CONTENTS

INTRODUCTION

To the Earth Science Teacher XI
Expectations for Each Investigation XI
References XIII

ABOUT THE AUTHORS XIX

ABOUT THESE LABS XXI

CHAPTER 1

PROCESS OF SCIENCE AND ENGINEERING DESIGN 1

1A. Testing Your Horoscope Lab 3
1B. Reading Minds Lab 7
1C. Estimating With Metrics Lab and Measurement Formative Assessment 14
1D. Science Process Vocabulary Background Reading and Panel of Five 22
1E. Explain Everything With Science Trivia 26
1F. Controlled Experiment Project 30

CHAPTER 2

EARTH’S PLACE IN THE SOLAR SYSTEM AND THE UNIVERSE 39

2A. Sizing up the Solar System Lab 41
2B. Keeping Your Distance Lab 47
2C. Reflecting on the Solar System Lab 57
2D. Comparing Planetary Compounds Lab 65
2E. Kepler’s Laws Lab 72
2F. Phasing in the Moon Lab 77
2G. Reason for the Seasons Reading Guide and Background Reading 82
2H. Changing Lunar Tides Lab 86
2I. Finding That Star Lab 95
2J. Rafting Through the Constellations Activity 105
CHAPTER 3

EARTH’S SURFACE PROCESSES

3A. Periodic Puns Activity
3B. Weighing in on Minerals Lab
3C. Knowing Mohs Lab
3D. Classifying Rocks and Geologic Role Lab
3E. Edible Stalactites and Stalagmites Lab
3F. Weathering the Rocks Lab
3G. Hunting Through the Sand Lab
3H. The Basics of Rocks and Minerals Background Reading

CHAPTER 4

HISTORY OF PLANET EARTH

4A. Unearthing History Lab
4B. Drilling Through the Ages Lab
4C. Decaying Candy Lab
4D. Superposition Diagram Challenge
4E. Mapping the Glaciers Lab
4F. Geoarchaeology Background Reading

CHAPTER 5

EARTH’S INTERIOR SYSTEMS

5A. Shaking Things up Lab
5B. Mounting Magma Lab
5C. Hypothesizing About Plates Activity
5D. Cracking up With Landforms Lab and Landforms Formative Assessment
“THE ART OF TEACHING IS THE ART OF ASSISTING DISCOVERY.”
MARK VAN DOREN (1894–1972)

This book is dedicated to the power that collaboration has among classroom teachers. Special mention goes to my friend, Mary Gallus, for her enhancement of lessons and expert collaboration.
This second edition of Earth Science Success: 55 Tablet-Ready, Notebook-Based Lessons provides a one-year Earth Science curriculum with 55 classroom-proven lessons designed to follow the disciplinary core ideas for middle school Earth and space science from the Next Generation Science Standards (NGSS). Intended for teachers of grades 5–9, Earth Science Success emphasizes hands-on, sequential experiences through which students discover important science concepts lab by lab and develop critical-thinking skills. Whereas the first edition focused more on the rationale for implementing the curriculum and the wisdom of using composition notebooks, this second edition focuses a special lens on the lessons themselves. The 55 lesson plans enable teachers to use electronic tablets, such as iPads, with best practice, field-tested methods.

Middle school Earth science teachers’ days are very busy with large classes, meetings and various duties, grading and correction, class preparation, answering communications from parents, and so on. Earth Science Success is the result of the authors’ desire to create a notebook-based, lab-focused, ready-to-use, and now tablet-ready curriculum that has been field-tested and refined for success. The authors have organized this curriculum into a series of investigations that emphasize the active involvement of students in a discovery process. Intended primarily for classroom science teachers as a survival guide for teaching a full Earth science course, Earth Science Success follows a three-step pattern of active involvement in the discovery process, which includes anticipation, evidence collection, and analysis. The topics chosen and the laboratory approach employed in Earth Science Success reflect the core ideas involved in scientific and engineering practices, which lead to the four main categories of performance expectations from NGSS: Engineering Design, Earth’s Place in the Universe, Earth’s Systems, and Earth and Human Activity. Earth Science Success is also a valuable tool for training future science teachers, who will enjoy implementing and discussing the investigations featured in this book.

To the Earth Science Teacher

Like you, the author is a busy classroom science teacher. Successful strategies include those that save time and promote skillful organization. Both composition notebooks and electronic tablets offer tremendous opportunities in this regard. The
lessons in *Earth Science Success* lend themselves toward either approach. Combining the two, however, is even better.

The same successful pattern is followed for each lab report, no matter what the learning target or concept. See “Expectations for Each Investigation,” p. XIII, for a summary of the expectations for each component of the lab report. The point value shown in parentheses is flexible, and is based on a 30-point total for each lab report grade.

Among iPad apps, *Paperport Notes*, *Evernote*, and *Notability* all provide for fully integrated note taking. The author uses the *Notability* app with the Divider set as Science, and the Subjects set as Labs and Lessons, Reference Pages, and Glossary. She creates a PDF of each lab report template and posts it on her website (both *Google* and *Schoology*), for students to download. She encourages “auto syncing” to *Google Drive* or *Dropbox*, so if a glitch happens with the electronic lesson, the work has been backed up. Students submit their assignments electronically to *Schoology*, but *Showbie* and *eBackpack* also work well in that capacity. These Learning Management Systems allow teachers to “push” the assignments onto the students’ tablets, and provide due date calendar systems, as well.

The author uses a mini-conference method for typical in-class grading. This involves collecting all of the iPads (or composition notebooks with bookmarks placed in the current lab) in the front of the classroom, on a cart. The lab reports are graded in random order, while students work on other assignments and lessons, such as the graphing or analysis portions of the following lab, at their desks. Students are called up to sit next to the teacher, to witness the grading, as individuals, in a semiprivate conference. Input from the student and feedback from the teacher become clear and lasting through the use of this method. The author has found that a class of 32 iPad lab reports can be graded using the mini-conference system in a typical 50-minute class period.

Why are notebooks, both electronic and nonelectronic, so valuable? One of the most important reasons is that students are able to organize, reflect upon, and retrieve their learning. This enables them to increase their scores assessments and achieve at higher levels. Students tend to have fewer missing assignments, and “no name” papers are a thing of the past. While tablets enable connections to internet research, word-processing capabilities, real-time data, and access to rich video vignettes to expand learning, the composition notebooks have many benefits as well. Composition notebooks are durable. The fact that no pages can be torn out enables students to refer to past results. Any important handouts and foldables can be glued or taped in, and students can incorporate labeled sketches, data tables, predictions, analysis questions, personal reflection, vocabulary, and correction of misconceptions in each lesson. The tablets and composition notebooks are great
resources to use at parent/teacher conferences. The evidence to show student learning through investigations is clear. By the time students reach middle school, using hands-on activities to teach meaning in science is critical (NAEP 2013).

Expectations for Each Investigation

Based on a 30-point total, the author uses the following system to grade lab reports.

1. **Title (1 point):** The title should include several descriptive words, not a complete sentence, dealing with the chosen topic of the experiment. It should be brief and catchy, but should also indicate the variable(s) that were tested.

2. **Problem (1 point):** This provides the anticipatory question, which lends focus to learning for the experiment. It should be a complete sentence and phrased as a question. The problem explicitly states the experimental question being investigated, providing enough detail so the audience can understand what will be done.

3. **Prediction (1 point):** The prediction (or hypothesis, depending on the particular requirements in each lab) must be a complete sentence and on-topic. It is not graded for accuracy, but it is often compared and contrasted later with the final outcome of the investigation. This is where the author often targets the correction of misconceptions through class discussion and formative assessment.

4. **Thinking About the Problem (3 points):** This section gives the student necessary background information and content descriptions related to the investigation. The expectation is for the student to develop strengths in literacy by highlighting important sentences while the teacher reads the section out loud. This process helps the student to write three main points from the background information (see Figure I.1, p. XIV for an example). The teacher should have students share several main points out loud, after writing, so that misconceptions can be anticipated and explained.

5. **Labeled Image (3 points):** The image should clearly show the labeled materials and experimental setup, so that the student can describe all procedures. On each lab report, there is a designated space where students can place their image (or draw their sketch, when using composition notebooks). See Figure I.2, p. XV, for an example.
FIGURE I.1.

STUDENT SAMPLE OF “THINKING ABOUT THE PROBLEM” SECTION IN SCIENCE NOTEBOOK

**Problem:** What is so special about water?

**Prediction:** Give a working definition of water molecule.

**Water Molecules will stick to their Surroundings.**

Thinking about the Problem:

What does H₂O mean? Each molecule (molecule = small bit in Latin) of water is made of two hydrogen atoms (H₂) and one oxygen atom (O). What is special about water molecules is that they tend to “stick” to each other (cohesion) and to other molecules (adhesion). They do this because water is built like a magnet, with a positive end and a negative end. This helps it bond well.

Water makes life on Earth possible. It covers almost three-fourths of the surface of our planet. Because there is so much of it, water may seem very ordinary to us, and yet it is unique when compared to all other substances. For example, water is the only substance on Earth that occurs naturally in all three states: solid, liquid, and gas. In addition, solid H₂O (ice) is less dense than its liquid form (water), so it floats. Most other solids are denser than their liquid form, so they sink!

Another difference, with respect to water, is that large amounts of energy must be added to water to achieve even a relatively small change in temperature. That is why our oceans moderate the temperatures of coastal communities on Earth.

Thinking about the Problem:

1. Each molecule of water is made of two hydrogen atoms (H₂) and one oxygen atom (O).
2. Water is built like a magnet, with a positive and negative end.
3. Water is the only substance on Earth that occurs naturally in all three states: solid, liquid, and gas.

**Materials:**
- 8 oz. Drinking Glass
- Dish Soap
- Eye Dropper
- A variety of water containers (assortment of five glasses, buckets, bowls, etc.)
- Many Pennies (or replacement item…control for size)
- Other Coins

**Procedures:**
1. Predict which of your five large containers (each full to the rim with water) will be able to withstand the addition of the greatest number of pennies (or replacement item) without spilling over. Test and record your results. Take photos with your iPad while conducting this step.
2. Place a dry penny on a piece of paper towel.
3. Predict the number of drops you can pile on the penny before water runs over the edge.
4. Test and record for each particular coin. Take photos with your iPad during this step.
5. Draw a photograph and label a sketch/image of the water on the surface of the coin just before the water spilled over.
6. Conduct the same tests with the soapy water.

**Analysis:**
1. Describe the shape of the water as it “sits” on a coin:

   ![Curved on the penny like a upsidedown V](water.png)
2. Why does water pile up on a coin, rather than spilling over the edges immediately? How is the
soapy water different? (Describe the science behind your thoughts… “Thinking about the Problem” will
help you here.)
The water sticks making it come up and the soapy water does not stick so it falls off the edge.

3. Use science concepts to suggest reasons why each of the five containers holds a different number
of pennies.
   I found out that a glass with a bigger rim will hold more pennies because there is more surface area/more room for water to bend around rim.

4. Explain “surface tension” as if you were explaining it to a second grader.
   Allows objects like bugs to sit on water.

Labeled Sketches/Images:

FIGURE 1.2.
STUDENT SAMPLE OF LABELED IMAGES IN SCIENCE NOTEBOOK
6. **Data Tables and Graphs (8 points):** All labs contain at least one data table, and many include graphs, charts, concept maps, and so on. Students are expected to correctly label graphs and tables so the audience can understand them. The evidence presented in the data tables and graphs should be complete and accurate.

7. **Analysis Questions (8 points):** These questions vary in their approaches. Some require students to describe the purpose and procedure for the experiment, while others require a discussion about how variables were controlled. Students will describe what evidence was observed and what was measured, and they will compare the original prediction with the results to help defeat misconceptions. They will also include how the results are supported by other related scientific concepts, research, or theories (using the “Thinking About the Problem” section as a guide). Many analysis questions include internet searches and links to electronic resources and concept maps to promote personal reflection and further the correction of misconceptions. There are also questions for enrichment, which the teacher can use for differentiation. The expectation is that students will answer the analysis questions completely and with accuracy.

8. **Learning Targets (0 points):** This briefly lists a main objective for the lesson or concept learned while conducting the experiment.

9. **“I Learned ...” Statement (1 point):** These are facts and main ideas that apply to what students learned during the investigation. A complete sentence is expected.

10. **“Redo” Statement (1 point):** One of these sentences is due for each investigation. Students must think of a change in the variables (materials or procedures) that might result in a totally new outcome on the lab. An example might be: “I would try the experiment using a black light, rather than sunlight.” A good sentence framework to use is, “Instead of using ___, I would use ___.”

11. **Identify One “Manipulated Variable” (1 point):** A manipulated variable is a particular component of the experiment that is purposefully changed in order to see results. Students should list the main manipulated variable, but do not need a complete sentence.

12. **Identify One “Measured Variable” (1 point):** A measured variable is the evidence of the experiment, which was observed, measured, and recorded.
in a data table. Students list one of the measured variables, but do not need a complete sentence.

13. **Identify One “Controlled Variable” (1 point):** A controlled variable is held constant, and it should remain unchanged during the lab. It allows the student to determine what, if any, change took place in their variables during the experiment. Students can list one of the controlled variables, but do not need a complete sentence.

14. **Glossary (0 points):** This is a required section of any notebook, whether or not it is electronic. Definitions of terms can be used as flash card starters, as well. It serves mainly as a study guide and help for analysis and flash card generation but is not a graded portion of each lab report.

15. **Reference Pages (0 points):** These are also a required section of any notebook, whether or not it is electronic. They serve mainly as study guides and help for analysis but are not graded portions of each lab report.

**References**

During the development and field-testing of both editions of *Earth Science Success*, care was taken to produce a curriculum that would complement well-known Earth science print materials through a research-proven investigation methodology. Among the works consulted, three held the greatest influence: the National Science Teachers Association’s four-volume series *Project Earth Science* (Ford and Smith 2000); the two-volume *Hands-on Science* series (Fried and McDonald 2000a, 2000b); and the *Curriculum Research and Development Group* series (Pottenger and Young 1992). Each of these would constitute a valuable resource for teachers who have chosen the lab-centered activities of *Earth Science Success* as their main source of lesson plans and student handouts. Along with the great ideas suggested during field-testing by colleagues, we are also indebted to the National Aeronautics and Space Administration (NASA). Two summers spent at NASA’s Space Academy for Educators were instrumental in the original decision to write this book.


INTRODUCTION


About the Authors

Catherine Oates-Bockenstedt

Catherine has been a teacher of science at the middle-school level for almost 30 years and currently teaches at Central Middle School in Eden Prairie, Minnesota. She received both her BA and MA in science education from the University of Northern Iowa. Certified by the National Board for Professional Teaching Standards (NBPTS) in early adolescent science, she credits the professional development opportunities she has had with NBPTS and with NASA Space Academy for Educators for providing the impetus to write Earth Science Success. Wife of Paul, a natural resources biologist, and mother of Lara and Daniel, she lives with her family in Eden Prairie, Minnesota. She is very grateful for the support of her family, friends, and colleagues.

Michael D. Oates

Without the contributions of Michael D. Oates, this book never would have been a possibility. Michael was a professor at both the secondary and university levels for 42 years. Michael received his PhD in French and Linguistics from Georgetown University and is the author of two French textbooks. In 2008, he was decorated by the French government as Chevalier dans l’ordre des Palmes Académiques. Invited by his daughter, Catherine, to collaborate on Earth Science Success, he became an avid student of science. He was always very grateful for the support of his wife (Catherine’s mother), Maureen. Diagnosed with an aggressive form of brain cancer, shortly after seeing Earth Science Success become published by the National Science Teachers Association, he passed away in April of 2009.
Each of the labs in every chapter of this book is organized to follow a pattern of active involvement by students. Students are continually presented with searching for evidence using a three-step discovery approach. The three steps are: anticipation, evidence collection, and analysis. Anticipation involves reflection on observations and a problem statement, recall of previous knowledge about the topic, discussion of misconceptions, and definition of concepts. Evidence collection includes hands-on laboratory investigation techniques. Analysis requires confirmation or rejection of results, reporting the findings, and making conclusions about the observations.

The hope is that students will form good habits about testing and controlling all possible variables in their experiments whenever they are collecting evidence. They should be able to identify the manipulated, measured, and controlled variables in each experiment. Results should be reliable and valid. And students should set up controls, as a basis of comparison, so they can determine the actual changes in their data. This pattern of active involvement by students is followed throughout Earth Science Success.

Please see the sections found in our introduction for more specifics on successful approaches for each of the labs and lessons, especially “To the Earth Science Teacher” and “Expectations for Each Investigation.” In addition, teacher notes are provided to clarify differentiation possibilities, and answers are given whenever the lesson requires one particular response.
HISTORY OF PLANET EARTH
4A. Unearthing History Lab

Problem

Where do life forms appear in a timeline of Earth history?

Prediction

Answer the problem statement.

(Teacher note: Have students share several predictions out loud, so misconceptions can be anticipated and explained.)

Thinking About the Problem

How old is Earth? Geologists use information from rocks, rock layers, fossils (fossus “dug up” in Latin), and other natural evidence to piece together the history of our planet. Geologists consider time from the formation of the Earth to today, following a geologic timescale that breaks Earth’s history into manageable pieces. Geologic time is divided and subdivided into eons, eras, periods, epochs, and ages. They have used this information to put geologic events and fossil organisms (evidence of living things) in their correct sequence on this timeline. The boundaries are set by major events that have been preserved in the rock record.

More recent events can be measured in the soil, as well. For example, Earth systems scientists now believe that an early culture of humans, known as the Clovis people, wandered North America, hunting mammoths and sloths. Their culture came to an end when a mile-wide comet wiped them out. Scientists believe this due to evidence found in a thin layer of black soil, containing iridium from comets, which coats more than 50 sites in North America, especially near the Great Lakes.

Through research, including the use of the geologic time scale, most scientists conclude that Earth is approximately 4.6 billion years old. You will learn more about what evidence scientists use to determine this age in our next lab. Compared to 4.6 billion years, living things have been around for a relatively short time. This lab will help you learn about the geologic timeline for the Earth and more clearly understand the various geological periods and events you will hear described in the media.
Materials

- Earth History on a Rope Scale Model Measurements
- Masking tape
- Rope or twine (5 meters long)
- Ruler
- Scrap paper for labels

Procedure

1. Lay the rope out on the ground in front of you. At the far right end, tape the label “Present Day.”
2. Starting from the “Present Day” mark, measure back exactly 4.6 meters. Label this “Formation of the Earth.”
3. Measure from the Present Day mark, using Data Table 4.1 (p. 157), and label each eon, era, period, and epoch (with a different color code).
4. Use Data Table 4.2 (p. 158) to label each event in Earth’s history.

(Teacher note: This is treated as a presentation of “Earth History on a Rope” for Enriched Science, and an “Earth History Timeline” for Regular Science—using a 46 cm line drawn on paper. The four sample analysis questions are for “practice” to prepare for their two presentation questions in front of their peers. As a small group, students work on the rope timeline and you spot-check three particular measurements. If the students are within 2 cm of actual, then they get full credit for the rope timeline. If they are not, then they each lose 2 points for each incorrect measurement (out of 30 points total). Then, for individual accountability, each student has to answer two questions from the list on this document. Each question costs them 2 points per wrong answer. This means that the lowest score any student will receive, should they work in a group on the rope timeline, is 20 out of 30. Data tables include information pertinent to the state of Minnesota.)

Sample Analysis

1. Hypothesize how the geologists divided the time scale into smaller units.
2. Where on the timeline are the two major extinction events?
3. The time from 4.6 billion years ago up until the beginning of the Phanerozoic eon is called Precambrian Time. Find this part of your timeline. How does Precambrian Time compare in length with the rest of the geologic time scale?

4. The Cenozoic era is the most recent era, and it includes the present. How does the Cenozoic era compare in length with the other eras?

Geologic Timescale Presentation Questions

Make questions #1 and #26 available to prepare students, while they get their rope timelines and are waiting to be called on. (Teacher note: Answers are given in parentheses.)

1. How many points, or lengths from present day, are marked with events or dates on your rope? (46)

2. Name the eras that are marked on your rope. (Paleozoic, Mesozoic, Cenozoic)

3. Describe what the color code is for the five colors that you used. (Need five colors: eons, eras, periods, epochs, and fossil/events)

4. The time on your geologic time scale from 4.6 billion years ago up until the Phanerozoic eon is called Precambrian time. How does the length of the Precambrian time compare to the rest of the scale? (Precambrian is longer.)

5. The Cambrian period marks the beginning of the complex life forms (like trilobites) in Earth history. How does the length of the Cambrian to present compare with the length of the rest of the geologic time scale? (Cambrian is shorter.)

6. When on the timeline are the two major extinction events? (248 million years ago and 65 million years ago)

7. Hypothesize or explain how you think geologists divided the time scale into smaller units. (Based on life forms found in each unit)

8. Which came first, the Rocky Mountains or the dinosaur extinction? (Rocky Mountains)

9. Which came first, the mammals or the reptiles? (Reptiles)

10. Which came first, the mammals or the flowering plants? (Mammals)

11. Which came first, the amphibians or the reptiles? (Amphibians)
12. Which came first, the flowering plants or the dinosaur extinction? (Flowering plants)

13. Which came first, the Rocky Mountains or the continental ice age being over? (Rockies)

14. Which came first, the green algae or the trilobites? (Green algae)

15. Which came first, the amphibians or the trilobites? (Trilobites)

16. Which era lasted longer, Paleozoic or Mesozoic? (Paleozoic)

17. Give a good Redo Statement for this lab.

18. The Archean eon marks the beginning of the simple life forms (like bacteria) in Earth history. How does the length of the Archean to the beginning of the Cambrian period compare with the length of the Cambrian period to present day? (Archaen to Cambrian is longer.)

19. The Proterozoic eon marks the halfway point for Earth’s history. How does the length of the Proterozoic to Cambrian compare with the length of the Cambrian to present day? (Proterozoic to Cambrian is longer.)

20. Which came first, the extinction of dinosaurs or the greatest mass extinction? (greatest mass extinction)

21. Which came first, the mammals or the greatest mass extinction? (Greatest mass extinction)

22. Which came first, the continental ice age or the modern humans? (Modern Humans)

23. Which came first, the Carboniferous period or the reptiles? (Carboniferous)

24. Which came first, the Ordovician period or the first trilobite? (Trilobite)

25. Which came first, the Cenozoic era or the extinction of the dinosaurs? (They’re both the same date)

26. Why is the following phrase significant? Pregnant camels often sit down carefully. Perhaps their joints creak… though possibly they’re not quick. (First letter of all periods.)

27. Which came first, the Paleozoic era or the Mesozoic era? (Paleozoic)

28. Which period lasted longer, Cambrian or Ordovician? (Cambrian)

29. Which came first, the Carboniferous period or the Silurian period? (Silurian)

30. Which came first, the Miocene epoch or the Eocene epoch? (Eocene)
31. Which lasted longer, the Jurassic period or the Cretaceous period? (Cretaceous)
32. Which Precambrian eon lasted longer, the Priscoan or Archean? (Archean)
33. Which came first, the Triassic period or the Tertiary Palaeogene period? (Triassic)
34. Which lasted longer, the Ordovician period or the Silurian period? (Ordovician)
35. During which period are trilobites first found? (Cambrian)
36. During which period were the first mammals found? (Triassic)
37. During which period were the first flowering plants found? (Cretaceous)
38. During which period did the Rocky Mountains begin to rise? (Cretaceous)
39. During which period were the first amphibians found? (Devonian)
40. During which epoch were modern humans first found? (Pleistocene)
41. What event marks the beginning of all of the epochs? (The extinction of the dinosaurs)
42. During which period were the first reptiles found? (Carboniferous)
43. During which eon were the first green algae found? (Precambrian Protobiotic)
44. Which came first, the Ordovician period or the Quaternary period? (Ordovician)
45. Which came first, the Permian period or the Cenozoic era? (Permian)
46. Which eon came first, the Precambrian Priscoan or the Precambrian Archean? (Priscoan)
47. Which came first, the Eocene epoch or the Pliocene epoch? (Eocene)
48. Which Epoch lasted longer, the Oligocene or the Miocene? (Miocene)
49. Which came first, the Carboniferous period or the Permian period? (Carboniferous)
50. Which came first, the continental ice age or the start of the Pleistocene epoch? (Pleistocene)
51. Which epoch lasted longer, the Pliocene or the Miocene? (Miocene)
52. Which era lasted longer, the Mesozoic or the Cenozoic? (Mesozoic)
53. Which event came first, the first green algae or the first bacteria? (Bacteria)
54. Which event came first, the rise of the Rocky Mountains or the first mammal? (Mammal)
55. Which period lasted longer, the Devonian or the Triassic? (Devonian)
56. Which eon lasted longer, the Precambrian Priscoan or the Precambrian Archean? (Archean)
57. Which came first, the Silurian period or the first amphibian? (Silurian)
58. Which period lasted longer, the Tertiary Neogene or the Quaternary? (Tertiary Neogene)
59. Which came first, the Holocene epoch or the end of the continental ice age? (Holocene)
60. Which eon came first, the Precambrian Priscoan or the Precambrian Archean? (Precambrian Priscoan)
61. Which came first, the rocks in Lac Qui Parle, Minnesota, or the rocks in Taylor’s Falls, Minnesota? (Lac Qui Parle)
62. Which came first, the inland sea or the glaciers covering Minnesota? (Inland sea)
63. Which came first, the glaciers or the humans? (humans)
64. Which came first, the glaciers or the Minnesota River Valley? (glaciers)
65. Which event came first, the inland sea in Minnesota or the flowering plants? (inland sea)
66. During which eon were the gneiss rocks formed in Lac Qui Parle State Park, Minnesota? (Precambrian Archean)
67. During which period was Minnesota covered by inland seas? (Jurassic)
68. During which period did the Superior Lobe and Des Moines Lobe Glaciers leave deposits in Minnesota? (Quaternary)
69. How would the rope timeline compare in length with one created for Mars? (Both ropes would be the same length)
70. How would the rope timeline compare in length with one for the Moon? (Both ropes would be the same length)
### DATA TABLE 4.1.  
#### EARTH HISTORY

<table>
<thead>
<tr>
<th>GEOLOGISTS’ DIVISION OF EARTH HISTORY</th>
<th>HOW MANY MILLIONS OF YEARS AGO IT BEGAN</th>
<th>MEASUREMENT ON ROPE (0.1 CM = 1 MILLION YEARS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronometric Eons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precambrian Priscoan</td>
<td>4600</td>
<td>460.0 cm</td>
</tr>
<tr>
<td>Precambrian Archean</td>
<td>3800</td>
<td></td>
</tr>
<tr>
<td>Precambrian Proterozoic</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>Phanerozoic</td>
<td>544</td>
<td></td>
</tr>
<tr>
<td>Eras</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleozoic</td>
<td>544</td>
<td>54.4 cm</td>
</tr>
<tr>
<td>Mesozoic</td>
<td>248</td>
<td></td>
</tr>
<tr>
<td>Cenozoic</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Periods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambrian</td>
<td>544</td>
<td></td>
</tr>
<tr>
<td>Ordovician</td>
<td>490</td>
<td>49.0 cm</td>
</tr>
<tr>
<td>Silurian</td>
<td>443</td>
<td></td>
</tr>
<tr>
<td>Devonian</td>
<td>417</td>
<td></td>
</tr>
<tr>
<td>Carboniferous</td>
<td>354</td>
<td></td>
</tr>
<tr>
<td>Permian</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>Triassic</td>
<td>248</td>
<td></td>
</tr>
<tr>
<td>Jurassic</td>
<td>206</td>
<td></td>
</tr>
<tr>
<td>Cretaceous</td>
<td>144</td>
<td></td>
</tr>
<tr>
<td>Tertiary Paleogene</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Tertiary Neogene</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Quaternary</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Epochs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleocene</td>
<td>65</td>
<td>6.5 cm</td>
</tr>
<tr>
<td>Eocene</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Oligocene</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Miocene</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Pliocene</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Pleistocene</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Holocene</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>
### DATA TABLE 4.2.

#### EVENTS IN EARTH’S HISTORY

<table>
<thead>
<tr>
<th>EVENTS</th>
<th>TIME (MILLIONS OF YEARS AGO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continental ice age is over in United States</td>
<td>0.001</td>
</tr>
<tr>
<td>Glacial river Warren carves out the Minnesota River Valley</td>
<td>0.0012</td>
</tr>
<tr>
<td>Superior Lobe and Des Moines Lobe Glaciers leave deposits in Minnesota</td>
<td>0.002</td>
</tr>
<tr>
<td>Modern humans</td>
<td>0.5</td>
</tr>
<tr>
<td>Early humans</td>
<td>2</td>
</tr>
<tr>
<td>Extinction of dinosaurs</td>
<td>65</td>
</tr>
<tr>
<td>Rocky Mountains begin to rise</td>
<td>80</td>
</tr>
<tr>
<td>Flowering plants</td>
<td>130</td>
</tr>
<tr>
<td>Twin Cities are covered by seas</td>
<td>150</td>
</tr>
<tr>
<td>First mammal</td>
<td>210</td>
</tr>
<tr>
<td>Greatest mass extinction</td>
<td>248</td>
</tr>
<tr>
<td>First reptiles</td>
<td>315</td>
</tr>
<tr>
<td>First amphibians</td>
<td>367</td>
</tr>
<tr>
<td>Inland Sea covers Minnesota</td>
<td>480</td>
</tr>
<tr>
<td>Minnesota is positioned over the equator</td>
<td>300</td>
</tr>
<tr>
<td>First trilobite</td>
<td>554</td>
</tr>
<tr>
<td>First green algae</td>
<td>1000</td>
</tr>
<tr>
<td>Basalt rocks formed in Taylor’s Falls, Minnesota</td>
<td>1100</td>
</tr>
<tr>
<td>Gneiss rocks formed in Lac Qui Parle State Park, Minnesota</td>
<td>3600</td>
</tr>
<tr>
<td>First bacteria</td>
<td>3800</td>
</tr>
</tbody>
</table>
4A. Unearthing History Lab

**NGSS Alignment**

**MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history.

**MS-ESS2-3.** Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.
4B. Drilling Through the Ages Lab

Problem
How can we use drilling for wells as a way to understand geologic history?

Prediction
What methods can be used to determine the ages of rock layers?

(Teacher note: Have students share several predictions out loud, so misconceptions can be anticipated and explained.)

Thinking About the Problem
Why are geologists interested in drilling? Geologists work together with engineers when drilling for groundwater wells. Drilling allows geologists to examine where different layers of rock begin and end. In the search for water, geologists frequently look for a layer of sandstone perched above a layer of impermeable shale.

Geologists also have an interest in drilling because rock layers provide a record of events that have occurred on Earth. They can contain the remains and imprints of the different plants and animals that have lived on Earth. There are many deep wells (water, oil, and so on) available for geologists to examine.

Scientists estimate that Earth is approximately 4.6 billion years old. There are many pieces of supporting evidence for this. One piece of supporting evidence is the thickness of the rock layers on Earth. Scientists can perform experiments to determine how long it takes to create one meter of a particular rock type. They then multiply this time by the actual thickness of those particular rock layers on Earth. This allows scientists to roughly estimate the age of the Earth. Most geologists believe that it would have taken approximately 4.6 billion years to generate all the layers of rock found on Earth. This study of rock layer depths has been backed up by much more accurate evidence from radioactive minerals and index fossils in the rocks.

Earth scientists study the evidence associated with when the continents began to solidify. Newly discovered Greenland outcrops (an ancient piece of the sea floor, which was raised up by crustal movement) are among the oldest measured, at 3.8
billion years, while most of the continents are much younger, at 2.5 billion years old.

By understanding some simple rules about rock layer formation, we can use the layers and the associated rock types to measure the amount of time that has passed. One important thing to remember is that rock layers form horizontally. A second important factor is that the older rocks will normally be found farther beneath the surface, while younger rocks will normally be closer to the top. This allows scientists to use the positions underground to determine the “age based on position.”

Scientists can use index fossils to determine the “relative age” of layers. Index fossils are the remains of a single species that are so widespread and well known (age-wise), that its fossils enable geologists to correlate environments and time. They can also measure the radioactive minerals found in a rock layer to determine the “absolute age” of the layer.

Write three main points from the “Thinking About the Problem” reading:

1. 

2. 

3. 

Procedure

1. At each drilling site on Figure 4.1 (p. 163), place a small horizontal line at the depths described in Data Table 4.3 (p. 162). Write the name of the rock on that line. The first line for Water Well C, sandstone, has been done for you.

2. Draw a line across the page to connect the areas on all three wells where the rock layers are the same.

3. Use the notes from Data Table 4.3 to determine the age of each rock layer. Write the age in parentheses to the right of the rock layer name.

4. Complete Data Table 4.4 (p. 164) in order from youngest (1) to oldest (11).
### DATA TABLE 4.3.

#### INFORMATION FROM WATER WELLS A, B, AND C

<table>
<thead>
<tr>
<th>WATER WELL A</th>
<th>DEPTH (M)</th>
<th>ROCK</th>
<th>GEOLOGIST NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Conglomerate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Sandstone</td>
<td>135 million years old (Index fossils found)</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Impermeable Shale</td>
<td>No Date Available</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Breccia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Shale</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WATER WELL B</th>
<th>DEPTH (M)</th>
<th>ROCK</th>
<th>GEOLOGIST NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Shale</td>
<td>21 million years old (Index fossils found)</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Conglomerate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Impermeable Shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Breccia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Sandstone</td>
<td>280 million years old (Radioactive dating)</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Shale</td>
<td>310 million years old (Index fossils found)</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Schist</td>
<td>385 million years old (Radioactive dating)</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Marble</td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>Basalt</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WATER WELL C</th>
<th>DEPTH (M)</th>
<th>ROCK</th>
<th>GEOLOGIST NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Sandstone</td>
<td>0.5 million years old (Radioactive dating)</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Conglomerate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Sandstone</td>
<td>51 million years old (Index fossils found)</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Impermeable Shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Breccia</td>
<td>230 million years old (Index fossils found)</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>Shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Schist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Marble</td>
<td>405 million years old (Radioactive dating)</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>Basalt</td>
<td>460 million years old (Radioactive dating)</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 4.1.

DRILLING THROUGH THE AGES DIAGRAM

*Sandstone (0.5 my)
### DATA TABLE 4.4.

**AGES OF EACH ROCK LAYER**

<table>
<thead>
<tr>
<th>NUMBER OF ROCK LAYER</th>
<th>ERA</th>
<th>PERIOD</th>
<th>AGE OF ROCK LAYER</th>
<th>METHOD USED TO DETERMINE AGE</th>
<th>TYPE OF ROCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cenozoic</td>
<td>Quaternary</td>
<td>0.5 million years</td>
<td>Radioactive</td>
<td>Sandstone</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### DATA TABLE 4.5.

**GEOLOGIC TIME TABLE**

<table>
<thead>
<tr>
<th>MILLIONS OF YEARS AGO</th>
<th>ERA</th>
<th>PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2</td>
<td>Cenozoic</td>
<td>Quaternary</td>
</tr>
<tr>
<td>2–24</td>
<td>Cenozoic</td>
<td>Tertiary Neogene</td>
</tr>
<tr>
<td>24–65</td>
<td>Cenozoic</td>
<td>Tertiary Paleogene</td>
</tr>
<tr>
<td>65–141</td>
<td>Mesozoic</td>
<td>Cretaceous</td>
</tr>
<tr>
<td>141–195</td>
<td>Mesozoic</td>
<td>Jurassic</td>
</tr>
<tr>
<td>195–230</td>
<td>Mesozoic</td>
<td>Triassic</td>
</tr>
<tr>
<td>230–280</td>
<td>Paleozoic</td>
<td>Permian</td>
</tr>
<tr>
<td>280–310</td>
<td>Paleozoic</td>
<td>Pennsylvanian</td>
</tr>
<tr>
<td>310–345</td>
<td>Paleozoic</td>
<td>Mississippian</td>
</tr>
<tr>
<td>345–395</td>
<td>Paleozoic</td>
<td>Devonian</td>
</tr>
<tr>
<td>395–435</td>
<td>Paleozoic</td>
<td>Silurian</td>
</tr>
<tr>
<td>435–500</td>
<td>Paleozoic</td>
<td>Ordovician</td>
</tr>
<tr>
<td>500–570</td>
<td>Paleozoic</td>
<td>Cambrian</td>
</tr>
</tbody>
</table>
Analysis

1. Explain one other way to find out the age of the rock in layer #5.

2. Explain whether or not all of the similar rock types are found at the same depth.

3. Describe the difference between the relative age of a rock layer and its absolute age.

4. (Enrichment) What type of evidence would be found in the rock layers if there had been volcanic eruptions in the past?

5. (Enrichment) Construct a scientific explanation about how you would use evidence found in rock layers, in order to prove that volcanic eruptions had happened in the past.

6. (Enrichment) Contact a local water, oil, or gas drilling company to discover and learn from their methods of collecting evidence on the rock layers underground in our community. Create an iMovie trailer to share with the class to teach them what you’ve learned.

Learning Target

Use the rock layers and the associated rock types to measure the amount of time that has passed.

I Learned:

Redo:

Manipulated Variable:

Measured Variable:

Controlled Variable:
4B. Drilling Through the Ages Lab

**NGSS Alignment**

**MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history.

**MS-ESS2-1.** Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.

**MS-ESS2-2.** Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.

**MS-ESS2-3.** Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

**4-ESS1-1.** Identify evidence from patterns in rock formations and fossils in rock layers for changes in a landscape over time to support an explanation for changes in a landscape over time.
Decaying Candy Lab

Problem
How many half-lives will it take for a sample of candy to decay?

Prediction
Give a working definition of “half-life.”

(Teacher note: Have students share several predictions out loud, so misconceptions can be anticipated and explained.)

Thinking About the Problem
When are rocks born? How do we know what their birthdays are? For igneous rocks, that birthday is when they first harden from magma or lava to become rock. All of the elements within an igneous rock help us to identify it. Most elements within the rock are stable and remain the same through the years. Some, however, are unstable. Over time, these elements decay, or break down, changing into new elements by releasing energy and subatomic particles. This process is called radioactive decay. Radioactive elements, such as uranium and radon, occur naturally in igneous rocks.

Unstable elements are said to be radioactive. During radioactive decay, the atoms of one element break down to form atoms of another element. As a radioactive element within the igneous rock decays, it changes into another element. So the composition of the rock changes slowly over time. The amount of the radioactive element decreases, while the amount of the newly formed element increases. The particular rate of decay for each radioactive element never changes, and is referred to as the half-life. The half-life measures how long it takes for any quantity of radioactive elements within the rock to decay by half. Geologists use the rate at which these elements decay to calculate the rock’s age. They can use radioactive dating to determine what is called the absolute age, or the birthday, of rocks.

As all plants and animals grow and travel through their lives, carbon atoms are added to their tissues. There is a radioactive form of carbon called carbon-14.
All living things contain carbon atoms, including some carbon-14. It has a shorter half-life (5,730 years) than the elements found in igneous rocks, and can be used to determine the age of some living things. After an organism dies, no more carbon is added to the tissues. But since the carbon-14 in the organism’s body is radioactive, it decays. It breaks down into a stable nitrogen-14 atom. To determine the age of a once-living thing, scientists measure the amount of carbon-14 that is left in the living thing’s remains. From this amount, they can determine the absolute age, or years that have passed since its birthday. Carbon-14 has been used to determine the age of frozen mammoths and prehistoric humans.

Write three main points from the “Thinking About the Problem” reading:

1. Geologists use radioactive dating to ...

2.

3.

Procedure

1. Place 50 “atoms” of candy (M&Ms) in the cup, and gently shake for 10 seconds, representing its half-life.

2. Gently pour out candy. Count the number of pieces with the M&M side up. These atoms have “decayed.” Record amount in Data Table 4.6.

3. Return only the pieces with the print-side down to the cup. You may consume the “decayed” (print-side up) atoms.

4. Continue gentle 10-second shaking, counting, and consuming until all the atoms have decayed. Draw a sketch of your materials in box on p. 169.

5. Combine all of the class data, and graph the whole-class average data (Data Table 4.7).

6. In Figure 4.2 (p. 171), label time (seconds) on the x-axis. Label the number of undecayed atoms on the y-axis. Give your line graph a descriptive title.
### Data Table 4.6: Small-Group Data

<table>
<thead>
<tr>
<th>Half-Life (Seconds)</th>
<th># of Undecayed Atoms (Running Total)</th>
<th># of Decayed Atoms (Running Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DATA TABLE 4.7.

WHOLE CLASS-DATA ON UNDECAYED ATOMS

<table>
<thead>
<tr>
<th>HALF-LIFE (SEC)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 2</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 3</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 4</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 5</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 6</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 7</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 4.2. ____________________________
(Teacher note: Student provides descriptive graph title.)
Three Graphing Hints for Students

1. Read Procedure #6 again.

2. Use the full graph—it should be a big picture of important data. Count by an appropriate number.

3. Use the line on your graph to determine what the half-life of the candy sample is, in seconds.

Analysis

1. Give a working definition of half-life.

2. In the experiment, what was the half-life of the candy sample?

3. At the end of two half-lives what fraction (or percent) of the atoms had not decayed?

4. (Enrichment) How good is our assumption that half of the candy atoms will decay in each half-life? Explain.

5. (Enrichment) Is there any way to predict when a particular atom of candy will decay? (If you could follow the fate of one M&M, is there any way to predict exactly when it will “decay?”) Explain.

6. Describe the shape of the curve drawn in on your graph of the class data.

7. Why did we combine to get the whole-class data? How does this relate to radioactive dating?

8. If you started with a sample of 600 atoms of candy, how many would remain undecayed after three half-lives?

9. (Enrichment) If 175 undecayed nuclei remain from a sample of 2,800 nuclei, how many half-lives have passed?

10. (Enrichment) The element Strontium-90 has a half-life of 28.8 years. If you start with a 10 g sample of Strontium-90, how much will remain after 115.2 years? Show your math.
Learning Target
Use the radioactive half-life of elements to determine a sample’s absolute age.

I Learned:

Redo:

Manipulated Variable:

Measured Variable:

Controlled Variable:

4C. Decaying Candy Lab

NGSS Alignment

**MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history.

**MS-ESS2-3.** Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

**MS-PS1-1.** Develop models to describe the atomic composition of simple molecules and extended structures.
4D. Superposition Diagram Challenge

Directions

With the Law of Superposition, your goal is to determine, and find evidence for, the sequencing of different events in the rock layers of the Earth. Now you will use those sequencing skills to determine the relative ages of various rock layers in a diagram.

Determine the relative age (oldest to youngest) of the rock layers and surfaces in Figure 4.3, labeled A through J, shown in a cross-section diagram of Earth.

Each rock layer or surface is associated with an event that caused it to develop. Some surfaces may have developed due to erosion and weathering. Some rock layers may have developed due to volcanic activity underground. Some may have developed due to deposition and cementation as a sedimentary rock layer. There are many reasons why rock layers develop.

Give clear evidence for why you believe each particular rock layer or surface is older or younger than surrounding layers or surfaces. You will need to be confident with your evidence, so you can defend your choice to others.

Complete Data Table 4.8 (p. 176) to show your sequence and evidence.
FIGURE 4.3.

SUPERPOSITION CHALLENGE
DATA TABLE 4.8.

DATA ON RELATIVE AGE OF ROCK UNITS AND SURFACES A THROUGH J

<table>
<thead>
<tr>
<th>YOUR HYPOTHESIS (RANKING FROM OLDEST TO YOUNGEST)</th>
<th>BRIEF EVIDENCE</th>
<th>ALTERNATE HYPOTHESIS #1 (FROM ANOTHER GROUP)</th>
<th>ALTERNATE HYPOTHESIS #2 (FROM ANOTHER GROUP)</th>
<th>ALTERNATE HYPOTHESIS #3 (FROM ANOTHER GROUP)</th>
<th>QUESTIONS THAT REMAIN OR OTHER EVIDENCE NEEDED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 4D. Superposition Diagram Challenge

**NGSS Alignment**

**MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history.

**MS-ESS2-1.** Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.

**MS-ESS2-2.** Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.

**MS-ESS2-3.** Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

**4-ESS1-1.** Identify evidence from patterns in rock formations and fossils in rock layers for changes in a landscape over time to support an explanation for changes in a landscape over time.
Mapping the Glaciers Lab

Problem
How were Minnesotan landscapes affected by glaciers?

Prediction
Give a complete sentence answer to the problem statement above.

(Teacher note: Have students share several predictions out loud, so misconceptions can be anticipated and explained.)

Thinking About the Problem

Glaciers are composed of fallen snow that accumulates over time and compresses into thickened ice masses. As the snow piles up, ice begins to form on the bottom of the snow mass. As the mass becomes greater, the ice on the bottom of the snow begins to melt and the pile begins to slide. At this point the snow mass is known as a glacier.

There have been several major ice advances during the last two million years. During these ice advances, glaciers covered large parts of Minnesota. The last of these glacial advances ended about 11,000 years ago.

These glaciers were enormous sheets of ice over a mile thick and covering thousands of square miles. They exerted massive forces due to their tremendous weight. As the glaciers melt, they release a torrent of meltwater, which carved many of the surface landforms visible in Minnesota today. Many of our 12,000 lakes, the Minnesota River Valley, The Great Lakes, and the deep potholes of Taylor’s Falls all owe their existence to glacial processes.

In nature, glaciers can move quickly or slowly downslope, depending on the angle of slope, changes in atmospheric temperature and glacial load. As a glacier moves over the land, it “plucks” rock and soil debris from the surface. These plucked rocks become embedded in the ice and act as cutting tools, which in turn smooth and polish the rock surfaces beneath the moving glacier. From time to time, the glacier will drop rocks and sediments to produce glacial landforms, such as boundary piles, called moraines.
Glacial deposits are generally grouped into two classes: till and outwash. Till occurs when different-size sediments (such as sand, clay, and boulders) are deposited from a glacier. Outwash is a glacial deposit of sediment left from the melting ice of a glacier. The melted water from the glacier carries sediments and creates channels in the same manner as a river or stream.

Write three main points from the “Thinking About the Problem” reading:

1. Glaciers are composed …

2.

3.

Procedure

1. Use 3-D satellite image maps for the Upper Midwest, obtained from a local United States Geological Survey (USGS) Office. These maps can also be downloaded and printed from the USGS.gov website. Research glacier terms on the internet for any information gaps that remain. (Teacher note: The author recommends laminating the maps, so the maps can be marked on and reused.)

2. As a group, work with the satellite image 3-D map. Begin by outlining and labeling the states in one color.

3. Using a hand lens if necessary, find two different land formations that you believe might have been formed by glaciers scraping surfaces, or by glaciers piling up debris. Trace the outlines and label, in a new color, of where you believe the glaciers likely generated these scrape marks or piles. Write your evidence for these glacial land formations in Data Table 4.9 (p. 180).

4. As a group, find two different land formations that you think might have been formed by the flow of water as glaciers melted. Circle and label the two landforms that you believe resulted from these glacial events. Be able to give evidence, as well as detailed descriptions of where those landforms are found. List your evidence in Data Table 4.9 (p. 180).
5. As a group, find two different places on the map where you believe there is evidence showing which direction the glaciers were moving. Determine the direction in which you believe the glaciers traveled, and show it by arrow on the map. Be able to give evidence for your selection. List your evidence in Data Table 4.9.

**DATA TABLE 4.9.**

---

**EVIDENCE FROM THE SATELLITE IMAGE 3-D MAP**

<table>
<thead>
<tr>
<th>Evidence for Procedure #3</th>
<th>Evidence for Procedure #4</th>
<th>Evidence for Procedure #5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. What landforms are created by glacial activity? Read the description of each of the formations below. Then find one spot on the map where this type of formation seems to be present. It is okay to repeat spots from earlier. Label them as described below.

a. Lateral Moraine: Lateral moraines form on the side of the glacier. A moraine is a large pile of glacial debris left behind by a glacier. These formations mark the edges of where the glacier once was, similar to
a riverbank. Circle the spot where you think a lateral moraine has formed and label it “Lateral Moraine.”

b. Terminal (End) Moraine: The terminal moraine marks the farthest advance of the glacier. This type of moraine forms along the front of the glacier, similar to how a bulldozer pushes material in front of it. Circle the spot where you think a terminal moraine has formed and label it “Terminal Moraine.”

c. Kettle Lakes: As glaciers melt and break up, they often leave behind large blocks of ice partially buried in the ground. As the ice blocks melt, depressions remain in the landscape. The depressions fill with snowmelt and rainwater to produce kettle lakes. In the satellite view, this will look like a region with many small, shallow lakes. Circle the area where you think kettle lakes are located and label it “Kettle Lakes.”

7. Now that your group has labeled all of the formations, take a clear picture of your 3-D map to show where you circled evidence. Label the image, and place it in the box below. Once your group has their map approved, use a damp paper towel to clean your map.
9. Compare and contrast snow banks (in the school parking lot in winter) with glaciers. Complete the thinking map in Figure 4.4.

(Teacher note: A lesson called “Comparing and Contrasting Thinking Maps” in Appendix D on page 317, helps students learn how to complete the thinking map.)

**FIGURE 4.4.**

**THINKING MAP: COMPARING AND CONTRASTING GLACIERS WITH SNOW BANKS**

**Analysis**

1. What is one important observation about how North American landforms were affected by glaciers?

2. Summarize Figure 4.6 by giving one similarity and one difference between snow banks and glaciers:
   - Similarity:
   - Difference:

3. How does weather play a role in changing glaciers and snow piles?

4. What could happen to the ground underneath glaciers and snow piles?

5. What do you know about glaciers in Minnesota now that you have spent time observing evidence for them closely?

6. (Enrichment) Use what you know about glaciers to describe in detail exactly what will happen to the snow piles in our school parking lot, over time as they melt.
7. (Enrichment) Some landforms are too small to be visible on a large 3-D map. Conduct some internet research to determine how drumlins, eskers, and till are formed.

Learning Target

Use maps, satellite images, and other data sets to describe patterns and make predictions about local and global systems involving glaciers.

I Learned:

Redo:

Manipulated Variable:

Measured Variable:

Controlled Variable:

4E. Mapping the Glaciers Lab

**NGSS Alignment**

**MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history.

**MS-ESS2-2.** Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.
Geoarchaeology Background

Reading

How do we know what the Earth was like millions of years ago? Geoarchaeology is a science that uses evidence derived from the application of Earth sciences to archaeological problems. The physical landscape of the Earth is the setting in which human activities have taken place. Geoarchaeology has contributed to our understanding of the human past. It has shown us evidence for environmental change and the evolution of Earth’s physical landscape. It has also shown us the processes that affect the formation, preservation, and destruction of archaeological sites.

Geoarchaeology derives its evidence from the shape of the landscape, deposits within the landscape, and soils developed across it. Major changes in the physical landscape—continents, mountain chains and oceans—mostly take place on geological timescales of millions of years. Smaller-scale changes in, for example, the position of rivers and coastlines, however, occur on the shorter archaeological timescale. Such changes in the shape of the physical landscape are studied by the science of geomorphology (literally the study of “earth shapes”) and are of importance to archaeology at the landscape scale in several ways.

How do we know what happened long ago? First, by observing modern processes, the environments in which they take place, the landforms which they produce, and the fossils present, we can infer the processes that operated in the past. The shape and structure of features enables us to reconstruct past environments using a key geology idea, the principle of uniformitarianism, which states that, “the present is the key to the past.”

Second, understanding of the physical landscape is a requirement for reconstructing the prehistoric geography of a region. The structure of the landscape affects the types of activities that human groups can carry out with a reasonable expectation of success—dictating the types of soils present (potential for agriculture), water supplies, the viable communication routes (rivers and mountain passes), and the defensibility of sites.

Third, the survival of archaeological evidence is affected by modern-day processes, which can destroy sites or cover them so they are no longer visible at the surface. Scientists need to have some knowledge of how the landscape has changed from the historic period under study through current day.
Geoarchaeologists describe the structure of landscapes in terms of three main things: bedrock, drift geology, and landforms.

Bedrock is the foundation rock. The composition of rocks in any area will affect their resistance to weathering and erosion. Harder, more compact rocks (granite and basalt) tend to resist weathering and erosion better than loosely consolidated ones (sandstone and chalk). The harder rocks will tend to form high-standing features. The composition of the bedrock will also affect the nature of the soils developed on its surface.

Drift geology involves any unconsolidated sediment that lies on top of the bedrock. These sediments are usually of geologically recent origin—dating from the Quaternary epoch. They comprise sediments such as boulder clays or tills (deposited by former ice sheets), terrace gravels (deposited by ancient rivers), and marls or clays (deposited in former lake basins).

Landforms are the shape of the physical landscape. Landforms may be described by their mode of origin as either erosional or depositional. Erosional landforms are those features that are cut into the surface of the bedrock and/or drift geology and include features such as the U-shaped troughs of glaciated valleys and cliffs cut by the action of the sea. Depositional landforms are those that are built up and are composed of deposits. They include river terraces, drumlins, kames, eskers, and end moraines.

In all cases it is a combination of the shape of a feature, its composition, and its internal structure that enables description and interpretation of a landform’s origin. It is important to distinguish between those processes that result in the breakdown, disintegration, and alteration of rocks and sediments (collectively termed “weathering”), as well as those that result in the transportation and movement by gravity, wind, and water of material that has previously been weathered (collectively termed “erosion”). The study of the physical landscape and the processes operating within it, geoarchaeology, is essential to all of these processes.
### 4F. Geoarchaeology Background Reading

<table>
<thead>
<tr>
<th>NGSS Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MS-ESS1-4.</strong> Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history.</td>
</tr>
<tr>
<td><strong>MS-ESS2-1.</strong> Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.</td>
</tr>
<tr>
<td><strong>MS-ESS2-2.</strong> Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.</td>
</tr>
</tbody>
</table>
Index

Page numbers printed in boldface type refer to figures or tables.

A
Abstract paragraph, 33, 34, 35, 36
Acid Rain Background Reading, 285–286
    alignment with NGSS, 286
Acids and bases, 279–284
Age of Earth
    Drilling Through the Ages Lab, 160–166
    Unearthing History Lab, 151–159
AirServer, 268, 309
Albedos of solar system objects, 57–60, 62
    gray scale chart of, 63
Analysis, in discovery process, xi, xxi
Analysis questions, xvi
Android tablets, 307
Anemometer, 241, 255, 257
Anticipation, in discovery process, xi, xxi
Apple iPad, 307
    apps for, xii, 308–309
Assessment(s)
    mini-conference method for grading lab
    reports, xii
    point system for grading lab reports,
    xiii–xvii
    sample formative assessment on
    landforms, 216, 217
    sample formative assessment on
    measurement, 20–21, 20–21
Astronomy, 41. See also Earth’s Place in
    the Solar System and the Universe unit
Atmospheric pressure, 27, 241, 242, 243,
    244, 312
Authentic science, 23, 30, 306

B
Barometer, 241, 255
The Basics of Rocks and Minerals
    Background Reading, 145–147
    alignment with NGSS, 147
BioInteractive EarthViewer app, 308
Bloom’s Taxonomy, 310
Boiling, 234–236, 239
Book Creator app, 308

C
Carbon-14 dating, 167–168
Changing Lunar Tides Lab, 86–94
    alignment with NGSS, 94
    analysis of, 89–91, 90
    data table for, 88–89
    learning target for, 94
    prediction for, 86
    problem for, 86
    procedure for, 87
    graphing data, 92–93
    thinking about the problem, 86–87
Classifying Rocks and Geologic Role Lab, 126–131
    alignment with NGSS, 131
    analysis of, 131
    data table for, 128
    learning target for, 129
    prediction for, 126
    problem for, 126
    thinking about the problem, 126–127
    Rock and Role Classification Key, 130
    rock cycle, 126, 127, 129
Cloud cover, 57, 241, 243, 244, 245
Clouds, 57, 206, 221, 223, 250, 252, 262–266, 264, 265, 267, 269
Coal mining, 293–298
ComicBook! app, 225, 240, 308
Common Core State Standards, lesson
    alignment with, 305–306
Community Connection, 33–34, 36, 37
Comparing and Contrasting maps, 317, 317–318
Comparing Planetary Compounds Lab, 65–71
    alignment with NGSS, 71
    analysis of, 70
    data tables for
INDEX

Densities of Planet Components, 68
Density Comparison, 69
Known Densities of Planets, 69
learning target for, 71
prediction for, 65
problem for, 65
procedure for, 67, 68–69
tinking about the problem, 65–66
Composition notebooks, xi, xiii
benefits of using, xii–xiii
method for grading lab reports in, xii
Condensation, 28, 221, 234, 236, 239, 250
Constellations. See also Earth’s Place in the Solar System and the Universe unit
Finding That Star Lab, 95–104
Rafting Through the Constellations Activity, 105–108
Controlled Experiment Project, 30–37
abstract of, 33
alignment with NGSS, 37
category options for, 30–31
Community Connection for, 33–34
conducting experiment, 33
presentation of, 34–35
audience questions for, 35
props and photos for, 35
sample script for, 36–37
presentation requirements for, 31–32
procedure recap for, 35–36
procedure steps and labeled image for, 32
results of, 34
sample letter to students and parents about, 30
Cracking up With Landforms Lab and Landforms Formative Assessment, 209–218
alignment with NGSS, 218
data table for, 213
helpful video for, 215
learning target for, 215
materials for, 210
prediction for, 209
problem for, 209
procedures for day 1, 210–212
procedures for day 2, 214–215
sample landforms formative assessment
learning target for, 216, 217
thinking about the problem, 209–210
Critical-thinking skills, xi
Crosscutting concepts, 305, 306
Curriculum Loft KUNO, 307
Curriculum Research and Development Group series, xvii
D
Data tables, xvi, 24
for Changing Lunar Tides Lab, 88–89
for Classification of Rocks and Geologic Role, 128
for Comparing Planetary Compounds Lab
Densities of Planet Components, 68
Density Comparison, 69
Known Densities of Planets, 69
for Cracking up With Landforms Lab and Landforms Formative Assessment, 213
for Decaying Candy Lab
Small-Group Data, 169
Whole-Class Data on Undecayed Atoms, 170
for Drilling Through the Ages Lab
Ages of Each Rock Layer, 164
Geologic Time Scale, 164
Information from Water Wells A, B, and C, 162
for Estimating With Metrics Lab and Measurement Formative Assessment
Estimating Dimensions, 18
Estimating Mass, 17
Estimating Temperatures, 18
Estimating Volume, 19
for Finding That Star Lab, 99
for Hunting Through the Sand Lab, 143
for Keeping Your Distance Lab, 50
for Kepler’s Laws Lab, 73
for Knowing Mohs Lab
Hardness Test Results, 123
Mohs Hardness Scale, 123
Mohs Mineral Hardness Values, 124
for Making Your Own Cloud Chart, 264
for Oatmeal Raisin Cookie Mining Lab, 295
for Periodic Puns Activity, 112
for pHiguring out Acids and Bases Lab, 283

Copyright © 2015 NSTA. All rights reserved. For more information, go to www.nsta.org/permissions.
TO PURCHASE THIS BOOK, please visit www.nsta.org/store/product_detail.aspx?id=10.2505/9781941316160
INDEX

for Piling up the Water Lab
   Drops of Soapy Water on Coins, 230
   Drops of Water on Coins, 230
   Predictions and Results for Full Containers, 230
for Reading Minds Lab, 9
for Reflecting on the Solar System Lab
   Albedos of Various Solar System Objects, 62
   Planetary Albedos With Gray Scale Chart, 63
   Time vs. Temperature for LAD, 61
for Sizing Up the Solar System Lab, 44
for Superposition Diagram Challenge, 176
for Sweating About Science Lab
   Percentage of Relative Humidity, 274
   Relative Humidity Data, 273
for Unearthing History Lab
   Earth History, 157
   Events in Earth’s History, 158
   for Weather Instrument Project, 256–257, 257, 259
for Weathering the Rocks Lab, 137
for Weighing in on Minerals Lab
   Density of Minerals (class average), 118
   Density of Minerals (small group), 117
Decaying Candy Lab, 167–173
   alignment with NGSS, 173
   analysis of, 172
data tables for
   Small-Group Data, 169
   Whole-Class Data on Undecayed Atoms, 170
learning target for, 173
   prediction for, 167
   problem for, 167
   procedure for, 168, 171
   graphing hints for students, 172
   thinking about the problem, 167–168
Deciphering a Weather Map Lab, 241–247
   alignment with NGSS, 247
   analysis of, 242–243, 244
   weather symbols, 242–243, 245–247
glossary for, 241
learning target for, 243
   prediction for, 241
   problem for, 241
   thinking about the problem, 242
Density of minerals, 114–120
Density of planets, 65–71
Dew point, 28, 241, 243, 244, 250
Dinosaurs, 27, 153, 154, 155, 158, 207
Disciplinary core ideas, xi, 305
Discovery process, xi, xxi
Distances between planets, 47–56
Drilling Through the Ages Lab, 160–166
   alignment with NGSS, 166
   analysis of, 165
data tables for
   Ages of Each Rock Layer, 164
   Geologic Time Scale, 164
   Information from Water Wells A, B. and C, 162
learning target for, 165
   prediction for, 160
   problem for, 160
   procedure for, 161, 163
   thinking about the problem, 160–161
Dropbox, xii, 31
Dry ice, 234, 239

E
Earth Science Bingo, 315, 315
EarthNow app, 308
Earthquakes, 28, 139, 189–194, 210, 313
Earth’s Interior Systems unit, 187–218
   Cracking up With Landforms Lab and Landforms Formative Assessment, 209–218
   Hypothesizing About Plates Activity, 201–208
   Mounting Magma Lab, 195–200
   Shaking Things up Lab, 189–194
Earth’s Place in the Solar System and the Universe unit, 39–108
   Changing Lunar Tides Lab, 86–94
   Comparing Planetary Compounds Lab, 65–71
   Finding That Star Lab, 95–104
   Keeping Your Distance Lab, 47–56
   Kepler’s Laws Lab, 72–76
   Phasing in the Moon Lab, 77–81
   Rafting Through the Constellations Activity, 105–108
Index

Reasons for the Seasons Reading Guide and Background Reading, 82–85
Reflecting on the Solar System Lab, 57–64
Sizing Up the Solar System Lab, 41–46
Earth’s Surface Processes unit, 109–147
The Basics of Rocks and Minerals Background Reading, 145–147
Classifying Rocks and Geologic Role Lab, 126–131
Edible Stalactites and Stalagmites Lab, 132–134
Hunting Through the Sand Lab, 139–144
Knowing Mohs Lab, 121–125
Periodic Puns Activity, 111–113
Weathering the Rocks Lab, 135–138
Weighing in on Minerals Lab, 114–120
Earth’s Weather unit, 219–275
Deciphering a Weather Map Lab, 241–247
Lining up in Front Lab, 250–254
Making Your Own Cloud Chart, 263–266
Phasing in Changes Lab, 234–240
Piling up the Water Lab, 227–233
Sweating About Science Lab, 269–275
Weather Instrument Project, 255–261
Weather Proverbs Presentation, 267–268
Wednesday Weather Watch Reports, 248–249
Wondering About Water Lab, 221–226
Edible Stalactites and Stalagmites Lab, 132–134
alignment with NGSS, 134
analysis of, 134
materials for, 132
prediction for, 132
problem for, 132
procedure for, 132–133, 133
Electronic tablets, xi, xii, 307
benefits of using, xii–xiii
iPad apps for, xii, 308–309
method for grading lab reports on, xii options for, 307
point system for grading lab reports on, xiii–xvii
student sample of Piling up the Water Lab in, 232
The Elements app, 111, 308
Energy sources, renewable and nonrenewable, 293–298
Engineering design lessons, 4, 237, 257, 266, 305. See also Process of Science and Engineering Design unit
Enrichment opportunities, xvi, 305, 306.
See also specific lessons
Estimating With Metrics Lab and Measurement Formative Assessment, 14–21
alignment with NGSS, 21
analysis of, 16
data tables for, 17–19
Estimating Dimensions, 8
Estimating Mass, 17
Estimating Temperatures, 18
Estimating Volume, 19
learning target for, 15–16
prediction for, 14
problem for, 14
procedure for, 15
sample formative assessment on measurement, 20–21, 20–21
tinking about the problem, 14–15
Evaporation, 146, 221–222, 224, 250, 269
Evernote app, xii, 308
Evidence collection, in discovery process, xi, xii
Experimental design. See Process of Science and Engineering Design unit
Explain Everything app, 26, 32, 268, 308
Explain Everything With Science Trivia, 26–29
alignment with NGSS, 29
questions for, 26–28
F
Family homework opportunity for extra credit, 316
Field testing of curriculum, xi, xvii
Finding That Star Lab, 95–104
alignment with NGSS, 104
analysis of, 97
data table for, 99
learning target for, 98
materials for, 96
prediction for, 95
problem for, 95
procedure for, 96, 100–102
teacher directions to read aloud for, 97
thinking about the problem, 95–96
Flashcardlet app, 308
Fossil fuels, 285, 286, 293
Fossils, 146, 151, 153, 160–161, 162, 184, 207, 293
Freezing, 138, 234, 236, 239
Frost, 135, 250
Frost line, 65–66

G
Galaxy tablet, 307
Geoarchaeology Background Reading, 184–186
alignment with NGSS, 186
Geology. See Earth’s Surface Processes unit; History of Planet Earth unit
Glaciers, 156, 158, 178–183, 216, 217, 222, 224, 231
Glossary, xii, xvii. See also Vocabulary for Deciphering a Weather Map Lab, 241 for Knowing Mohs Lab, 121
Google Chromebook, 307
Google Drive, xii, 31, 308
Gravity, 86, 90, 209
Newton’s law of, 74, 204
Greenhouse effect, 58, 266, 312

H
Hands-on Science series, xvii
Hardness of minerals, 121–125
History of Planet Earth unit, 149–186
Decaying Candy Lab, 167–173
Drilling Through the Ages Lab, 160–166
Geoarchaeology Background Reading, 184–186
Mapping the Glaciers Lab, 178–183
Superposition Diagram Challenge, 174–177
Unearthing History Lab, 151–159
Human Impacts on Earth Systems unit, 277–302
Acid Rain Background Reading, 285–286
Oatmeal Raisin Cookie Mining Lab, 293–298
pHiguring out Acids and Bases Lab, 279–284
The Poetry of Earth Science Project, 299–302
Researching Scientists Project, 287–290
Science Article Reviews, 291–292
Hunting Through the Sand Lab, 47–56
alignment with NGSS, 56
analysis of, 50–51
data table for, 50
learning target for, 49
prediction for, 47
problem for, 47
procedure for, 48

I
Igneous rocks, 28, 121, 126, 127, 129, 129, 130, 131, 144, 167, 168
InClass app, 308
iPad, 307
apps for, xii, 308–309

J
Journals, 24, 34

K
Kahn Academy, 309
Kahoot! app, 308
Keeping Your Distance Lab, 47–56
alignment with NGSS, 56
analysis of, 50–51
data table for, 50
learning target for, 49
prediction for, 47
problem for, 47
procedure for, 48
INDEX

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>thinking about the problem, 47–48</td>
<td></td>
</tr>
<tr>
<td>walk through the solar system worksheet for, 51–56, 52</td>
<td></td>
</tr>
<tr>
<td>Kepler’s Laws Lab, 72–76</td>
<td></td>
</tr>
<tr>
<td>alignment with NGSS, 76</td>
<td></td>
</tr>
<tr>
<td>analysis of, 75</td>
<td></td>
</tr>
<tr>
<td>data table for, 73</td>
<td></td>
</tr>
<tr>
<td>learning target for, 76</td>
<td></td>
</tr>
<tr>
<td>prediction for, 72</td>
<td></td>
</tr>
<tr>
<td>procedure for, 75, 75</td>
<td></td>
</tr>
<tr>
<td>thinking about the problem, 72–74</td>
<td></td>
</tr>
<tr>
<td>Keynote app, 30, 34, 36, 192, 198, 288, 289, 308, 310</td>
<td></td>
</tr>
<tr>
<td>Knowing Mohs Lab, 121–125</td>
<td></td>
</tr>
<tr>
<td>alignment with NGSS, 125</td>
<td></td>
</tr>
<tr>
<td>analysis of, 125</td>
<td></td>
</tr>
<tr>
<td>data tables for</td>
<td></td>
</tr>
<tr>
<td>Hardness Test Results, 123</td>
<td></td>
</tr>
<tr>
<td>Mohs Hardness Scale, 123</td>
<td></td>
</tr>
<tr>
<td>Mohs Mineral Hardness Values, 124</td>
<td></td>
</tr>
<tr>
<td>glossary for, 121</td>
<td></td>
</tr>
<tr>
<td>learning target for, 125</td>
<td></td>
</tr>
<tr>
<td>prediction for, 121</td>
<td></td>
</tr>
<tr>
<td>problem for, 121</td>
<td></td>
</tr>
<tr>
<td>procedure for, 122</td>
<td></td>
</tr>
<tr>
<td>thinking about the problem, 121–122</td>
<td></td>
</tr>
<tr>
<td>KUNO, 307</td>
<td></td>
</tr>
<tr>
<td><strong>L</strong></td>
<td></td>
</tr>
<tr>
<td>Lab reports</td>
<td></td>
</tr>
<tr>
<td>expectations for, xii</td>
<td></td>
</tr>
<tr>
<td>method for grading of, xii</td>
<td></td>
</tr>
<tr>
<td>point system for grading of, xiii–xvii</td>
<td></td>
</tr>
<tr>
<td>Labeled images, xiii, xv, 24, 32, 34. See also specific lessons</td>
<td></td>
</tr>
<tr>
<td>LabTimer app, 308</td>
<td></td>
</tr>
<tr>
<td>Law, scientific</td>
<td></td>
</tr>
<tr>
<td>definition of, 204</td>
<td></td>
</tr>
<tr>
<td>differentiating from theory and hypothesis, 204–206</td>
<td></td>
</tr>
<tr>
<td>Law of Superposition, 174–177</td>
<td></td>
</tr>
<tr>
<td>Learning management systems, xii, 307, 308</td>
<td></td>
</tr>
<tr>
<td>Learning targets, xvi. See also specific lessons</td>
<td></td>
</tr>
<tr>
<td>Lining up in Front Lab, 250–254</td>
<td></td>
</tr>
<tr>
<td>alignment with NGSS, 254</td>
<td></td>
</tr>
<tr>
<td>analysis of, 252</td>
<td></td>
</tr>
<tr>
<td>learning target for, 252</td>
<td></td>
</tr>
<tr>
<td>prediction for, 250</td>
<td></td>
</tr>
<tr>
<td>problem for, 250</td>
<td></td>
</tr>
<tr>
<td>procedure for, 251, 253</td>
<td></td>
</tr>
<tr>
<td>thinking about the problem, 250–251</td>
<td></td>
</tr>
<tr>
<td>Lunar tides, 86–94</td>
<td></td>
</tr>
<tr>
<td><strong>M</strong></td>
<td></td>
</tr>
<tr>
<td>Making Your Own Cloud Chart, 263–266</td>
<td></td>
</tr>
<tr>
<td>alignment with NGSS, 266</td>
<td></td>
</tr>
<tr>
<td>directions for, 262–265, 264, 265</td>
<td></td>
</tr>
<tr>
<td>Mapping the Glaciers Lab, 178–183</td>
<td></td>
</tr>
<tr>
<td>alignment with NGSS, 183</td>
<td></td>
</tr>
<tr>
<td>analysis of, 182–183</td>
<td></td>
</tr>
<tr>
<td>data table for, 180</td>
<td></td>
</tr>
<tr>
<td>learning target for, 183</td>
<td></td>
</tr>
<tr>
<td>prediction for, 178</td>
<td></td>
</tr>
<tr>
<td>problem for, 178</td>
<td></td>
</tr>
<tr>
<td>procedure for, 179–182, 182</td>
<td></td>
</tr>
<tr>
<td>thinking about the problem, 178–179</td>
<td></td>
</tr>
<tr>
<td>Materials list, 24, 32. See also specific lessons</td>
<td></td>
</tr>
<tr>
<td>Melting, 234–236, 239</td>
<td></td>
</tr>
<tr>
<td>of glaciers, 178–179, 181, 231</td>
<td></td>
</tr>
<tr>
<td>Metamorphic rocks, 28, 121, 126, 127, 129, 130, 131, 146</td>
<td></td>
</tr>
<tr>
<td>Metric measurements, 14–21</td>
<td></td>
</tr>
<tr>
<td>Minerals. See Earth’s Surface Processes unit</td>
<td></td>
</tr>
<tr>
<td>Mini-conference method for grading lab reports, xii</td>
<td></td>
</tr>
<tr>
<td>Moment Magnitude Scale (MSS), 28, 190</td>
<td></td>
</tr>
<tr>
<td>Moon. See also Earth’s Place in the Solar System and the Universe unit</td>
<td></td>
</tr>
<tr>
<td>Changing Lunar Tides Lab, 86–94</td>
<td></td>
</tr>
<tr>
<td>Phasing in the Moon Lab, 77–81</td>
<td></td>
</tr>
<tr>
<td>Reflecting on the Solar System Lab, 57–64</td>
<td></td>
</tr>
<tr>
<td>Mother’s Day greeting card activity, 311–312</td>
<td></td>
</tr>
<tr>
<td>Mounting Magma Lab, 195–200</td>
<td></td>
</tr>
<tr>
<td>alignment with NGSS, 200</td>
<td></td>
</tr>
<tr>
<td>analysis of, 198</td>
<td></td>
</tr>
<tr>
<td>learning target for, 198</td>
<td></td>
</tr>
<tr>
<td>materials for, 196</td>
<td></td>
</tr>
<tr>
<td>prediction for, 195</td>
<td></td>
</tr>
<tr>
<td>problem for, 195</td>
<td></td>
</tr>
<tr>
<td>procedure for, 197, 199</td>
<td></td>
</tr>
<tr>
<td>thinking about the problem, 195–196</td>
<td></td>
</tr>
<tr>
<td>myHomework Student Planner app, 308</td>
<td></td>
</tr>
</tbody>
</table>
INDEX

N
NASA app, 308
National Aeronautics and Space Administration’s (NASA) Space Academy for Educators, xvii
National Earthquake Information Center, 193
National Oceanic and Atmospheric Association, 242, 249, 270
National Science Teachers Association, xvii
Newton’s law of gravity, 74, 204
Next Generation Science Standards (NGSS), lesson alignment with, xi, 305–306
Acid Rain Background Reading, 286
The Basics of Rocks and Minerals Background Reading, 147
Changing Lunar Tides Lab, 94
Classifying Rocks and Geologic Role Lab, 131
Comparing Planetary Compounds Lab, 71
Controlled Experiment Project, 37
Cracking up With Landforms Lab and Landforms Formative Assessment, 218
Decaying Candy Lab, 173
Drilling Through the Ages Lab, 166
Edible Stalactites and Stalagmites Lab, 134
Estimating With Metrics Lab and Measurement Formative Assessment, 21
Explain Everything With Science Trivia, 29
Finding That Star Lab, 104
Geoarchaeology Background Reading, 186
Hunting Through the Sand Lab, 144
Hypothesizing About Plates Activity, 208
Keeping Your Distance Lab, 56
Kepler’s Laws Lab, 76
Knowing Mohs Lab, 125
Lining up in Front Lab, 254
Making Your Own Cloud Chart, 266
Mapping the Glaciers Lab, 183
Mounting Magma Lab, 200
Oatmeal Raisin Cookie Mining, 292
Periodic Puns Activity, 113
Phasing in Changes Lab, 240
Phasing in the Moon Lab, 76
pHiguring out Acids and Bases Lab, 284
Piling up the Water Lab, 233
The Poetry of Earth Science Project, 302
Rafting Through the Constellations Activity, 108
Reading Minds Lab, 13
Reasons for the Seasons Reading Guide and Background Reading, 85
Reflecting on the Solar System Lab, 64
Researching Scientists Project, 289
Science Article Reviews, 292
Science Process Vocabulary Background Reading and Panel of Five, 25
Shaking Things up Lab, 194
Sizing Up the Solar System Lab, 46
Superposition Diagram Challenge, 177
Sweating About Science Lab, 275
Testing Your Horoscope Lab, 6
Unearthing History Lab, 159
Weather Instrument Project, 261
Weather Proverbs Presentation, 268
Weathering the Rocks Lab, 138
Wednesday Weather Watch Reports, 249
Weighing in on Minerals, 120
Wondering About Water Lab, 226
Notability app, xii, 32, 192, 268, 291, 308
Note-taking apps, xii, 308

O
Oatmeal Raisin Cookie Mining Lab, 293–298
alignment with NGSS, 297
analysis of, 297
data table for, 295
learning target for, 297
materials for, 294
prediction for, 293
problem for, 293
procedure for, 294, 296
thinking about the problem, 293–294
Orbital periods, 72–76

P
Panel of Five game, 22, 22–23, 82
Paperport Notes app, xii, 308
Performance expectations, xi, 305, 306
INDEX

Periodic Puns Activity, 111–113
  alignment with NGSS, 113
  data table for, 112
  answers for, 113
  directions for, 111
pH
  Acid Rain Background Reading, 285–286
  pHiguring out Acids and Bases Lab, 279–284
Phasing in Changes Lab, 234–240
  alignment with NGSS, 240
  analysis of, 236
  learning target for, 236
  prediction for, 234
  problem for, 234
  procedure for, 235, 237, 238
  reinforcement of learning for: Melting and Boiling Point Graph of a Pure Substance, 238–239
  thinking about the problem, 234–235
Phasing in the Moon Lab, 77–81
  alignment with NGSS, 81
  analysis of, 81
  learning target for, 81
  prediction for, 77
  problem for, 77
  procedure for, 78–80, 79, 80
  thinking about the problem, 77–78
pHiguring out Acids and Bases Lab, 279–284
  alignment with NGSS, 284
  analysis of, 281
  data table for, 283
  learning target for, 281
  prediction for, 279
  problem for, 279
  procedure for, 280
  thinking about the problem, 279–280
Photos, 32, 34, 35
Piling up the Water Lab, 227–233
  alignment with NGSS, 233
  analysis of, 229
  data tables for
    Drops of Soapy Water on Coins, 230
    Drops of Water on Coins, 230
    Predictions and Results for Full Containers, 230
  learning target for, 231
  liter bottle world water analogy for, 231
materials for, 228
  prediction for, 227
  problem for, 227
  procedure for, 228
  student sample from electronic notebook, 232
  thinking about the problem, 227–228
Planets. See Earth’s Place in the Solar System and the Universe unit
Planispheres, 95–104, 99–102
Plate tectonics
  Cracking up With Landforms Lab and Landforms Formative Assessment, 209–218
  Hypothesizing About Plates Activity, 201–208
  Shaking Things up Lab, 189–194
  theory of, 139, 189, 207, 209
The Poetry of Earth Science Project, 299–302
  alignment with NGSS, 302
Point system for grading lab reports, xiii–xvii
Precipitation, 221–222, 241, 246
  acid rain, 285–286
  precipitation gauge, 241, 255
Prediction, xiii. See also specific lessons
Presentation of experiment, 34–35
  audience questions for, 35
  props and photos for, 35
  sample script for, 36–37
Problem statement, xxiii, 23–24, 31. See also specific lessons
Process of Science and Engineering
  Design unit, 1–37
  Controlled Experiment Project, 30–37
  Estimating With Metrics Lab and Measurement Formative Assessment, 14–21
  Explain Everything With Science Trivia, 26–29
  Reading Minds Lab, 7–13
  Science Process Vocabulary Background Reading and Panel of Five, 22–25
  Testing Your Horoscope Lab, 3–6
Project Earth Science series, xvii
Q
  Quizlet app, 308
INDEX

R
Radioactive half-life of elements, 167–173
Rafting Through the Constellations Activity, 105–108
alignment with NGSS, 108
legend of Orion the hunter, 105–108
writing a RAFT story, 105
Reading Minds Lab, 7–13
alignment with NGSS, 13
analysis of, 10–11
data table for, 9
deck of cards for, 12
learning target for, 11
materials for, 7
prediction for, 7
problem for, 7
procedure for, 7–8
Reasons for the Seasons Reading Guide and Background Reading, 82–85
alignment with NGSS, 85
background reading for, 83–84
reading guide directions for, 82–83
using vocabulary from, 84–85
Reflecting on the Solar System Lab, 57–64
alignment with NGSS, 64
analysis of, 58–60
data tables for
Albedos of Various Solar System Objects, 62
Planetary Albedos With Gray Scale Chart, 63
Time vs. Temperature for LAD, 61
learning target for, 60
prediction for, 57
problem for, 57
procedure for, 58
thinking about the problem, 57–58
Relative humidity, 27, 250, 269–271, 273, 274
Reliability of results, xxi, 24
Researching Scientists Project, 287–290
alignment with NGSS, 290
research a nontraditional scientist, 287–288
problem for, 287
procedure for, 288
thinking about the problem, 287
research a scientist who looks like me, 289–290
Resources for teachers, xvii
Results of experiment, xii, xvi, xxi
abstract of, 33, 34, 35, 36
photos of, 34, 35
presentation of, 34–35
reliability and validity of, xxi, 24
reporting of, 24–25, 34
Rock candy, 132–134
Rock cycle, 126, 127, 129, 146
Rocks. See Earth's Surface Processes unit; History of Planet Earth unit
S
Scan app, 53, 308
Schoology, xii, 20, 216, 308
Science Article Reviews, 291–292
alignment with NGSS, 292
directions for, 291
format for electronic science article reports, 291–292
learning target for, 291
Science notebooks, xi. See also Composition notebooks; Electronic tablets
benefits of using, xii–xiii
method for grading lab reports in, xii
point system for grading lab reports in, xii–xvii
student sample of labeled images in, xv
student sample of Thinking About the Problem section in, xiv
Science process. See Process of Science and Engineering Design unit
Science Process Vocabulary Background Reading and Panel of Five, 22–25
alignment with NGSS, 25
background reading for, 23–25
rules and procedures for Panel of Five, 22, 22–23
Scientific and engineering practices, xi, 305
SciShow, 309
Seasons, 82–85
Sedimentary rocks, 28, 121, 126–127, 129, 129, 130, 131, 146, 174
Shaking Things up Lab, 189–194
alignment with NGSS, 194
earthquake monitoring and mapping instruction document for, 193–194
learning target for, 193
materials for, 190, 191
INDEX

prediction for, 189
problem for, 189
procedure for, 192
thinking about the problem, 189–190
Showbie, xii, 308
Sizing Up the Solar System Lab, 41–46
alignment with NGSS, 46
analysis of, 45
data table for, 44
learning target for, 46
problem for, 41
procedure for, 43
sketch for, 41
thinking about the problem, 41–42
Sling psychrometer, 27, 241, 255, 269, 270, 271
Soils, 139–144, 143
Solar system. See Earth’s Place in the Solar System and the Universe unit
Spacecraft 3D! app, 308
Specific gravity, 114, 121, 145
Star Walk app, 103, 308
Stars. See also Earth’s Place in the Solar System and the Universe unit
Finding That Star Lab, 95–104
Rafting Through the Constellations Activity, 105–108
Sublimation, 234, 239
Sun. See Earth’s Place in the Solar System and the Universe unit
Superposition Diagram Challenge, 174–177
alignment with NGSS, 177
data table for, 176
directions for, 174, 175
Sweating About Science Lab, 269–275
alignment with NGSS, 275
analysis of, 271
data tables for
   Percentage of Relative Humidity, 274
   Relative Humidity Data, 273
learning target for, 272
prediction for, 269
problem for, 269
procedure for, 270–271
thinking about the problem, 269–270

T
Teacher notes, xxi. See also specific

lesions
Temperature, 236, 241–243, 244
dew point and, 250
dry of dry ice, 239
estimation of, 18
of low albedo device in Sun, 57–60, 61
measurement of, 15, 241
melting and boiling points of a pure substance, 239
phase changes and, 221, 234–235, 236
planet composition and, 65–66
relative humidity and, 241, 250, 269–271, 274, 275
rock weathering and, 135, 138
Temperature converter, QR code for, 270
Testing Your Horoscope Lab, 3–6
alignment with NGSS, 6
part 1: experimental plan, 3
part 2: potential statements for experimentation, 4
sample from student’s electronic science notebook, 5
Theory, scientific
definition of, 202, 203–204
differentiating from law and hypothesis, 204–206
of plate tectonics, 139, 189, 207, 209
Thermometer, 20, 20, 21, 255, 270
metric, 15, 58
Thinking About the Problem, xiii, xiv, 24, 31–32, 35. See also specific lessons
Tic-Tac-Know activity, 310, 310
Time Capsule activity, 313–314
Transformer Pad tablet, 307

U
Unearthing History Lab, 151–159
alignment with NGSS, 159
data tables for
   Earth History, 157
   Events in Earth’s History, 158
geologic timescale presentation questions for, 153–156
materials for, 152
prediction for, 151
problem for, 151
procedure for, 152
sample analysis of, 152–153
United States Geological Survey (USGS), 179, 190, 192, 193
INDEX

 Universe. See Earth’s Place in the Solar System and the Universe unit
 Unobook tablet, 307

 V
 V Sauce, 309
 Validity of results, xxi, 24
 Variables
 manipulated, xvi, 24
 measured, xvi–xvii, 24
 testing and control of, xxi, 24, 33
 Vocabulary, xii
 for Deciphering a Weather Map Lab, 241
 for Knowing Mohs Lab, 121
 for Reasons for the Seasons Reading Guide and Background Reading, 84–85
 for Science Process Vocabulary Background Reading and Panel of Five, 22–25
 Volcanoes, 195–200, 205, 216, 217

 W
 Water
 hydrologic cycle, 221–223, 222, 224, 225
 Phasing in Changes Lab, 234–240
 Piling up the Water Lab, 227–233
 Wondering About Water Lab, 221–226
 Weather. See Earth’s Weather unit
 Weather Instrument Project, 255–261
 alignment with NGSS, 261
 data collection and reporting for, 256–257, 257, 259, 260
 12 facts report, 258
 instrument choices for, 255, 255
 required research for, 256
 student tasks for, 256
 Weather Proverbs Presentation, 267–268
 alignment with NGSS, 268
 directions for, 267
 examples of, 267
 requirements for, 268
 Weather stone, 255, 255
 WeatherBug app, 308
 Weathering the Rocks Lab, 135–138
 alignment with NGSS, 138
 analysis of, 138
 data table for, 137
 learning target for, 138
 materials for, 136
 prediction for, 135
 problem for, 135
 procedure for, 136
 thinking about the problem, 135–136
 Wednesday Weather Watch Reports, 248–249
 alignment with NGSS, 249
 learning target for, 248
 presentation for, 248–249
 requirements for, 248
 Wegener, Alfred, 206–207
 Weighing in on Minerals Lab, 114–120
 alignment with NGSS, 120
 analysis of, 116–117
 data tables for
   Density of Minerals (class average), 118
   Density of Minerals (small group), 117
 density concept flow map for, 119, 119
 learning target for, 117
 prediction for, 114
 problem for, 114
 procedure for, 115
 thinking about the problem, 114–115
 Wind direction, 241, 242, 243, 244, 245
 Wind speed, 241, 242, 243, 244, 245
 Wind vane, 241, 255
 Wondering About Water Lab, 221–226
 alignment with NGSS, 226
 analysis of, 223
 Water Wonders Comic Book, 225
 Water Wonders story, 224
 prediction for, 221
 problem for, 221
 thinking about the problem, 221–222, 222
The authors of this book are a daughter-and-father team with decades of teaching experience between them, so they know how hard you work to keep up in the classroom. That’s why they developed this fully revised version of Earth Science Success, specially designed to work with modern tablets. Their goal: to make teaching easier and more effective by combining best practices with new tools and standards to fit the changing times.

All 55 lessons enable you to incorporate electronic tablets with teacher-tested methods. In addition, the investigations all incorporate the disciplinary core ideas from the Next Generation Science Standards. Through these investigations, students become actively involved in the discovery process, from anticipation to evidence collection to analysis. The emphasis is on hands-on, sequential experiences through which students explore science concepts lab by lab while also developing critical-thinking skills. Topics include astronomy, geology, meteorology, and environmental impacts.

With a full year of Earth science lessons right at hand, you’ll soon think of this valuable book as your survival guide for the tablet age.