SCIENTISTS IN THE FIELD

Where Science Meets Adventure

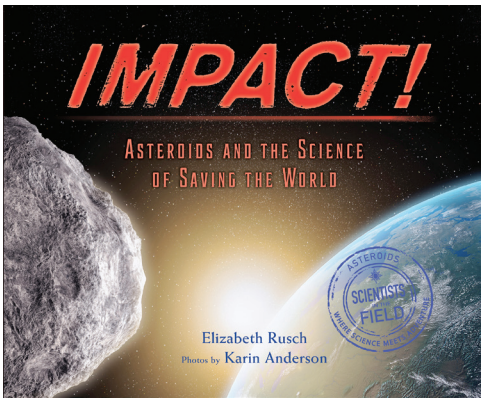
DISCUSSION AND ACTIVITY GUIDE

Impact! Asteroids and the Science of Saving the World

BY ELIZABETH RUSCH (PHOTOGRAPHY BY KARIN ANDERSON)

About the Series

Impact! is part of the award-winning Scientists in the Field series, which began in 1999. This distinguished and innovative series examines the work of real-life scientists doing actual research. Young readers discover what it is like to be a working scientist, investigate an intriguing research project in action, and gain a wealth of knowledge about fascinating scientific topics. Outstanding writing and stellar photography are features of every book in the series. Reading levels vary, but the books will interest a wide range of readers.



Impact!
by Elizabeth Rusch
Photography by Karin Anderson
978-0-544-67159-1

About the Book

About sixty-five million years ago, an asteroid larger than Mount Everest wiped the dinosaurs off the face of the Earth. About seventy-five percent of all plant and animal life was destroyed. The Earth took about three to four million years to recover. Rusch presents this evidence in convincing fashion that reads like a science fiction thriller. Asteroids continue to rain down in our solar system. What makes this book even more important is the conclusion drawn from the scientific community: Another large asteroid could hit again! The good news is that lots of hardworking, smart scientists are working together to make sure we are prepared.

About the Author

Elizabeth Rusch has written about robots, crayons, exploding volcanoes, musicians, and inventors—anything that catches her interest! She didn't always write for kids, though, having started her career writing about kids for *Teacher* magazine, an award-winning magazine for teachers. Her books for children have won many awards, including an Orbis Pictus Honor and an NSTA Outstanding Trade Book. She lives in Oregon, where she watches for things falling from the sky.

About the Photographer

Karin Anderson is a veteran photojournalist who has worked for or been published in the *New York Times, The Washington Post, The Los Angeles Times, The Chicago Tribune, The San Francisco Chronicle, The Chicago Sun*, and CNN. Karin's picture editing and/or photography has received numerous national awards. For fun, Karin likes to spend time with her nutty long-haired dachshund, write, travel, cook mostly healthy food, and of course, make pictures, including these for her childhood friend Elizabeth Rusch.

EDUCATOR'S GUIDE

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Pre-Reading Activities

Brainstorm a list of all the things that could fall from the sky and the risks to students related to these items. What happens, for example, to that bullet shot into the sky to celebrate Independence Day? Review terminal velocity and how it is influenced by size, shape, and mass.

Get a plastic bowl and fill it halfway with water. Drop a golf ball, a tennis ball, and other items into the bowl from various measured heights. Have students predict how much water will be lost. Change the shapes and sizes and mass. Change just one variable. For example, change the shape without changing the size or the mass. Or have two objects exactly the same size and shape, but have one that is much heavier. Can an object dropped be larger and not have much water spilled out, compared to a smaller object? Can an object be very small and cause much more of a splash?

Make a catalog of items seen in the night sky. Use telescopes or binoculars, if available. Make a picture dictionary, flashcards, an online guide, etc., of the differences between stars, planets, moons, comets, meteors, and other items. Include constellations and other astronomy terms. Review basic concepts such as orbits, rotation, gravity, atmosphere, and equinox.

What do students know about geology? Show the class various types of rocks, including the same rocks in different sizes and shapes. Make sure to show igneous, metamorphic, and sedimentary rocks. Have students guess where the rocks are most abundant. It will be helpful to discuss how layers of rock correspond to different times—the oldest rocks are on the bottom, for the most part, unless the land has been uplifited. Have students go out and collect as many different types of rocks as they can find and bring them in. Have students sort them as well as they can and write down the attributes used. This website has a guide for students learning to sort rocks: www.skidmore.edu/~jthomas/fairlysimpleexercises/rockid.html.

When knowledge becomes accepted truth, people have a tendency to merely accept it without much comment or thought. Examine what students believe is the reason why dinosaurs went extinct.

Discussion Questions

What do you predict the public response will be to the evidence that we could be hit by an asteroid? What is the role of science in confronting skepticism about science exploration? What should the government's response be in terms of asteroid research? When does science demand perfection and when does science ask us to take bold risks?

What do we need to do as a country to make sure that the average citizen has a better understanding of why we need to act now on a problem that is, perhaps, hundreds of years away? One of the main thrusts of this book is using information to make sure we do not become complacent and taking the necessary steps now to be safe later. This need to use information as the basis for action, however, is balanced against the harm that one may cause by overstating the problem. What should the government do to sell its citizens on the need to continue funding this research?

NASA knows about 13,000 asteroids and estimates this is about 2 percent of the total. Should we be worried? Does it make a difference that we do not yet have a way to change the trajectory of an asteroid or to destroy one in space? Brainstorm a list of social problems such as world hunger. With many other competing problems, how much of a priority should we give to researching asteroids?

The Chelyabinsk asteroid was as tall as a six-story building. It made a 20-foot wide hole through the ice of a frozen lake in Siberia. What would it have done if it hit land instead of a lake? If it had hit water instead of ice? Note this asteroid caused roofs to collapse more than 50 miles (80 km) away.

Asteroids could strike anywhere on the planet. How important and how likely is global cooperation in ensuring the safety of the entire planet? What happens if one country does not agree with the majority of the world's scientific community? How should international disputes be handled?

This book has links in the back matter for tracking asteroids. Will you track asteroids even if your teacher

or school does not require you to do so? If not, what could this book have done, if anything, to make it more likely that you would? How do nonfiction authors attract your attention to subjects that may not be your favorites?

On page 6, the author speaks of the view of space and asteroid belts from a Hollywood perspective and compares that to the actual information of this same space. Not surprisingly, they are very different. Does the entertainment industry do the scientific community a disservice in the way it depicts science?

Applying and Extending Our Knowledge

Sometimes with informational books we get so caught up with the information, we forget to notice the superb writing, photographs, and book layout! Informational books must address the who, where, when, what, and why; award-winning books must grab our attention and make us turn to the next page. Read the first chapter one more time.

- Does the author grab your attention while answering these questions? Why or why not?
- Make a list of the verbs and adjectives used in these pages. What other choices did the author have? Evaluate the choices Rusch makes. Does she answer the questions of who the subject is, where we should look, when the action transpires, what the problem is, and why she is writing about it? Keep this in mind while reading. Look at some of your own writing and ask about steps you could have taken to make it more interesting to read without inventing information.
- Find a favorite piece of fiction and compare the first seven pages of that book to the first seven pages here. What things are similar? How do they differ? Create a Venn diagram or report orally on the similarities and differences.
- The Russian teacher, unsure of what is happening, yells to the students to "Duck and cover!" (p. 1). How does this phrase set the mood of the book? Ask your grandparents or older adults about this phrase and report back. Record the range of responses. Do a search using this term and compare with the oral responses of the various people that responded.
- Look at the cover, endpapers, title page, and all the illustrations up to the end of the first chapter. Note the colors, page layout, background colors, font colors, page design, and other details. Each photograph and design choice was intentional. Write about what you think the publisher was trying to accomplish with book size, cover image, photograph size, fonts, endpapers, colors, and other choices. How successful were these choices? Are there choices that you would have made differently? Explain how effectively the photography works with the text, including a rationale for any changes you would have made.
- Show students other books in the Scientist the Field series and have a discussion about branding so that readers instantly identify a book as part of a series.

Common Core Connections

CCSS.ELA-Literacy.RH.6-8.7 Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.

CCSS.ELA-Literacy.W.7.7 Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

CCSS.ELA-Literacy.W.6.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-Literacy.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-Literacy.RI.6.1 Cite textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

CCSS.ELA-Literacy.RI.6.2 Determine a central idea of a text and how it is conveyed through particular details; provide a summary of the text distinct from personal opinions or judgments.

CCSS.ELA-Literacy.RI.6.4 Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings.

CCSS.ELA-Literacy.RI.6.5 Analyze how a particular sentence, paragraph, chapter, or section fits into the overall structure of a text and contributes to the development of the ideas.

CCSS.ELA-Literacy.RI.6.6 Determine an author's point of view in a text and explain how it is conveyed in the text.

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CCSS.ELA-Literacy.RI.6.9 Compare and contrast one author's presentation of events with that of another (e.g., a memoir written by, and a biography on, the same person).

We learn in the first chapter that the Chelyabinsk asteroid caused roofs to collapse more than 50 miles (80 km) away at School No. 37 and caused damage that extended 60 miles (96.56 km) from impact. The asteroid was as tall as a six-story building.

- Prepare a presentation that shows what areas would have been affected had this asteroid fallen in the center of your city. Draw a circle around your city with a 60–mile radius. [Note: the circle offers plenty of math extensions, such as the number of people affected, the number of buildings damaged, fiscal impacts, and more.]
- Find Chelyabinsk and create the same 60-mile radius. We know that 7,000 buildings were damaged. What cities and areas of note are in this circle? Research population numbers and predict where, besides Chelyabinsk, other damages were reported.
- Prepare a news report on this Chelyabinsk asteroid from the point of view of the landforms, flora, and fauna found in this part of the world. Research the plants and animals found in this lake. Nothing is mentioned in the text about what happened to this lake ecosystem. Write a fictional story, as if it were nonfiction reporting, on what happened to the lake and its geology, plants, and animals. Revise this writing after reading about the Chicxulub crater in chapter 4.
- We learn that size and shape and mass are factors that contribute to the destructive power of an asteroid like the one that blew up over Chelyabinsk. If you were designing a scenario for the most destructive asteroid possible, what shape would your asteroid be (assuming that it were still the same weight and size)? Where would it fall? Show a highlighted map of the region affected. Make sure to do research so that you do not forget to factor in things like what would happen to your shape entering the atmosphere with the friction and heat. Write a justification to support your location, asteroid shape, and other elements. Should several individuals or groups come up with very different shapes and rationales, debate the merits of each and determine whether or not a consensus winner is possible.
- Divide your students into teams to investigate the relative effects of the asteroid. Prepare a spreadsheet or graphic that shows the effects monetarily and, when appropriate, physically (especially in ways that alter existing landforms, destroy iconic features, or inflict large-scale destruction on urban areas). Estimate the financial loss by looking at the value of property, businesses, houses, etc. Make sure to discuss the estimated long-term cost that covers things like decreases in tourist revenue, rebuilding expenses, etc.
- Page 5 shows pictures of asteroids that have been visited by spaceships as of 2014. Look at the previous activities and have groups explore, compare, and contrast the likely results if one of these asteroids had hit instead of the one that did.

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CCSS.ELA-Literacy.SL.7.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.

CCSS.ELA-Literacy.W.7.7 Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

CCSS.ELA-Literacy.W.6.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-Literacy.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.

We read on page 7 that about once a year an asteroid as big as a car strikes the Earth, most doing very little damage.

- Perhaps with the help of a school library or public library, research this yearly occurrence. Make a list of the asteroids and map locations.
- Create a card for each, showing when it hit, how big it was, damage, shape, and mass, and other details. Include pictures, if possible.
- Prepare a poster for young students, explaining to

them why asteroids as big as cars hitting Earth's atmosphere are not usually a problem. The goal is to show young students, in a way they can understand, how the gasses in our atmosphere protect us. Write an annotation for the poster explaining key topics, including a glossary that puts scientific terms in simple but clear language. Write a rationale justifying your poster approach.

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CCSS.ELA-Literacy.W.6.2 Write explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
CCSS.ELA-Literacy.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.

The Birth of the Solar System sidebar on page 6 includes this sentence: "But the truth is, most of the asteroid belt is just cold, black, empty space." Now look at the photo just before page 1. Watch one of the Star Wars asteroid clips, such as this one, www.youtube.com/watch?v=KvJDItC6tE0.

- Why does Hollywood get the actual science so wrong? Prepare an Animoto video showing what this scene would look like if it were based on science. Would it be as entertaining?
- What responsibility does the entertainment industry have in accurately portraying science information? Assign sides to debate the question: Is Hollywood misleading millions of students by purposely distorting scientific information?
- Could you develop a storyline that uses "cold, black, empty space" as a means to generate suspense and interest in people traveling through an asteroid belt? Create a trailer for an invented movie in which accurate science information is the source of the suspense and viewer interest. Share these and have the class provide feedback on what does or does not work for them. Come to a consensus and share the favorite with the whole school or with your extended community.
- An interesting extension would be to have students report on movies from a science perspective, such as these folks do: screenrant.com/most-accurate-sci-fi-science-fiction-movies-all-time. This link shows movies with accurate information. Perhaps the class can come up with a scale that factors in how much of the movie includes science information and how accurately the science scenes are depicted. Entertainment value might be a factor as well. Each movie could also include a brief annotation. Bonus points if students are able to model it after the Torino Scale found on page 54.

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CCSS.ELA-Literacy.W.7.7 Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research.
CCSS.ELA-Literacy.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.
CCSS.ELA-Literacy.RI.6.4 Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings.
CCSS.ELA-Literacy.RI.6.7 Integrate information presented in different media or formats as well as in words to develop a coherent understanding of a topic.

The study of asteroids has changed a lot from the days in which folks used to sing about "falling stars." Look at this version: tmbw.net/wiki/Lyrics:What_Is_A_Shooting_Star%3F by Hy Zaret and Lou Singer recorded in 1959.

- Write song lyrics, and, if possible, work with a music teacher to compose music that does an accurate job of explaining things such as a fireball, asteroid, meteorite, comet, or any other term.
- The book tells us that we probably would not see meteorites falling but that we might hear them. The American Meteor Society speaks of the invisible "dark flight" of a meteorite (www.amsmeteors.org/fireballs/faqf/#8). And after the popping stops, any meteoroids that are now meteorites because they landed are only recognized (if at all) because of how different they appear compared to other rocks. Perhaps this invisible, dark flight deserves a

poem (or song, picture book, illustration, play, or musical). Check to make sure that your science information is accurate. Does your writing reinforce Rusch's purpose and point of view?
- Perform or display your work. Answer questions from those attending about the science involved in your interpretation.

Common Core Connections

CCSS.ELA-Literacy.SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
CCSS.ELA-Literacy.W.6.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
CCSS.ELA-Literacy.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.
CCSS.ELA-Literacy.RI.6.7 Integrate information presented in different media or formats as well as in words to develop a coherent understanding of a topic or issue.
CCSS.ELA-Literacy.RI.6.4 Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings.
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CCSS.ELA-Literacy.RI.6.6 Determine an author's point of view or purpose in a text and explain how it is conveyed in the text.

Chapters 3 and 4 detail the research done on the Meteor Crater in Arizona and the Chicxulub Crater in the Yucatán Peninsula of Mexico. David Kring is the scientist credited for solving the mystery of why dinosaurs disappeared and the role that these large asteroids had in that process. Even today, however, a quick search for why dinosaurs are extinct produces more than just Kring's asteroid answer. We see theories about volcanoes, disease, and food-chain imbalances, along with suggestions that it is still a mystery.

- How much of a mystery is it where you live? Interview a group of students and adults.
- Depending on your results, prepare a flier, essay, or podcast that reinforces the science that Dr. Kring has done to prove the reason behind the demise of the dinosaurs.
- The text on page 30 says, "When David studied a borehole sample taken from a crater in Mexico, he discovered that this contains shocked quartz, which can be made by only one thing: an asteroid impact." Write an explanation of why only an asteriod can cause this effect.
- Why is the presence of iridium that matched other samples another clue that helped Kring prove that an asteroid had destroyed the dinosaurs? Prepare an explanation of how scientists matched the iridium found in other locations. Why is this significant? Write an explanation for why this is compelling proof.
- In several places we see pictures of meteorites and read descriptions of what they look like. It is clear that meteorites are not obviously different from the rocks we have on Earth. The scientists say that finding a meteorite is often a matter of noticing a rock that does not seem to match the others. Have students look for anomalous rocks on your school grounds. Play a game in which students collect rocks that are mostly the same, but add one rock that is, upon inspection, different because of one or more attributes. Have other students try to guess the one that should be tested to see if it is a meteorite. The students should describe the one they cast to play the part of the possible meteorite and include why the rock selected is different.

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On page 38 we see a graph of the sky showing the parts of the sky that scientists and asteroid hunters

have searched. The photos on pages 40 and 41 show the process of identifying an object moving through the sky. In these pictures, the reader is assisted with red circles drawn around the potential asteroid. In the second chapter, we see that the search involves establishing a grid, walking and looking for something that seems out of place. Searching for asteroids involves hour after hour of staring at pictures of the night sky without the aid of red circles.

- Make copies of a picture of the night sky. Use the one, for example, just before page 1. Add a white dot about the same size as one of the middle-sized white dots (not the smallest and not the biggest) to four of the copies. As in the photos on pages 40–41, have these dots start at the left and move to the right in a line on an angle. Photocopy this set of four images so that students are not given texture or paper clues. Give them a copy of just the photo. See if they can find the additions.
- A lot of this work depends on the ability to know exactly where to look and how to detect differences. Have a student place a small rock inconspicuously somewhere on your school grounds. This rock should be one that the students can identify, but not one that is obviously different. Have this student come back and tell a group of students where it is. See if they can find it. Have them write clear directions on how to get to the spot. If possible, have them test their directions on a group of students coming to this activity for the first time. Refine and rewrite as the experience of students using these directions dictate.
- Now have students do the same rock-hiding exercise, but this time students will include the GPS coordinates for where the rock is located. Using Google Maps, zoom into the location of your school. Print out maps for students and have them insert and label a grid showing the precise location where the rock's placement. Share the exact GPS location, which can be found online: www.findlatitudeandlongitude.com. Have students practice finding the rock using the coordinates only. Then do this again including both the coordinates and a verbal description of where to look by the person hiding the rock. Have students discuss how to make this search easier. Discuss the different ways students labeled their grids. If students still had trouble finding the rock, have them come to an agreement how to make this easier.
- This work searching for asteroids requires patience and a strong attention to detail. Have students discuss how suited they are to this type of work and steps one would need to take to do this job well. Use the work they did identifying the "asteroid" above as the basis for this conversation. How long did it take? What is the range of times? What is the median time? If you were on the slow side, what would you need to do to improve? How do scientists deal with the tedium of searching day after day, night after night?

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CCSS.ELA-Literacy.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.
CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
CCSS.ELA-Literacy.SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

In chapter 6, we read about tracking asteroids by detecting infrared light. We read on page 47 that scientists detected 34,000 asteroids.

- Give one student a warm rock and have other students find it using an infared camera. See page 47 for other ideas for using an infrared camera.
- Later on page 48, Rusch informs us that the team pointed the telescope into deep space to cool it down. "The blackness of space is so cold that just by looking at it, the telescope loses heat." How does this work? First record your own prediction for how this works. Then do research. Try contacting Beth Fabinsky, the author of the quote, for an explanation. If that does not work, post the ques-

tion on Elizabeth Rusch's website (www.elizabethrusch.com/about).

- When Amy Mainser heard that NASA wanted her team to turn NEOWISE back on, it involved "a lot of science writing" (p. 49). We learned that a lot of preparation was involved; it is not just a simple matter of turning on a satellite or computer. Why was writing involved? What steps needed to happen? As above, try contacting the people involved to hear firsthand how this process works.
- Mainser was also concerned that the telescope might not work after all this time. It did, but what were the possible scenarios for NEOWISE not working? Have groups come up with a list. Any scenario proposed must include a justification based on the text or on research.
- On page 50, we learn that scientists are measuring asteroid sizes and how reflective the surfaces are, with the hope of discovering what the asteroids are made of. Mainser says, "A very, very important part is trying to understand the composition . . . for science—and for the planetary defense." How does this work? Why do lighter asteroids indicate they are rocky, etc.? Create a presentation showing why composition is important.
- Mainser uses the term "planetary defense." Prepare a persuasive essay for convincing an imaginary country to participate in a global effort to identify asteriods. Create a poster or brochure showing why participation is essential.

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The last chapter, entitled "How to Save the World," begins with a description of Apophis, an asteroid that crosses the Earth's path twice every 323 days. At first scientists calculated the odds of Apophis hitting Earth in 2029 at one in three hundred. These odds eventually dropped to one in forty-five. As work continued, scientists eventually concluded that Apophis was not a threat.

- This suspected threat refocused asteroid attention toward what we will do when we know an asteroid will hit the Earth—an 8 or higher on the Torino Scale. Read the scenarios about bombing, crashing into, pushing, vaporizing, and tugging asteroids. Write about which of these options or combination of options seems most worth pursuing and why. How would you deal with the possible dangerous side effects?
- Brainstorm ideas for dealing with dangerous asteroids with others and make a list. Evaluate the group options and come to a consensus concerning what scientists should do about dangerous asteroids. What would the backup plan be?
- Ninety-five percent of large asteroids have been discovered according to Mainser. How does Mainser know how many asteroids there are? Or is the point of this statement that there could still be a big one out there? The beginning of the book suggests that a big asteroid striking the Earth is more a question of when than if. After finishing this book, write a reflection of what scientists should be doing, and a projection for asteroid research in the next 25 years, particularly after the Asteroid Redirect Mission in December of 2020.
- Create a method for sharing the information in

this book with very young students—or debate if we should share information about something as potentially devastating as asteroids with very young students. Think about picture books, musicals, plays, puppets, poems, songs, and other formats for sharing this information.

Common Core Connections

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CCSS.ELA-Literacy.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.
CCSS.ELA-Literacy.RH.6-8.7 Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.

Other Websites to Explore

Skidmore College has an excellent site filled with activities that will help students with understanding basic geology principles. www.skidmore.edu/~jthomas/fairlysimpleexercises/Index.html

The Center for Near Earth Object Studies (CNEOS). It is the California Institute of Technology Jet Propulsion Lab site, which is a part of NASA. cneos.jpl.nasa.gov/about/life_on_earth.html

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