*Wings, loss of wing claws, loss of teeth, etc.*]
2. How might those features have arisen, hypothetically speaking? [*Feathers might have offered insulation, provided cushion against injury, attracted mates, served as camouflage, etc. Small wings might have been useful for trapping prey, swimming, mating displays, etc. Once birds could fly, it might have been less important to maintain defense features such as teeth.*]
3. What types of animals went extinct 66 million years ago? [*Non-avian dinosaurs, some branches of the bird family tree, many other vertebrates (fish/amphibians/reptiles/mammals), ammonites, belemnites, etc.*]

Extension Prompts:

4. What factors might have determined which animals went extinct and which survived? [*Larger animals would have found it hard to find enough food during the several-year-long winter that killed most plants, so there was strong selection for animals that were smaller at the time. Warm-blooded animals including mammals and birds did better in the cold. Depending on where they lived, animals may have been more or less affected by the impact event, the following climate change or atmospheric and ocean changes caused by volcanic eruptions.*]
5. How did the extinction lead to new diversity? [*Once the planet recovered, there was a lot of room and resources, but the surviving species were much fewer and smaller. Thus, there was plenty of opportunity for them to grow to larger sizes, become more numerous and diversify to fill ecological niches that had been previously filled by other species now extinct.*]

Biological Sciences Question Bank

What set of features distinguishes modern birds from dinosaurs like *Tyrannosaurus rex*?

How might those features have arisen, hypothetically speaking?

What types of animals went extinct 66 million years ago?

What factors determined which animals went extinct and which survived?

How did the extinction lead to new diversity?

EARTH SCIENCES

Discussion Questions:

1. What is the difference between a mineral and a rock? [*Minerals are pure elements or compounds, whereas rocks are mixtures of two or more minerals.*]
2. What type of rock forms the foundation of continents, and what minerals are in it? What type of rock forms the foundation of the ocean floor, and what are some of the major minerals in it? [*Continental plate is made mostly of granite, which contains feldspar, quartz and mica. Oceanic plate is made mostly of basalt, which contains augite, feldspar and other minerals.*]
3. What is the major type of rock in Earth's mantle, and what is the primary mineral in it? [*Peridotite, composed largely of olivine.*]
4. How does limestone form? What is the main mineral or compound in limestone? What is limestone mined to produce? [*Limestone forms from sedimentary deposition and compression of tiny seashells that accumulate at the bottom of the ocean. The main compound in limestone is calcite, or calcium carbonate. Limestone is mined for the stone for buildings, and pure calcium carbonate for chalk and antacids like Tums.*]

Extension Prompts:

5. How resistant is limestone to erosion? [*Limestone is partially soluble in water and can erode over time from water. Limestone is even more soluble in acidic conditions, such as acid rain.]*
6. What is a cenote? [*A sinkhole or natural well through limestone, generally leading from the surface down to water.*]
7. As discussed in the article "Devastation detectives," the Chicxulub impact churned a lot of material together. Based on the colors of the multicolor core samples mentioned in the article, as well as other information in the article, what minerals might be in the core samples? [*Black could be black biotite mica and/or black basalt. White could be white feldspar, white quartz and/or white limestone. Green could be olivine or peridotite. Red could be pinkish-red feldspar or iron originally from basalt or olivine/peridotite that has melted and come out and rusted to form hematite.*]
8. What would those minerals tell you about the original locations of rocks that were mixed together by the impact? [*Granite would have likely come from the continental crust, basalt from the seafloor crust and peridotite from the upper mantle.*]

9. Look at a map of cenotes in the Yucatán Peninsula, such as this one from NASA. Do you see any patterns? What do you think might have caused that pattern? [*Many of the cenotes form a semicircle. The edge of the Chicxulub impact crater may have caused this formation by damaging the limestone and making it more susceptible to the formation of cenotes. Since the actual crater is located under the ocean and 66 million years of deposits, the map of the cenotes might be a good way for students to visualize the crater.*]

Earth Sciences Question Bank

What is the difference between a mineral and a rock?

What type of rock forms the foundation of continents, and what minerals are in it? What type of rock forms the foundation of the ocean floor, and what are some of the major minerals in it?

What is the major type of rock in Earth's mantle, and what is the primary mineral in it?

How does limestone form? What is the main mineral or compound in limestone? What is limestone mined to produce?

How resistant is limestone to erosion?

What is a cenote?

As discussed in the article "Devastation detectives," the Chicxulub impact churned a lot of material together. Based on the colors of the multicolor core samples mentioned in the article, as well as other information in the article, what minerals might be in the core samples?

What would those minerals tell you about the original locations of rocks that were mixed together by the impact?

Look at a map of cenotes in the Yucatán Peninsula provided by your teacher. Do you see any patterns? What do you think might have caused that pattern?

PHYSICAL SCIENCES/MATHEMATICAL PROBLEM SOLVING

Discussion Questions:

1. Using Blackline Master 3 or the diagram titled "Ringing true" on Page 18 of "Devastation detectives," describe how the Chicxulub crater formed. [*The "space rock" made a deep crater impacting both the upper crust and lower crust. Rocks from deep within the surface quickly fill the voided space, forming an unstable central column. The column collapses and a peak ring forms.*]
2. Explosive energies are often measured in terms of the equivalent tons of TNT that would produce the same explosion. 1 ton of TNT = 4.184×10^9 Joules (J) of energy, or 1 kiloton (kT, thousand tons) = 4.184×10^{12} Joules. Determine the explosive energy of the nuclear bomb dropped on Hiroshima in tons of TNT and Joules. [*15,000 tons = 6.28×10^{13} Joules*]
3. If the Chicxulub impact released about 10 billion times as much energy as the Hiroshima bomb, what was its explosive energy in tons of TNT and Joules? [*1.5×10^{14} tons ≈ 6.28×10^{23} Joules*]

Extension Prompts:

4. The exact size, density and velocity of the Chicxulub impactor (asteroid, comet or terribly clueless Star Destroyer) are still somewhat uncertain. Assuming that the impactor was round with a radius of 6 km (12 km diameter), what was its volume? [$V = (4/3)\pi r^3 \approx 9.05 \times 10^{11}\ m^3$]
5. Assuming that the Chicxulub impactor had that volume and was a stony asteroid with a density of 3000 kg/m^3 (specific gravity of 3), what was its mass? [$m = pV \approx 2.71 \times 10^{15}\ kg$]
6. Assuming that the Chicxulub impactor had that mass and that its velocity immediately before impact was 17,000 m/sec (17 km/sec, approximately 50 times the speed of sound), what was its kinetic energy in Joules or tons? [$K.E.=mv^2/2 = 3.92 \times 10^{23}\ J = 9.37 \times 10^{13}\ tons$]
7. The impactor's kinetic energy became the explosive energy that was released upon impact. How much does your estimate of the kinetic energy differ from the earlier estimate of 10 billion Hiroshima bombs? [*10 billion Hiroshima bombs would be approximately 1.6 times the kinetic energy just calculated.*]
8. What factors might account for the different numbers? [*The 10 billion Hiroshima bombs estimate itself might be somewhat off, or the impactor might have been somewhat larger, had a higher density (iron meteorites have a density of 7000–8000 kg/m^3) or may have had a higher velocity (perhaps closer to 20 km/sec).*]

Physical Sciences/Mathematical Problem Solving Question Bank

Using Blackline Master 3 or the diagram titled "Ringing true" on Page 18 of "Devastation detectives," describe how the Chicxulub crater formed.

Explosive energies are often measured in terms of the equivalent tons of TNT that would produce the same explosion. 1 ton of TNT = 4.184 x 10^9 Joules (J) of energy, or 1 kiloton (kT, thousand tons) = 4.184 x 10^{12} Joules. Determine the explosive energy of the nuclear bomb dropped on Hiroshima in tons of TNT and Joules?

If the Chicxulub impact released 10 billion times as much energy as the Hiroshima bomb, as stated in the article, what was its explosive energy in tons of TNT and Joules?

The exact size, density and velocity of the Chicxulub impactor (asteroid, comet or terribly clueless Star Destroyer) are still somewhat uncertain. Assuming that the impactor was round with a radius of 6 km (12 km diameter), what was its volume?

Assuming that the Chicxulub impactor had that volume and was a stony asteroid with a density of 3000 kg/m^3 (specific gravity of 3), what was its mass?

Assuming that the Chicxulub impactor had that mass and that its velocity immediately before impact was 17,000 m/sec (17 km/sec, approximately 50 times the speed of sound), what was its kinetic energy in Joules or tons?

The impactor's kinetic energy became the explosive energy that was released upon impact. How much does your estimate of the kinetic energy differ from the earlier estimate of 10 billion Hiroshima bombs?

What factors might account for the different numbers?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions:

1. How could you spot unknown asteroids or comets in space that might collide with Earth? [*Photographing the same region of stars at different times, then comparing them to look for objects that have changed their position relative to the stars. Of those objects that have changed position, one can eliminate those that are known planets, asteroids or comets, and then—with enough images—determine the orbits of any newly discovered objects that remain.*]

Extension Prompts:

2. How could you potentially prevent a future impact that might cause a mass extinction? *[An object might be nudged by using rockets to push it, or by detonating nuclear bombs near it. The farther away and longer the time before an object hits Earth, the smaller change in the object's trajectory is required to make it miss Earth. If you shatter it with nuclear bombs, one or more of the pieces might still be on a collision course.]*
3. If another Chicxulub-type impact could not be prevented, how could some humans survive the impact and its aftermath? *[Send an "ark" with some humans, animals and plants into orbit. They could later return to restart civilization. Or, equip shelters with protection against the blast/tsunamis, enough food and nuclear power to survive the long winter and enough animals and plants to restart civilization afterward. Or just give up and hold the biggest "going out of business" sale of all time.]*

Engineering and Experimental Design Question Bank

How could you spot unknown asteroids or comets in space that might collide with Earth?

How could you potentially prevent a future impact that might cause a mass extinction?

If another Chicxulub-type impact could not be prevented, how could some humans survive the impact and its aftermath?

SN IN HIGH SCHOOLS
February 4, 2017

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Cross-Curricular Discussion

Directions: Use the diagram from "Devastation detectives" to answer the related discussion questions assigned by your teacher.