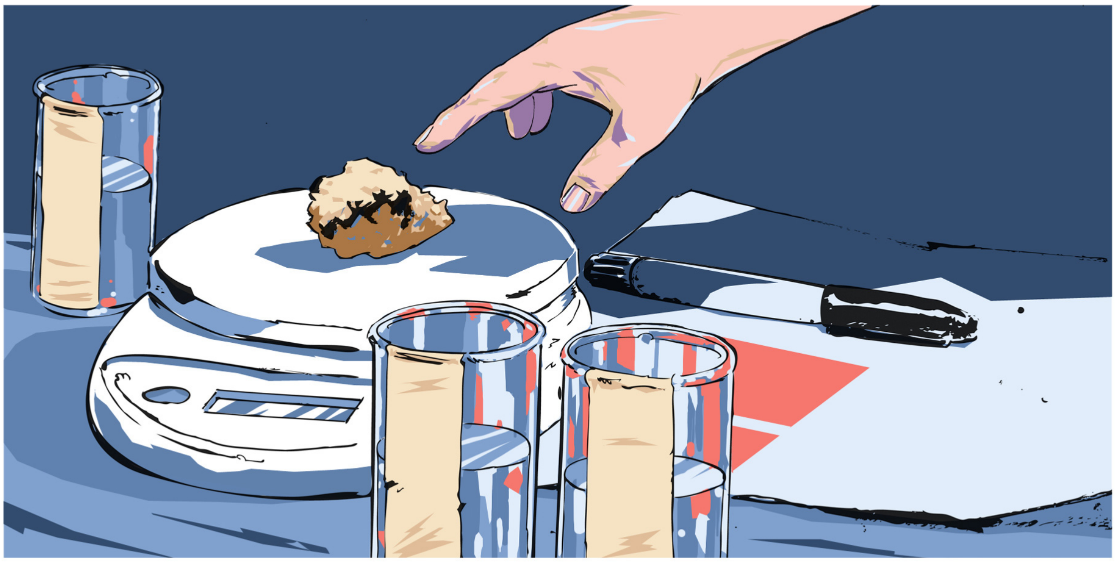
# Grade 4

The Inquiry Project

*Seeing the world through a scientist's eyes*



## Grade 4

# Investigating Earth Materials

## Which Properties Change and Which Stay the Same?

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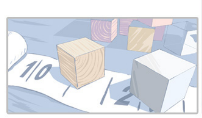

Grade 3

Grade 4

Grade 5

# The Inquiry Project

*Seeing the world through a scientist's eyes*

This curriculum was developed by TERC, Cambridge, Massachusetts 02140 www.terc.edu. TERC is a not-for-profit education research and development organization dedicated to improving mathematics, science, and technology teaching and learning.

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# What is the Inquiry Project?

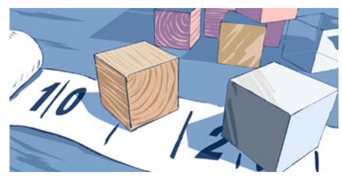
The Inquiry Project brings together research, curriculum, assessment, and professional development to deepen students understanding of the nature of matter.

## The Curriculum (Grades 3–5)

In the Inquiry Curriculum, Grade 3–5 students learn core ideas, scientific practices, and crosscutting concepts to progressively build a rich network of experiences and understanding about the structure and properties of matter. The concepts of **material, weight, volume, and matter** are emphasized as these ideas are essential for all of science and provide the necessary foundation for robust understanding of the particulate model of matter in later grades.

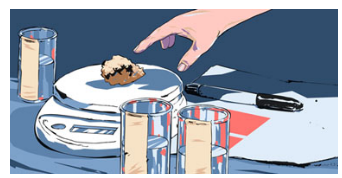
Students use scientific practices that are central to inquiry such as reasoning from evidence, building and using models, and developing explanations. They learn crosscutting concepts that span the disciplines of science, such as system and scale. They work collaboratively with their classmates and teachers, using measurement, mathematical and graphical representations, and discussion to build scientific explanations about objects and materials in the world around them.

### Grade 3: Investigating Things in My World



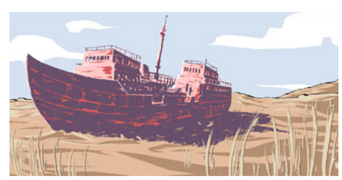

In grade 3, investigations of weight and material are front and center and volume is introduced briefly at the end of the unit. Within their investigations, students learn to use data tables and measure lines to represent weight. They express their ideas through discussions, writing, and drawing.

### Grade 4: Investigating Earth Materials



In grade 4, students investigate properties of earth materials. They learn to distinguish and measure weight and volume and investigate their relationships in different solid and liquid materials. By the end of grade 4, students ask which properties of matter stay the same during transformations such as crushing (weathering) and reshaping, and which properties do not.

### Grade 5: Investigating Water Transformations



In grade 5, students investigate properties of gases. They deepen their understanding of matter as they investigate phase change and transformations of water as it freezes, melts, evaporates, and condenses. By the end of grade 5, students are able to describe transformations of water at two scales: the macroscopic or visual scale and in terms of particles that are way too small to see.

## Curriculum Resources

- A teachers' guide
- Student notebook
- A materials kit for student investigations
- A "Curriculum at a Glance" chart
- Embedded assessments
- Child and Scientist Essays (background information)
- Cross-grade concept chart
- Video introduction to the curriculum (on inquiryproject.terc.edu)

## How the Curriculum Works

Each lesson within the curriculum is called an investigation and each unit consists of 16 or 17 investigations. Each investigation (a) introduces an Investigation Question, (b) includes an exploration or data gathering activity, and (c) wraps up with a class discussion so students can make meaning of their work and have a chance to clarify their understanding through talking and listening. Throughout the lesson, students write in their science notebooks, for example, recording their ideas, predictions, and measurements, representing their findings, and proposing explanations.

A complete investigation takes about 50–60 minutes and includes both the firsthand science experiences, literacy-related notebook writing, and whole class discussion. When science classes are scheduled for 45 minutes, teachers are encouraged to find an additional 15 minutes for students to complete their notebook writing or have an unhurried discussion where they practice articulating their ideas and explaining their reasoning.

### The Research

The Inquiry Curriculum is based on extensive research about children's ideas and learning. It is also informed by a 3-year longitudinal study comparing the learning of grade 3-5 children who used the Inquiry Curriculum with those who did not. This study showed that children using the curriculum made more progress in moving from perception-based to model-mediated understanding of materials and matter. (Learn more at inquiryproject.terc.edu, Research Tab)

### Formative Assessment Opportunities

The opportunities for assessment are endless in the Inquiry Curriculum. Anytime you observe what children do, listen to what they say, or review what they've written and drawn, there is opportunity to take account of their ideas and how these ideas are developing. However, watching, listening, and reviewing work must be done with specific questions and criteria in mind. In other words, you need to know explicitly what you are watching, listening, and reviewing work for.

Throughout the Inquiry Curriculum opportunities for assessment are identified and criteria, questions and guidelines for reviewing students' work are provided as part of the lesson description. These opportunities for assessment align with the learning goals, provide ongoing information about students' ideas and help to inform next steps in the learning for both teachers and students. **Student notebooks** and **Concept Cartoons** found within each unit are also opportunities for assessment. (Learn more at inquiryproject.terc.edu, Assessment Tab)

### Professional Development Opportunities

Guidelines for facilitating **Curriculum Implementation Workshops** are provided for each curriculum unit. Through the implementation workshop you'll become familiar with the organization of a unit, its goals and specifics of each investigation. **Talk Science**, professional development is a web-based program aligned with the Inquiry Curriculum to increase the productivity of classroom science discussions. (See inquiryproject.terc.edu, PD Tab)

## Meeting the Vision of the NRC Framework and NGSS Science Standards

Consistent with the new *Science Framework* and *Standards*, the Inquiry Curriculum emphasizes deeper understanding of core ideas, crosscutting concepts, and the practices of science and engineering. The new vision calls for increased coherence. In the Inquiry Curriculum, ideas, concepts and practices progress grade to grade with each supporting the other and developing systematically over multiple years. There is also coherence between curriculum, instruction, and assessment within each grade. Learn more about how the Inquiry Curriculum meets the new vision at: http://doingnewsciencestandards.org

| Central Inquiry Science Concepts | | | | |
|---|---|---|---|---|
| | **Weight** | **Volume** | **Material** | **Matter** |
| **Grade 3** | The weight of objects can be compared using a pan balance and standard (gram) units. | Two solid objects cannot occupy the same space.<br><br>The amount of 3D space that objects occupy can be compared. | Objects can be described in terms of their weight and volume and the materials they are made of (clay, cloth, paper, etc.).<br><br>Materials have observable physical properties such as color, size, texture, flexibility, etc.<br><br>Same size objects can have different weights when they are made of different materials. | Materials can be subdivided into small pieces and the pieces still have weight. |
| **Grade 4** | The weight of solids and/or liquids can be compared using a digital scale and can be represented on a weight line or a table.<br><br>Weight is conserved during crushing and reshaping. | Liquid and solid volumes can be measured in cubic centimeters.<br><br>When immersed, a solid displaces a liquid volume equal to the solid volume. | The relationship between weight and volume (i.e. density) is a property of solid and liquid materials. | Matter can be divided into tiny pieces, and even the tiniest pieces have weight and take up space. |
| **Grade 5** | Weight is conserved during dissolving, freezing, melting, evaporation and condensation. | Volume may not be conserved in phase change. | Air is a mixture of gaseous materials composed of particles too small and spread apart to see.<br><br>Melting, freezing, evaporation and condensation change the form of matter but do not change the material. | Matter is composed of particles that have weight, occupy space, and are too small to see.<br><br>Gases, liquids and solids are all forms of matter and have weight and take up space. |

## What information about the Inquiry Curriculum is on the website?

There is no need to carry the teachers' manual home as the full curriculum and more is freely available on the Inquiry Project website (inquiryproject.terc.edu). On the web, you'll also find:

- Videos cases from classrooms engaged in the curriculum
- Video interviews with scientists that provide insight into scientists' thinking
- Formative assessment examples embedded within the curriculum
- PD support for leading productive discussions

# Overview of Grade 4 Curriculum

## Investigating Earth Materials

### Which Properties Change and Which Stay the Same?

Look down, what's under your feet? Carpet or grass? Sand or cement? Over the next couple of months we'll metaphorically step outside to investigate earth materials, such as rock, sand, clay, water, shells, and oil that are found on the surface of our planet.

Earth materials are complex and varied, and include both liquids and solids. These materials provide a rich context for ongoing study of important cross-grade concepts such as weight, volume, and density as we look for evidence that helps us make sense of this complexity.

The unit includes five sections. In Section 1, Underfoot, we investigate a variety of earth materials, examining and describing their properties. We discover that rocks can contain many different minerals. Through further investigation, we find evidence that minerals have some properties that stay the same regardless of the size of the sample. In Section 2, Heavy for Size, we measure the weight of liquid and granular samples of material, and think about which materials are "heavy for size." In Section 3, The Liquid Materials, we measure both volumes and weights of liquids and compare the properties of oil and water. We focus on The Mineral Materials in Section 4, using water displacement to measure the volumes of rocks and of samples of granular material (such as sand). This gives rise to a discussion about how much space is between the particles, and what could fill those spaces. Finally, in the culminating Section 5, we consider Transformations, such as the natural grinding of earth materials, leading to consideration of the weathering processes. When an object, such as a shell or a rock, is transformed, what changes and what stays the same?

We hope to have a great time finding answers to the question: "What's underfoot?" We suspect we'll walk away from our investigations with increased understanding and appreciation of the natural materials that lie on Earth's surface.

Inquiry Project Grade 4 Curriculum

# Investigating Earth Materials: Which Properties Change and Which Stay the Same?

| 1. UNDER FOOT | 2. HEAVY FOR SIZE | 3. LIQUID MATERIALS | 4. MINERAL MATERIALS | 5. TRANSFORMATIONS |
|---|---|---|---|---|
| **1.1 What are some different kinds of earth materials?** Students begin by imagining what they would find under their feet at various locations on Earth's surface. They then explore a small collection of common earth materials. As they sort the materials in different ways, they come to appreciate the variety of things that make up the surface of our planet. | **2.1 Same volume, same weight?** Students compare the weights of equal volumes of two liquids and two granular solids using a digital scale. They see evidence that equal volumes of different materials can have different *weights,* and that some materials are "heavy for their size." | **3.1 How can we compare the volumes of liquids?** Students arrange different-shape containers of water in order by the amount of space the water takes up. Use a "fair test" to compare the "volumes" of water. Discuss the meaning of "taking up space" and contrast it with measurements such as length or height, or weight. | **4.1 What causes the water level to rise?** Students gather evidence to decide if weight or volume is the determining factor in the displacement of water. | **5.1 What happens to shells when we crush them?** Students are introduced to the idea of conservation of matter through a classroom activity that mimics the long-term effects of weathering. |
| **1.2 What can we learn about rocks by observing them carefully?** Students focus on a set of four rocks. They use magnifiers to explore the rocks closely and they record their observations about one of the rocks in their notebook. After sharing their observations, students develop some general statements that apply to all the rocks. | **2.2 What makes a good weight line?** Students study a set of weight lines. Through their analysis of these lines they discover the essential characteristics of a good weight line. Careful work with weight and volume measure lines lays a foundation for later understanding of information displayed in conventional graphs. | **3.2 How can we measure the volume of a liquid?** Students get a hands-on introduction to cubic centimeters, a common unit of volume used by scientists. They then make and calibrate their own measuring cups and use them to measure some water volumes. | **4.2 How can we measure the volumes of rocks?** Students discover that when a rock is submerged in water, it displaces a "rock's worth" of volume. They find a way to measure that volume in cubic centimeters. They learn that the volume of solid objects can be found by measuring the amount of water they displace. | **5.2 What happens to weight and volume when we reshape a ball of clay?** Students manipulate plasticene—a stand-in for clay, a malleable earth material. They record the weight and volume of the plasticene, form it into a new shape, and then measure weight and volume again. |
| **1.3 What can we learn about minerals by observing them carefully?** Students begin by investigating eight minerals, considering some of their properties and sharing their observations. They then return to the four rocks they studied in the last investigation to see if they can identify any minerals in them. | **2.3 What can a good weight line show us about our earth materials?** Students are challenged to construct a weight line that will help them see – *really see* – how much heavier some earth materials are than others. | **3.3 How do oil and water compare?** Students compare some properties of oil and water by sight, then they measure volumes of oil and water at three different weights. They find a relationship between the weights and volumes and consider whether the relationship holds true for all weights of these materials. | **4.3 What happens when we add earth materials to water?** Students continue their investigation of volume and water displacement by adding solid, liquid, and granular materials to water and recording the volumes that result. They discover that when a granular material is added to a liquid, the combined volume is equal to the sum of the separate volumes minus the volume of the air between the grains in the sample. | **5.3 What's under my feet?** Students imagine a place on Earth's surface and documenting the earth materials found there. |
| **1.4 What is soil made of?** Students observe two soil samples, one sandy and one more organic, then compare their properties in a Venn diagram. They try to identify components of the soils, and consider the "empty" spaces between grains. They ponder where soil comes from and learn about weathering. | **2.4 Same weight, same volume?** Students review the weight data for the materials they have studied so far – sand, water, mineral, and organic soil. Then they predict how the *volumes* of these materials will compare if the *weights* are held constant. | | | |

# 1. Under Foot

What's under foot? As we walk around on Earth every day, we might not consider what's right under our feet, but these materials are literally the foundation of our planet. In these investigations, students "get their hands dirty" and become familiar with some of the materials that make up Earth's surface: gravel, clay, rocks, minerals, soil, bits of plants and trees, oil and water.

These materials, while ordinary, are complex and varied. One goal of this unit is to help students learn how to make sense of this diversity by closely observing earth materials and recording their properties. We begin by investigating properties of rocks and the minerals that compose them. We then move to soil — including the "empty" spaces between the grains that may be filled with air or water.

As they investigate their collection of earth materials, students become familiar with their properties, size and composition, and begin to consider the idea of "parent material."

### Investigations:

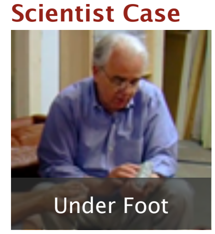
- 1.1 What are some different kinds of earth materials?
- 1.2 What can we learn about rocks by observing them carefully?
- 1.3 What can we learn about minerals by observing them carefully?
- 1.4 What is soil made of?

### The Child and the Scientist

**The Child:** The Challenges of Developing Explanations Based on Data and Reasoning

**The Scientist:**
What's important about reasoning and evidence?

**Scientist Case**




Watch Michael Haritos doing Under Foot Investigations

Available online at inquiryproject.terc.edu

### Letters from the Engineer

While students use science practices to deepen their understanding of scientific ideas throughout this curriculum, some of their investigations bridge to the engineering world. To highlight some of the instances where students engage in an engineering practice or gain insight into the engineer's world, the curriculum includes *Letters from the Engineer*. Look for these letters (in the special boxes) and read them to the class.

# The Challenges of Developing Explanations Based on Data and Reasoning

Theory building in science involves a constant interplay between making claims and gathering evidence, using one's imagination, reasoning, and prior knowledge to link and connect the two in complex ways. But what do children understand of this process?

> *Teachers can help students overcome these biases in memory by having them keep explicit records of their data and thinking—a practice that is critical to science*

Young children are constantly moving from evidence (specific observations) to claims (generalizations based on these observations) in their everyday lives. This is the basic process of *inductive reasoning*, which is at the heart of all learning from experience. For example, the child has repeated encounters with specific birds, each of which flies and concludes that all birds fly. Or the child has repeated encounters with nurses who are women, and concludes that all nurses are women. But children are not conscious of what they are doing in this process, which means they cannot engage in the self-conscious and more “controlled” inductive reasoning that is at the heart of modern science.

One challenge, then, is to get them to reflect on and conceptualize the process itself, explicitly distinguishing “the claims” from “the evidence.” This can be hard for children because for them claims and evidence blend seamlessly together into simply “the way things are.” Thus, when asked to explain how they know something, they might respond “I just know” rather than giving an appeal to specific evidence. Or when asked to explain an observation (Why do you think this cylinder is heavier?), they might just repeat the observation (because it feels heavier) rather than proposing a deeper explanation.

Inductive reasoning, of course, depends heavily upon our specific knowledge of an area, both for children and scientists. This is because our prior knowledge shapes what we see or pay attention to in any new situation. Both children and scientists must always be building on their prior knowledge and experience; at the same time, they often need to use these experiences to create new knowledge and to see things in new ways. Thus, another challenge for teachers is that, left unguided, children may notice or pay attention to things in a situation that the teacher thinks are irrelevant and fail to notice things that the teacher thinks are highly relevant. For example, in exploring water displacement, students might focus on how the object is put in the water or how heavy it is, and not pay attention to the subtler fact that the water is being displaced or pushed aside. Or when exploring a data table in search of patterns in the numbers, students might be looking for patterns based on addition or subtraction rather than multiplication or division; hence they may fail to find any meaningful generalization (such as when I double the volume of the water, I double its weight too).

This form of learning from experience—using new experiences to go beyond one's initial knowledge to develop new concepts and beliefs—is considerably more complex than simple inductive reasoning. It draws on many other thinking and reasoning abilities—such as engaging in thought experiments, making analogies, comparing and contrasting situations, and even engaging in simple deductive inferences in making predictions about what children expect will happen, given their existing beliefs. (The latter is a particularly powerful way of helping children notice and make changes in their own beliefs.) Children are actually able to engage in these other forms of reasoning as well, but they would not necessarily think to use them on their own. And rarely would they orchestrate them together in sustained reasoning about a new situation, which is what is needed in the process of belief revision and conceptual change. Hence, another challenge for teachers is to create the kinds of sustained classroom discussions, in which these forms of reasoning are productively combined.

Contributing to children's difficulty in distinguishing claims and evidence is the fact that knowledge acquisition in everyday life relies on their memory of experiences rather than careful record keeping, and memory is fundamentally *integrative* and *fallible*. That is, we don't store and remember every encounter with birds as separate events; rather we merge these together in our current knowledge of birds. Related to this, knowledge developed in everyday settings is subject to *confirmation bias*: the tendency to selectively attend to, highly value, and remember evidence consistent with a belief rather than evidence that is inconsistent with the belief. Students (and all people) would rather have an imperfect generalization (one that works only some of the time) rather than no generalization at all.

Thus, another challenge for teachers is helping students go beyond this confirmation bias and appreciate the importance of disconfirming evidence. Students may already have knowledge of counter-examples to generalizations from their experience (e.g., they may actually have met male nurses) that they have ignored or not considered. Teachers can help students overcome these biases in memory by having them keep explicit records of their data and thinking—a practice that is critical to science as well. This is one reason why the Inquiry Project curriculum stresses the use of student notebooks. This allows students in class discussions to productively consider, compare, and reflect on their data while considering alternative views. Teachers should also realize that students will not abandon one generalization until there is a better one available. That is why developing new ideas that are more consistent with (and explain) the entire pattern of data needs to go hand in hand with relinquishing old ones.

—Carol L. Smith

**The Scientist's Essay for *1. Under Foot***

# What's important about reasoning and evidence?

There are really only two valid ways to support a scientific claim: empirical evidence and logical reasoning from well-established principles. Most often one needs a combination of the two.

> *to be called "scientific" an explanation must rest on the twin pillars of reasoning and evidence*

In ordinary life, we rarely hold arguments to such high standards. We rely on analogy, anecdote, higher authority, and on hunch and intuition. That's not a criticism. As the great physicist Richard Feynman wrote, "if something is said not to be a science, it does not mean that there's something wrong with it; it just means that it is not a science." And scientists, too, use those informal ways of thinking as sources of ideas and inspiration. Still, in the end, to be called "scientific" an explanation must rest on the twin pillars of reasoning and evidence.

To offer an explanation in science is to claim that one phenomenon arises as a result of some other phenomenon or process. To say that stars shine because of their luminous character is not an explanation, but just a restatement of the question. To say that stars shine because they are very hot is an explanation, and a surprising one at that. To say that they shine because they are very hot as a result of nuclear reactions occurring at their cores is a more detailed explanation.

An explanation can be scientific and still be wrong. For example, many people will claim that it is hotter in the summer than in the winter because the earth is closer to the sun. In support we might invoke the observations that a source of heat feels more intense when you are closer to it and that in the summer the sunlight feels more intense than in the winter, and perhaps the recalled fact that the earth's orbit isn't perfectly circular. This is a legitimate scientific argument. It just doesn't happen to be correct.

A *good* scientific explanation accounts for, or is at least consistent with, *all* the relevant evidence. The idea that summer occurs when the earth is closer to the sun is inconsistent with the fact that when it's summer in New England, it's winter in Argentina. Scientists often come up with tentative explanations (hypotheses) that account for one observation or a few, but then try to consider whether other facts contradict the hypothesis (bad!) or are explained or clarified by it (good!). Attributing the temperature differences among the seasons to the tilt of the earth's axis also accounts for the length of the days, the lack of variation at the equator, and the midnight sun near the poles, among other effects.

This kind of rigorous self-criticism is difficult — we'd all rather think of reasons why we're right than come up with reasons why we're wrong — and even the greatest scientists sometimes fall short. Galileo felt that the existence of the tides provided strong evidence for his contention that the earth rotates, arguing that the rotation causes the oceans to slosh back and forth. But water in a smoothly rotating container doesn't slosh around, and even if it did, why should its sloshing have characteristic daily and monthly periods? (A correct explanation had to wait for Newton's understanding of gravity, and even then it's pretty subtle.)

Fortunately, if not always pleasantly, there are always other scientists around who are only too happy to point out the holes in our arguments. They, too, are playing a crucial role in the development of scientific explanations, and it is important to encourage the skill of respectful scientific disagreement, again based on evidence and reasoning. Criticizing someone else's argument can be difficult and even frightening, especially when it involves contradicting someone you like and/or respect, but it is absolutely essential to the scientific process.

—Roger Tobin

## 1. Under Foot: Investigation 1.1
# *What are some different kinds of earth materials?*

## Plan Investigation 1.1

What's underfoot? Carpet... wood... grass... sand... water? As we go about our daily lives, we seldom think about what's underfoot – unless we literally stumble across something new. In this study we "bring the outside in" to learn more about some of the natural materials that occur at or near Earth's surface. Students begin by imagining what they would find under their feet at various locations on Earth's surface and start to generate a list of materials they consider Earth materials. They then explore a small collection of common earth materials. Finally they gather to discuss the results, add to the list of Earth materials, and consolidate their ideas.

By the end of the investigation, students will have hands-on experience with common earth materials, including gravel, sand, clay, shells, organic soil, water, and oil. They will consider what might and might not be an earth material.

### Learning Goals

- Become familiar with a variety of common earth materials

| Sequence of experiences | | |
|---|---|---|
| 1. Introduce the unit | All Class | 5 Mins |
| 2. Elicit ideas | Discussion | 15 Mins |
| 3. Explore earth materials | Small Groups | 15 Mins |
| 4. Make meaning | Discussion | 10 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Student notebooks
- A large sheet of paper for recording a list of earth materials

For each tray (one tray for each group of 4 students*):

- 1 plate of earth materials containing approximately 20cc each of gravel, sand, clay, organic soil, pebbles, and shells, arranged in piles
- 1 capped 150cc container with exactly 40cc of fresh water**
- 1 capped 150cc container with exactly 40cc of mineral oil**
- 4 magnifying glasses
- 4 plates

**Note:** The clay is not in the familiar moist, malleable form that students will recognize. All of the water has been removed, and just the tiny dry particles of clay remain. Its form is now more like a powder.

**About mineral oil:** Like corn oil and olive oil, the mineral oil that students will investigate today began as vegetal matter. But this oil was formed millions of years ago and it was trapped under ground for most of that time, causing it to change. The mineral oil has been refined; parts of the original oil have been separated and removed, so it is cleaner, but it still has most of its original properties. The products sold as "baby oil" are typically mineral oil.

** You may need to adjust the groups to suit your class size and configuration.*
*** These containers are used again in Investigation 2.1.*

## 1. Introduce the new science unit

All Class 5 Mins

Tell students they will start a new science topic today, about earth materials. In each session, they will have a new question to investigate that will help them to understand more about earth materials.

***Letter from the Engineer***

*You may know something about the work that scientists do. Some study the stars and planets. Some study the different plants and animals on Earth. Some study the non-living parts of Earth, such as the rocks, ice, and oceans. All scientists study the natural world to learn more about how it works. They notice changes and they try to understand why the changes are happening. They ask questions, and they often work with other scientists to try to find the answers. For example, scientists might ask, "Why did the birds that use to come here every summer stop coming? What happened? What is different now?" Scientists can spend years trying to answer their own questions. They make careful observations, they take notes, and they work to make sense of the information or data they have collected.*

*Scientists sometimes work with engineers, but the main job of an engineer is different than the scientist's. The main job of an engineer is to solve problems, usually to provide people with something they need or want. Engineers also ask themselves questions, but their questions are about the problems they solve. They ask, "How can we build a car that uses less gasoline?" or "How can we build a robot that will help scientists explore Mars?" Engineers also study the materials that are used to make objects. They might ask, "Will this object work better if it is made from plastic or made from wood?" or "How can we make this glass stronger, so if something hits it, it will not break?"*

*In your investigations you will be thinking like a scientist most of the time, but there will also be times when you will need to think like an engineer, and solve problems that will then help you to learn more about the natural world.*

*Look for more Letters from the Engineer. These will point out some of the times when thinking like an engineer is important.*

## 2. Elicit ideas

Discussion 15 Mins

### Purpose of the discussion:

The purpose of this discussion is for students to become familiar with their own ideas about earth materials and to broaden their ideas by actively listening to others. The focus question for the discussion is: What earth materials are under your feet?

### Engage students in the focus question

Ask students to think about places where Earth's surface is not hidden by sidewalks, streets, buildings, or other human,Àìmade objects. Provide examples: a beach, or a park. These are places where Earth's natural surface is visible.

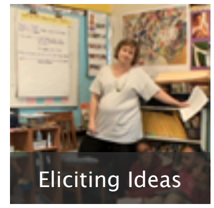
Ask students to provide other examples (e.g., a garden, a ball field, a dirt road, a back yard, a field at a summer camp, a mountain trail, an ocean).

Invite students to pick one of those places, close their eyes, and imagine they are standing there barefoot.

Provide time for students to collect their thoughts.

*Where are you? What earth materials are under your feet?*

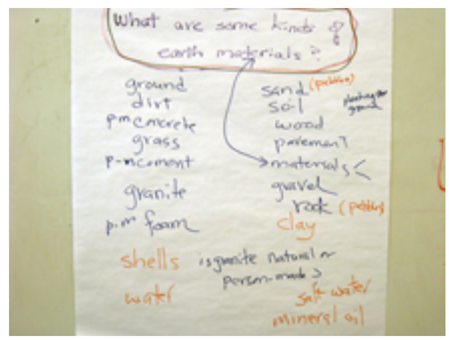
**Classroom Case 1**




The Role of an Elicitation Discussion in an Investigation

Available online at inquiryproject.terc.edu

Record student responses (e.g., dirt, rocks, dead leaves, twigs, mud, sand, puddles).




Accept all suggestions without hesitation or passing judgment. A key purpose of this discussion is to engage students personally in the new investigation by welcoming their contributions. Students will have an opportunity to revisit the list later in the class, once they have explored some earth materials and have had more time to reflect on this new topic.

> **Note:** Scientists do not include manufactured objects or living animals or plants as earth materials. They do consider dead or decomposed animals or plants as earth materials, along with rocks, sand, gravel, water, and other natural, non–manufactured materials. Do not share the scientists' definition of earth materials with students at this time. That can happen once they revisit the list they have generated, closer to the end of the session.

Demonstrate active listening and engagement by helping students build on and connect ideas, ask questions or make observations.

*Did anyone else have sand under their feet in a place that's not a beach?*

*(Student B) has added [a living thing, e.g. ants] to the list of earth materials and (Student C) respectfully disagrees. Would each of you explain your reasoning. We'll come back to this discussion later today.*

*We've thought of many different kinds of earth materials. Do you think all or most earth materials are on our list? Explain.*

### Summarize the discussion

Remind students that they started thinking about earth materials by imagining what might be under their feet in different places on Earth's surface, and came up with a class list. They will have time to suggest or debate changes to the list later. Explain that we might discover something else about the kinds of earth materials by closely observing some. So, the question we'll investigate today is:

*What are some different kinds of earth materials?*

## 3. Explore earth materials

Small Groups 15 Mins Notebook

### Introduce the science notebooks

Remind students that they will have a question to investigate in each session of the new science unit, and they will have a science notebook to record their observations and ideas. Hand out the science notebooks. Explain that all scientists have notebooks, where they record their observations, jot down their questions, make drawings, and record their ideas. The students will do the same thing; in fact, the first thing students will do in every science class is get out their notebooks.

Have the students write their name on their notebook, then find the first notebook page *[Observations of earth materials]*, and record today's date. Take a few seconds to explain why it's important to date scientific observations.

### Restate the investigation question

*What are some different kinds of earth materials?*

### Explore

Provide each group with a tray of materials. Not all students will be able to identify all of the materials on the tray, so spend a few minutes helping them with that so everyone will be able to communicate effectively. The clay, in particular, is not in a form that students are likely to recognize.

Ask students to take small samples of the solid materials, place them on their individual paper plates, and examine them using the magnifiers. They should keep the liquid containers closed.

*What do you see?*

*How do the materials compare?*

*What words can you use to describe them?*

As you circulate among the groups, ask students to record their observations in their notebooks *[Observations of earth materials]* using both words and drawings.

Emphasize the importance of careful observation and record keeping. Let students know that the correct term for the information they have recorded is data.

Data is the record of all observations. Data can be words, or drawings, or photographs, or measurements – or all of these. Data is the basis of all scientific understanding.

## 4. Make meaning

Discussion 10 Mins

### Purpose of the discussion

The purpose of the discussion is to consolidate students' growing awareness of the natural earth materials. Return to the investigation question for the discussion.

### Engage students in the focus question

Remind students of the investigation question.

*What are some different kinds of earth materials?*

Now that students have explored some earth materials, are they convinced that everything on the class list is an earth material, a part of the natural earth? Do they have new things to add, as a result of having explored some earth materials? Are there things they think should be removed from the list?

Return to any challenges students may have posed as the class developed the list, regarding the inclusion of manufactured objects (e.g., buttons, concrete) or living animals or plants. If no one has questioned the inclusion of these on the list, do so now. For example:

> *There is something about the [living thing mentioned] that seems different than the materials you just explored in your small groups, and different than most of the things you have added to the list. What do others think about including [living thing(s)] along with the rocks, gravel, and other things on the list?*

If there are several living things on the list (e.g., grass, worms, small mammals), include them as a group.

Listen as students share their thoughts and ask them to explain the reasoning behind their thinking. Through this process they may come to the conclusion that earth materials should not include living things or manufactured objects.

### Share the scientists' definition

Explain that scientists have also thought about this same question, and have decided that earth materials include the natural materials that are not alive and that have not been manufactured by humans (so, no concrete or buttons that we may find beneath our feet). After living animals and plants have died and have started to decay, scientists do consider them to be earth materials. So pieces of dead insects, dead leaves and pieces of wood, are included along with water, rocks, sand, gravel, and other natural earth materials.

Students are likely to have suggested "dirt" as an earth material. Now is the time to replace the term "dirt" with the term "soil", explaining that this is the term that scientists use.

### Summarize the discussion and recap the investigation

Students' responses to the questions below will serve as a summary.

> *What do you know now about earth materials that you didn't know before?*
>
> *What did you learn today that surprised you?*

Acknowledge that students have refined a list of earth materials, and have started to investigate eight of those materials: pebbles, gravel, sand, clay, shells, organic soil, water, and oil. Explain they will continue to investigate these eight materials and some new ones in the upcoming weeks.

Students have also started to record information called data in their science notebooks. Those notebooks will be an important part of the science unit over the next several weeks.

## 1. Under Foot:  Investigation 1.2

# *What can we learn about rocks by observing them carefully?*

## Plan Investigation 1.2

Have you ever come across a rock that seemed too interesting to pass by, picked it up, and slipped it into your pocket? Chances are your students have, too.

In this investigation, students focus on a set of four rocks. They use magnifiers to explore the rocks closely and they record their observations about one of the rocks in their notebook. After sharing their observations, students develop some general statements that apply to all the rocks.

By the end of this investigation, students will understand that rocks are *objects* that are composed of various *materials* called *minerals*. They will also begin to distinguish properties of rocks (e.g., size and weight) from properties of the minerals they are made of (e.g., color and sparkle).

### Learning Goals

- Understand the difference between *rocks* (objects) and *minerals* (the materials that rocks are made of)
- Discover some *properties* of rocks and minerals by looking at them closely

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 5 Mins |
| 2. Explore the rocks | Small Groups | 15 Mins |
| 3. Share data | All Class | 10 Mins |
| 4. Make meaning | Discussion | 15 Mins |

### Materials and Preparation

For the class:

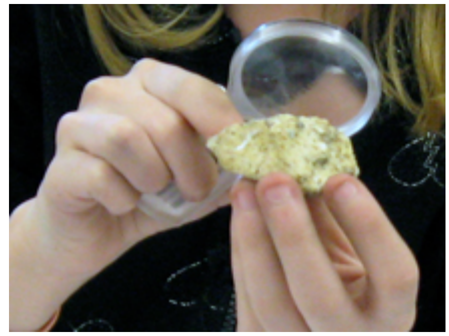
- Post the investigation question in a place where all students can see it.
- Make a class chart for recording observations about rocks and post it in a place where all students can see it; an example is found in Step 3.

For each tray:

- 1 plate of 4 rocks: sandstone, granite, conglomerate, and basalt; this set of rocks will also be used in the next investigation
- 2 Rock Reference sheets
- 4 magnifying glasses
- 1 piece of quartz, distributed in Step 4

## 1. Ask the question

All Class | 5 Mins



Recall some of the earth materials the students investigated last time — e.g., sand, clay, shells, and oil. Let students know that today they will investigate one of the earth materials more closely — rocks.

Invite students to share their experiences with rocks.

> *How many of you have found an interesting-looking rock somewhere, picked it up, and taken it home?*

Introduce the investigation question:

*What can we learn about rocks by observing them carefully?*

Have students brainstorm some ideas. Maybe they will indicate properties like size, weight, color, texture, temperature, or "sparkliness."

Let students know that scientists who study rocks closely are called *geologists*.

> **Did you know?** Rocks can be ancient-hundreds of millions of years old. They are the oldest things we'll ever touch. But some rocks are being formed right this minute, they are being made by volcanoes, out of lava.

## 2. Explore the rocks

Small Groups | 15 Mins | Notebook

Distribute a tray of materials to each group, but hold back the quartz for now. Write the names of the four rocks on the class chart and pronounce them for the class:

> Sandstone … Granite … Conglomerate … Basalt.

Allow a few minutes for students to pass the rocks around and identify each one, then ask students to hold on to whichever rock they have.

Now issue a challenge:

- You have a rock. You have a magnifying glass. You have your senses. Use all your powers of observation to learn everything you can about the rock you are holding.
- List at least six observations about your rock. Write your observations in your notebook. Include some drawings, too.

Have the students work in pairs. Though each student will describe only one rock, comparing the two rocks might elicit more observations.

As you circulate among the groups, draw attention to the different materials the rock is made of.

> *Are you talking about the black, bumpy stuff or the white, shiny stuff?*
>
> *Is the rock made of the same stuff all the way through?*

Make sure students are recording their observations in their notebooks *[Observations of a rock]*, and that they are distinguishing their "data" from their "ideas about data."

**Distinguishing "data" from "ideas about data."** Help students see the difference between data, which is simply a record of observations, and ideas about data, which include thoughts, questions, predictions, speculations, and hypotheses. *"There are sparkly flakes in the rock"* is data. *"I think the white rock may be heavier than the gray rock."* is a prediction.

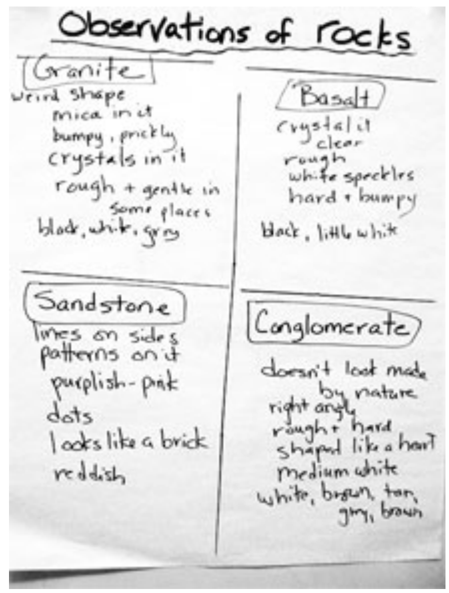
Encourage students to record both kinds of information in their notebooks, but to distinguish them in some way. They might put data on one side of the page and ideas and questions on the other. Or they might use colored pencils, and/or a code in the margin: D for Data, I for Idea; Q for Questions.

As the students finish up their observations, recall the investigation question:

*What have we learned about rocks so far, just by observing them carefully?*

## 3. Share the data

All Class 10 Mins




Compile students' observations about the four rocks on the class chart. To speed the process, take one rock at a time, asking each student who observed that rock to provide a different observation.

> *What else did you observe about [granite]?*

As students contribute their observations, make sure they distinguish between their data and their ideas about the data. Let them know they will discuss ideas and questions about the data in a minute. For now, they should simply list their observations about such things as **color, size, texture, weight, shape, and composition**. Let the students know that these characteristics of rocks are called *properties*.

Two types of observations are central to the goals of this session. It's likely that students will include them, but if not, ask if anyone made an observation about:

- The number of different materials in their rock (leading to an understanding that rocks are made of *minerals*)
- The size, shape, or weight of the rocks themselves (reinforcing the distinction between an object and its *materials*)

Remind students that each section describes the properties of a *particular* rock. Next they will talk about the properties that all the rocks have in common.

**How scientists share data.** As the students share their data, let them know that scientists spend a great deal of their time doing the same thing. Sharing data creates a larger set of data, inspires new ideas, and builds knowledge. Some of the ways scientists share their data are through e-mail and teleconferencing, at conferences, and in publications.

## 4. Make meaning

Discussion 15 Mins Notebook

### Purpose of the discussion

The purpose of the discussion is to elicit claims about rocks that can be supported by students' observations of four kinds of rock. Focus the discussion on the investigation question.

Talk Moves

Use this checklist to plan and reflect.

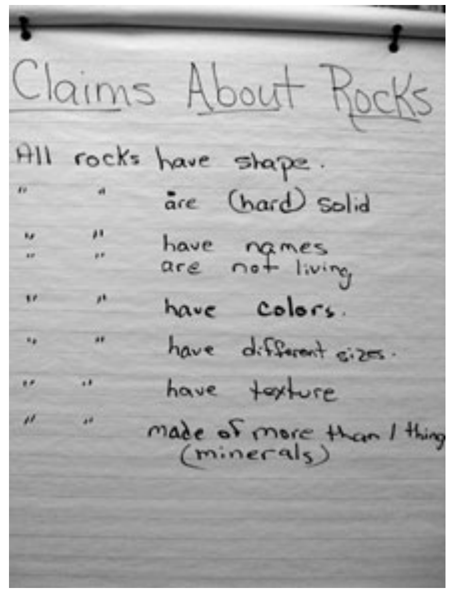
Available online at inquiryproject.terc.edu

### Engage students in the focus question

Revisit the investigation question:

*What can we learn about rocks by observing them carefully?*

Ask students to look at the class data and think about what they can say about all the rocks on the list, not just one kind. The goal is to move from observations about individual rocks to general statements — or *claims* — about all four rocks.




Take observations one at a time and see if they are generalizable. For example:

> *You observed that basalt is black. But are all rocks black? Some of you observed rocks with other colors. What can we say about color that is true for all of these rock samples?*

After eliciting ideas, try for consensus:

> *Can we agree on this statement: Rocks can be different colors, including gray, white, red, and black?*

Create a new class chart: **Claims About Our Rocks**.

> *Based on our observations of granite, basalt, conglomerate, and sandstone, what else can we claim about rocks?*

Continue the discussion until the class has agreed on six or eight statements that hold true for all four rocks. Point out that while the claims may be true for these four rocks, they may not be true for every rock in the world.

**What is a claim?** A claim is a statement that is believed to be true, but not proven to be true, and that is based on observations or data. When someone makes a claim, they should be prepared to identify the data on which they base it. As you develop the class list of claims, pause periodically and ask: "What evidence do we have to support this claim?"

### Summarize the discussion

Refer to the **Claims About Our Rocks** chart.

Explain that the materials that make up rocks are called *minerals*. Let the students know there are thousands of different minerals on Earth, and that *quartz* is one of the common ones.

Distribute a piece of quartz to each group.

> *Is there any of the mineral quartz in your rock?*
>
> *What properties does the quartz have that the rest of the rock doesn't have?*

As you recap the investigation, check for understanding of these two points:

- Rocks are *objects* made of *materials* called *minerals*
- Rocks and minerals have observable *properties*

There is a notebook page for students to record the class's claim about rocks. *[Properties of rocks]*

## 1. Under Foot: Investigation 1.3

# *What can we learn about minerals by observing them carefully?*

## Plan Investigation 1.3

Minerals in my toothpaste ... in my pencil ... in my salt shaker — and in *rocks*? Yes. Scientists have identified thousands of minerals, and they show up everywhere in our lives.

Students begin by investigating eight minerals, considering some of their properties and sharing their observations. They then return to the four rocks they studied in the last investigation to see if they can identify any minerals in them.

By the end of this investigation students will understand that minerals have specific and observable or testable properties. Students will have a clearer understanding of the difference between rocks (objects) and minerals (materials). They will also begin to appreciate the composite nature of many earth materials.

**Formative Assessment**

*Can students use their observations of properties of minerals as evidence that a mineral is present in a rock?*

Available online at inquiryproject.terc.edu

### Learning Goals

- Become familiar with the common properties of minerals
- Understand the difference between *rocks* (objects) and *minerals* (the materials that rocks are made of)

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 5 Mins |
| 2. Explore the minerals | Small Groups | 15 Mins |
| 3. Share the data | All Class | 10 Mins |
| 4. Make meaning | Discussion | 15 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Prepare a large-size class table, 8 rows by 5 columns, for recording mineral properties; pattern it on the table in the students' notebooks titled "Observations of some minerals."
- (optional) Copy the notebook page titled "Some properties of 8 minerals" onto a whiteboard or a large sheet of paper; this is where you will make histograms of the class data.

For each tray:

- 1 plate of 8 mineral samples: quartz, mica, biotite, feldspar, halite, hematite, talc, and graphite; this set of minerals will be used again in the next investigation
- 1 plate of 4 rocks: sandstone, granite, conglomerate, and basalt; this set of rocks was also used in the last investigation
- 2 Mineral Reference sheets
- 4 magnifying glasses
- 4 paper towels

## 1. Ask the question

All Class 5 Mins

Return to the piece of quartz and piece of granite from the previous investigation.

> *What did you discover about quartz and granite in the last investigation?*
>
> *Might the granite be made of other kinds of minerals as well as quartz?*

Explain that today's investigation will focus on minerals, the natural materials that often appear in rocks. There are thousand of different minerals in the Earth. While most of these minerals are mixed together to form the different types of rocks, sometimes they are found unmixed, like the piece of quartz. Today, students will explore just a few of the common minerals, separately ... somewhat like exploring the separate ingredients for cookies before they are mixed together and baked — the sugar, the chocolate, the flour and butter.

Students may be intrigued to learn that people have found many different ways to make use of Earth's minerals. For example:

- Quartz is used as sandpaper.
- Graphite is used in pencil lead.
- Salt or halite is used on food.
- Talc is used as a powder for babies.
- Mica is often used in toothpaste.

Draw attention to the investigation question:

*What can we learn about minerals by observing them carefully?*

This is the same question students explored in the last class, except that instead of observing rocks, this time the class will be observing minerals. Engage the class in imagining how this investigation will go.

> *Can we use the same techniques to observe minerals that we used to observe rocks?*
>
> *Do minerals have the same properties as rocks?*

As you listen to the students' responses, remind them to keep track of their ideas and questions in their science notebooks.

## 2. Explore the minerals

Small Groups | 15 Mins | Notebook

Distribute a tray of minerals to each group. The students are already experienced observers of earth materials. Have them pass the samples around, identify each mineral from the photo key, and briefly inspect each mineral by touch, by eye, and with the magnifier. Then ask each student to select two minerals for closer investigation and to record their observations in their notebooks.

Here's where the procedure differs from last time. While students are encouraged to record any information about the minerals that interests them, they are specifically asked to collect information about the following five properties of minerals. They are given a table to help them organize these observations *[Observations of some minerals]*. Together, review the five properties and explain how to record observations in the table.

| Property | What to record |
|---|---|
| Color | Describe the color of the mineral. If it's helpful, compare it with the color of something else. |
| Luster | Luster refers to the way a mineral reflects light. Is the mineral shiny or dull? |
| Hardness | Can you scratch the mineral with your fingernail? Use the magnifier to take a close look. If your fingernail leaves a mark, the mineral is fairly soft, answer No; if your fingernail doesn't leave a mark, it is pretty hard, answer Yes. |
| Translucence | Does light shine through the mineral? Answer Yes or No. |
| Friability | Friable means that the material crumbles easily. Can you break off small pieces of the mineral just by rubbing it with your fingers? Answer Yes or No. If Yes, the mineral is friable. |

**Graphite is messy** — as anyone who has ever emptied a pencil sharpener can tell you! Soft, flaky, and rather greasy, it smudges easily and leaves dark-colored marks. Students should handle the graphite sample loosely, taking care not to drop it. Marks can be removed from paper with an eraser; from hands with soap and water.

***Letter from the Engineer***
***It comes from the Earth***

*Everything that people make — toothpaste, sneakers, blue jeans, eye glasses, our houses and everything in them — comes originally from natural Earth materials, not just the rocks and minerals we are exploring in class, but many, many more rocks and minerals that are found on Earth. Often different natural Earth materials are mixed together to make a new material, but everything starts off as a natural Earth material. When scientists and engineers take natural Earth materials and turn them into things that are useful to people, we call the result technology. So a pencil is considered technology, just as an automobile is, or a cell phone is.*

*The more scientists and engineers learn about the properties of natural Earth materials, as you have been doing, the more ideas they get for how to use those materials in different ways. For example, once people noticed that graphite is soft and slippery, and that tiny pieces separate very easily from it (friable), they realized it could be used to make marks or drawings, and eventually someone invented the pencil.*

*Scientists and engineers will sometimes study the same materials, but they usually have different purposes. For example, the scientist might study graphite to better understand what makes it slippery (scientists study the natural world) while the engineer might study graphite to discover how long it can hold a point before it needs to be sharpened again (engineers solve problems).*

## 3. Share the data

All Class 10 Mins

Complete the class table that you prepared before class. Make sure you have consensus about the properties from all the students who observed that sample.

> *Who investigated [hematite]? What are the five properties you observed? Do you all agree?*

If there are disagreements, determine how you will settle them. Should they observe the mineral again? Should a third party decide?

Continue recording the data and talking about it until the entire table is filled in.

## 4. Make meaning

Discussion 15 Mins Notebook

### Purpose of the discussion

Use the discussion as an opportunity to elicit students' ideas about the difference between rocks and minerals. The aim is for students to recognize how knowing the properties of minerals helps them to identify minerals in their rocks. Use the investigation question, *What can we learn about minerals by observing them carefully?* as the focus of the discussion.

Talk Moves

Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage students in the focus question

To engage students in discussion, distribute the set of four rocks that they used in the last session. Ask students to explore the rocks to identify possible minerals. Color, luster and transparency are some properties that students may find most helpful as they look for evidence of specific minerals.

> *Did you find evidence of any of these minerals in the rocks you examined? What properties made you think this mineral was part of the rock?*

Provide a few minutes for students to record their ideas and claims in their science notebooks *[Can we find some minerals in our rocks?]*.

> **Which minerals?** It is likely that quartz, mica and biotite will be found in the granite sample, and that feldspar will be found in the basalt. It is possible that none of the eight sample minerals will be seen in the sandstone or conglomerate rocks.

#### Revisit the investigation question

*What can we learn about minerals by observing them carefully?*

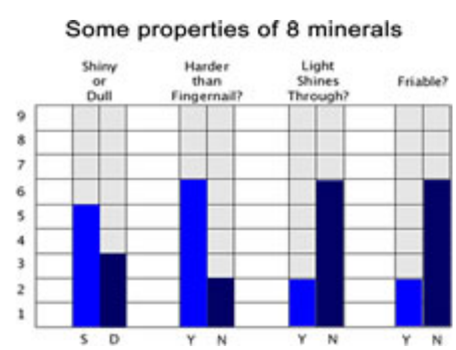
> *How did observing the properties of minerals, help you understand more about rocks?*

### Summarize the discussion and recap the investigation

Reinforce these ideas:

- When we look at minerals carefully, we can discover some of their properties ,Äî including color, luster, hardness, translucence, and friability.
- These properties can help us find even small quantities of particular minerals in rocks.
- Minerals are the materials that rocks (objects) are made of

#### (optional) Plot data




If time permits, compare the results by recording the data in the histograms you prepared before class. Students can also record this information in their science notebooks *[Some properties of 8 minerals]*. Note that "Color" cannot be plotted on a 2-column histogram, but you can list the colors separately.

Encourage students to help you transfer the data from the class list or notebooks to the histograms.

> *How many minerals are shiny?*

As the data are compiled, check that students understand how to read the graphs:

> *Are these minerals mostly hard or mostly soft? Can you back up your claim?*

# *What is soil made of?*

## Plan Investigation 1.4

If you scoop up a shovel full of soil on Cape Cod, it will be full of sand. Scoop it up in Georgia, and it will be full of clay. Your backyard soil may have bits of leaves and grass in it. Everywhere you go, soil has its own character — but it's all soil. Is there a way to think about soil no matter where we find it?

In this investigation, students observe two soil samples, one sandy and one more organic, and then compare their properties in a Venn diagram. They try to identify components of the soils, and consider the "empty" spaces between grains. They ponder where soil comes from and learn about weathering.

By the end of this investigation, students will understand that all soils are made up of small grains of minerals and or organic matter; and the spaces between the grains, hold air and or water.

**Formative Assessment**

*Do students recognize these components of soil: minerals, organic matter and spaces filled with air or water?*

Available online at inquiryproject.terc.edu

### Learning Goals

- Identify the components of soils
- Understand the meaning of parent material and organic matter

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | Small Groups | 5 Mins |
| 2. Explore the soil samples | Small Groups | 15 Mins |
| 3. Share the data | All Class | 10 Mins |
| 4. Make meaning | Discussion | 15 Mins |

### Materials and Preparation

**The two soil samples:** The kit material labeled "organic soil" already includes a mix of organic and mineral components. Adding sand to the soil increases the mineral content, creating a contrasting soil type for students to investigate.

Prepare two types of soil mix:

- Mix approximately 200cc of organic soil with approximately 100cc of sand. Put approximately 50cc of the mix into 6 capped containers; label these "A."
- Put approximately 50cc of the organic soil into each of 6 capped containers; label these "B."


For the class:

- Post the investigation question in a place where all students can see it.
- Prepare a large, blank Venn diagram for recording students' data; an example appears in Step 3.

For each tray:

- 1 container of the sandy soil mix "A"
- 1 container of the organic soil "B"
- 1 plate with 8 mineral samples: quartz, mica, biotite, feldspar, halite, hematite, talc, and graphite; this set of minerals was also used in the last investigation
- clear tape
- 2 spoons
- 4 magnifying glasses
- 4 plates

## 1. Ask the question

Small Groups 5 Mins

Show students a container of soil and ask if they recognize the contents. Affirm that it is dirt — or as scientists say: *soil* — and that it's a very important earth material.

> *How would Earth be different if it was just solid rock, if there were no soil?*
>
> - no land plants
> - no life on land

As students consider the importance of soil, introduce the investigation question.

*What is soil made of?*

Let students brainstorm some ideas, supporting questions might include

- Where does soil come from?
- Are rocks or minerals involved?
- Is the soil in your backyard the same as the soil in the desert?
- If you dig a hole a foot deep, is the soil at the top the same as the soil at the bottom?

Continue the discussion until a consensus emerges that soil is not a single material, but some combination of materials that appear in very small pieces, and that soils differ from place to place.

Recall the last two investigations, when students observed rocks and minerals using their senses and their magnifiers. Let students know that today they will observe two soil samples, record their observations, and consider what soil might be made of.

## 2. Explore the soil samples

Small Groups 15 Mins Notebook

Distribute the trays of materials. Have each student take a plate, draw a line down the center, and label the two halves "Soil A" and "Soil B," as shown in the notebook *[Observing soil grains]*, then sprinkle a small amount of each soil sample onto the appropriate side of the plate.

Let students know that the tiny particles of material they see in the soil are called "soil grains," then issue a challenge.

> *You have two kinds of soil on your plate. How is one different from the other? What are their properties? What kinds of materials are they made of?*

Students may work in pairs if they wish.

As your circulate among the students, see how many properties they can come up with on their own. If necessary, mention some other properties that might help them determine what soil is made of, e.g., color, smell, size, shape, and luster. Confirm that students see some organic matter in the soils, e.g. bits of leaves, sticks, and bark. Make sure students are recording both their observations and their ideas in their notebooks.

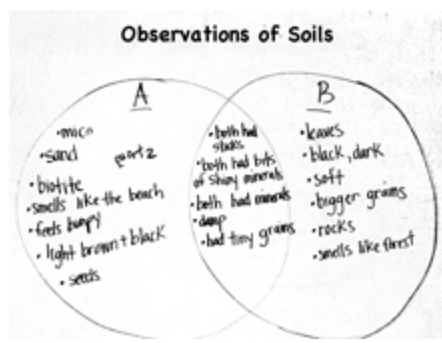
**What to do with the tape?** The tape can be used to isolate some small soil grains for close observation. Just press a short piece of tape onto some of the grains on the plate, lift the tape, and use a magnifier to examine the individual grains.

As the pace of data collection slows, have students answer the three questions in their notebooks *[Observing soil samples]*.

## 3. Share the data

All Class 10 Mins

Ask students to share their observations, and as they do, represent them in the large Venn diagram. Let the students decide whether an observation is particular to soil "A," particular to soil "B," or shared by both.




Help students to develop good data recording practices by asking that they read their observations directly from their notebooks.

Do not try to resolve seemingly contradictory data at this time. Instead, record all the students' observations.

## 4. Make meaning

Discussion | 15 Mins | Notebook

### Purpose of the discussion

The purpose of the discussion is to elicit students' ideas about soil now that they've made observation, and to encourage them to support their ideas with evidence from their observations. Return to the investigation question for the discussion.

Talk Moves

Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage students in the focus question

Begin by reviewing the class observations. Have students raise any questions or comment on what they noticed in the data.

Return to the investigation question:

*What ideas do you have now about what soil is made of? Not just these two soils, but all soils?*

Students might suggest that soil is a mixture of different sized pieces of rock. Or that soil contains plant material. Or that soil contains minerals. Ask them to support their claims, citing evidence from their own or class data.

> *What is between the bits of mineral and plant material in the soil?*

Students may be puzzled by the question. They may say there is "nothing" there; "just air" or "empty space." Affirm that the students are correct, and that the empty places are a very important part of the soil. The empty places hold air and water, which allow plants to grow.

There remains one last question:

> *Where do you think the soil grains come from?*

Let students brainstorm some ideas, making claims and supporting them as best they can with their data, e.g. *"I see little bits of quartz in the soil. I think a big piece got pulverized somehow."* Or, *"Soil B smells like the woods. I think there are rotten leaves in this soil."*

**Examples of weathering actions:** Weathering can happen as water flowing in a river bangs rocks against each another, chipping off pieces. Or as the tide rolls rocks and shells up and down the beach every day. Or as acid rain dissolves some of the minerals in rocks, causing pieces to break off.

Introduce the term "weathering." Explain that weathering is the natural process by which larger formations or pieces of rock and mineral break down into smaller pieces through the actions of water, wind, ice, expanding roots, and other forces. It's the *weathering* of rocks and minerals and the *decomposition* of plants and animals that create new soil grains. Those rocks, minerals, plants, and animals are called the *parent materials* of the soil.

Students may read the information sheet Weathering found in the back of the student notebook. They might also write about soil and weathering in their notebook *[Soil and weathering]*.

### Summarize the discussion and recap the investigation

As you summarize the discussion, reinforce these two big ideas:

- Soils are made up of minerals and organic matter, and include spaces between the soil grains that hold air and water.
- Soils come from *parent materials* that break down through processes of *weathering* and *decomposition*.

# 2. Heavy for Size

Which is heavier: a bucket full of water or a bucket full of sand? The materials take up the same amount of space, but do they weigh the same? The answer isn't obvious; it requires some thought and careful measurement.

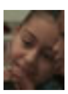
In these investigations, we return to our collection of earth materials to focus on the relationship between weight, volume, and material. We call the weight-volume relationship "heaviness for size." It lays the foundation for the important property of density, which scientists use to distinguish one earth material from another.

Students weigh samples of earth materials on digital scales and judge volume by eye. They create tables and weight lines to represent their data, and then consider the benefits and limitations of each representation. As they investigate the materials in this new way, students come to understand that weight and volume are separate properties of earth materials, and that some materials are heavier for their size than others.

### Investigations:

- 2.1 Same volume, same weight?
- 2.2 What makes a good weight line?
- 2.3 What can a good weight line show us about our earth materials?
- 2.4 Same weight, same volume?

### The Child and the Scientist



**The Child:** Why is density so hard for students to learn and for teachers to teach?

**The Scientist:**
What's important about density?

### Scientist Case


Watch Chris Swan doing the Heavy for Size investigations

Available online at inquiryproject.terc.edu

### Concept Cartoon

The Weight Line Concept Cartoon is part of Investigation 2.2 *What makes a good weight line?*.

**The Child's Ideas for *2. Heavy for Size***

# Why is Density So Hard for Students to Learn and for Teachers to Teach?

Density has a reputation for being an extraordinarily hard concept for students and teachers alike. Indeed, it is common for many adults to have difficulty with the concept and for teachers to report that it is frustratingly hard to teach. What makes it such a thorny idea both for students to learn and teachers to teach?

> *"if you were holding small and much larger pieces of steel, nothing would tell you that the two objects have exactly the same density"*

One source of difficulty is that, unlike an object's weight, we don't have direct perceptual access to an object's density. If you hold two objects in your hand, you can judge (albeit somewhat crudely) whether one object is heavier than the other or whether they weigh about the same. However, comparing the weights of two objects only gives you some indication of their relative densities primarily when they are roughly the same size. If you compare a small (light) piece of steel with a much larger (and heavier) piece of aluminum, your senses tell you the aluminum piece is larger and heavier, not that it is *less dense* than the steel. Further, if you were holding small and much larger pieces of steel, nothing would tell you that the two objects have *exactly the same density*. Our senses simply tell us that one piece is larger and heavier.

Density is fundamentally a *relational* concept. It can't be defined ostensively by simply pointing to an object and saying "This one is dense." Rather, density refers to *an inferred relation* between weight (or mass) and volume that uniformly characterizes objects made of a given material under standard conditions of temperature and pressure. Thus, building a concept of density depends upon relating many other concepts—weight, mass, volume, material, measurement, proportionality—that themselves are all under development by the young child.

A concept of density emerges as children puzzle about and seek deeper explanations for why objects weigh what they do or why some things might sink or float in a given liquid. An intermediate step is for them to form generalizations that some objects are made of heavier kind of materials than others (e.g., steel is a heavier kind of material than aluminum; aluminum is a heavier kind of material than wood). However, there are several challenges in helping them take this important step.

First, children initially think that small objects weigh nothing at all because they regard weight as felt weight, rather than as a measurable property related to the amount of material in the object. Helping them see that the weight of an object is equal to the sum of the weight of its parts—engages them in building an initial explanation of why objects weigh what they do. Understanding that tiny pieces of any material have weight, no matter how small, is necessary to prepare them to form generalizations about the weight differences of materials.

Second, children rarely have experience holding solid chunks of different materials in everyday life. They are usually handling specific objects that may be fashioned from multiple materials—such as pencils or toy cars—or objects that may be empty inside or filled with different materials—such as steel, aluminum or plastic cans that may be empty or filled with liquids like soup. Further, children have limited knowledge of what materials comprise these everyday objects. Consequently, some of the first ideas children develop about why things are heavy or light relates to how big they are or whether they are empty or full rather than generalizations relating weight to kind of material. Another step is to give them opportunity to explore different kinds of materials, as we do in the 3rd grade Inquiry curriculum, when children work with eight equal volume cubes made from a range of different materials (woods, plastics, and metals.)

Third, children initially use their pre-existing ideas to understand this new experience with the material cubes. They form generalizations such as "steel is *heavy*," "aluminum and wood are *light*," rather than the more nuanced "objects made of steel are *heavier for their size* than objects made of aluminum" or "steel is a *heavier kind of material* than aluminum." Thus, students do not fully realize that these generalizations call for a *fundamentally different sense of weight*—heavy for size rather than total weight—and are about a *fundamental property of materials* that is the same across all sample sizes for that material. For example, children who have seen that a large chunk of steel is heavier than a same size chunk of aluminum may not infer that a sliver of steel must also be heavier than a sliver of aluminum that is the same size. Instead, they simply say the slivers are both light, or both weigh nothing because they are making direct perceptual comparisons of their felt weight, rather than reasoning using knowledge of constant weight/size relationships of different materials.

Fourth, in their experiences comparing the material cubes, the object made of the denser material is also absolutely heavier. In order to get them to more clearly differentiate heavy and heavy for size, they need experiences where the object made of the heavier kind of material is not also absolutely heavier: for example, experiences where two objects made of different materials are the same weight (on a balance scale), but quite different in size. In this case, the object made of the heavier kind of material is much smaller than the object made of the lighter kind of material, reinforcing it is heavier for its size. We provide this further experience in the 4th grade curriculum.

All of these factors help explain why density is so difficult to teach. It is tempting for teachers to introduce students to the concept of density relatively late (in middle school) in the context of giving them a formal mathematical definition (density = mass/volume). But this "final form" teaching of density gives students too little too late. It ignores the fact that the beginning of the teaching of density must occur implicitly well before any distinct words or formulas are introduced by helping students understand that: even tiny things have weight and take up space; weight and space are measurable quantities; objects made of some materials "weigh" more than others; and there are important nonverbal precursors (for example attending to heaviness for size) to the concept of density that don't look like its final form version. This is what the Inquiry Project, with its cross-grade learning progressions approach, seeks to do.

—Carol L. Smith

**The Scientist's Essay for *2. Heavy for Size***

## What's important about density?

Why does a small pebble sink in water, while a much heavier piece of wood floats? Why does a balloon filled with helium float away, while one filled with air falls? Why is it hotter in the balcony than in the orchestra? How can you tell whether a piece of jewelry is really gold, or just gold-plated, without damaging it? These questions can't be answered by considering either weight or volume in isolation, but somehow involve the connection between them.

> *... density provides a way of saying that aluminum is "heavier for size" than oak, but less so than copper, without having to specify which pieces of aluminum, oak, or copper we're talking about.*

All of us have the intuitive sense that some materials are intrinsically "heavier" than others. We say that styrofoam is "light" and steel is "heavy", even though it's perfectly possible to have a (big) piece of styrofoam that weighs more than a (small) piece of steel. What we mean is that a piece of steel is heavier *for its size* than a piece of styrofoam. We can nail down the rough idea of "heaviness for size" more precisely by inventing a new composite quantity, *density*, defined mathematically as the ratio of weight (or mass) to volume: Density = Weight/Volume. We often read this in words as "density is equal to weight *per unit of volume*."

Apart from allowing us to answer questions like those in the first paragraph, the idea of density is productive as an example of what scientists call an *intensive quantity*. Many of the measurable quantities of a system increase in proportion to the size of the system: the size of a farmer's harvest is proportional to the acreage of her fields; the amount of gas your car burns is proportional to how far you drive; the amount of money a worker makes is proportional to the number of hours he works; the number of teachers in a school is (roughly) proportional to the number of students. These are “extensive” quantities. But for many purposes it's useful to devise ratios that are (at least roughly) independent of size: bushels of corn per acre, miles per gallon of gas, dollars per hour, number of students per teacher. You could think of lots of others: per capita income, 20% discounts, unit prices at the supermarket.

Among the virtues of intensive quantities is that they allow a “fair comparison” of things of dissimilar size — a large bag of potatoes for $4.99, or a smaller one for $1.99? In the case of materials, density provides a way of saying that aluminum is “heavier for size” than oak, but less so than copper, without having to specify which pieces of aluminum, oak, or copper we're talking about.

Density also provides a natural link to important and closely related ideas in mathematics, such as ratios, proportion, graphs, and linear functions. If two objects are made of the same material, for example, there is a proportional relationship between their volumes and their weights. If you plot the weights and volumes of several aluminum objects on a graph, the points will fall on a straight line. A similar graph for pieces of copper will also fall on a straight line, but a steeper one.

—Roger Tobin

## 2. Heavy for Size:  Investigation 2.1

# *Same volume, same weight?*

## Plan Investigation 2.1

Imagine three identical buckets:  one filled with water, one filled with shredded leaves and twigs, and one filled with sand. Each material takes up the same amount of space, but do they weigh the same? It's an old conundrum, and one that will take students four investigations to unravel completely.

In this investigation, students share what they know about volume, then compare the weights of equal volumes of two liquids and two granular solids using a digital scale. By the end of the investigation students will understand that volume describes the amount of space something takes up, that equal volumes of different materials can have different weights, and that some materials are "heavy for their size."

### Learning Goals

- Distinguish weight and volume
- Learn how to use a digital scale
- Understand that "heavy for size" is property of materials

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 10 Mins |
| 2. Compare the weights | Small Groups | 20 Mins |
| 3. Make meaning | Discussion | 15 Mins |

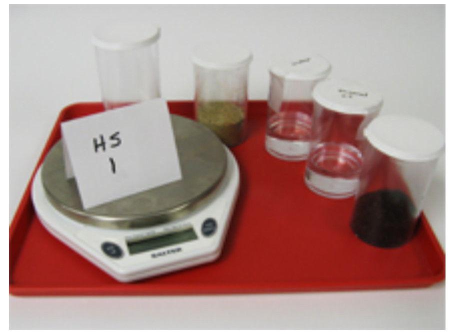
### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Make a class data table for recording the weights of the four samples; an example is found in Step 2.
- 1 unopened ream of 8.5 x 11 in. paper (not in kit)
- 1 150cc container approximately one-quarter filled with fresh water
- 1 150cc container approximately three-quarters filled with fresh water
- 1 150cc container filled to the top with sand
- 1 150cc container filled to the top with organic soil
- 1 20oz cup

For each tray:

- 1 capped 150cc container containing exactly 40cc of fresh water (from Investigation 1.1)*
- 1 capped 150cc container containing exactly 40cc of mineral oil (from Investigation 1.1)*
- 1 capped 150cc container containing exactly 40cc of sand*
- 1 capped 150cc container containing exactly 40cc of organic soil*
- 1 capped 150cc container, empty (to establish tare weight)
- 1 digital scale




** Note: These 4 containers are used again in the next investigation. It is key to this investigation that these four containers holding water, mineral oil, sand, and organic soil all have volumes that are close as possible to 40 cc's. All should appear to hold the same volume. Tap the containers holding sand and organic soil to settle the material in those two containers.*

## 1. Ask the question

All Class 10 Mins

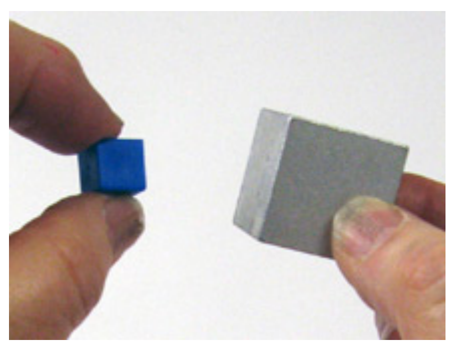
### Review the concept of volume

Get students talking about volume.

*When you hear the word 'volume' what do you think about?*

**Other ideas about volume:** When they first hear the word "volume," many students will think about the loudness of sound, or about volumes of books. Some students may offer a formula for calculating volume, e.g. height x width x length.

Acknowledge that the term volume has different meanings, and that knowing how to calculate volume is important. Explain that at this time we're talking about volume as the amount of 3-dimensional space that an object takes up.



Students typically confuse volume with measurements such as area or perimeter. Ask students explicitly to contrast area and volume. How are they different.

The brief demonstration below will help establish the difference between *area* and *volume* or 3-D space.

1. Show the class an unopened ream of 8.5 in. x 11 in. paper and ask students to identify some objects that have a volume that is less than the ream of paper - objects that take up less 3-dimensional space than the ream of paper. Their responses can help you gain insight into their grasp of the concept of volume.

2. Ask students to identify objects that have a volume greater than the ream of paper.

**Note:** Students may identify objects made of two or more materials, such as a container filled with a soft drink, or an object that includes air, such as a basketball. Those are acceptable examples, as long as you clarify that the volume of the object includes the volume of the aluminum *and* the volume of the soda, or the volume of the leather basketball *and* the volume of the air that is inside of it.

*How many of these reams of paper can I fit into my pocket?*

- None. The volume of my pocket is less than the volume of the ream.

*How many of these reams can you fit into a backpack?*

- Two? Three? Four?

3. Place the ream of paper flat down on a desk that all students can see, and point out that the ream is now covering part of the surface area of the desk. The ream still has its volume. That has not changed.

4. Rotate the ream so that the 2-3/4 in. x 11 in. side is on the desk surface.

*Is the ream of paper now covering more or less of the desk's surface area?*

- Less

*Has the volume of the ream of paper increased, stayed the same, or decreased?*

5. Summarize: Volume refers to 3-dimensional space; surface area refers to flat, 2-dimensional space. The flat top of the desk has a surface area. Each of the six faces of the ream of paper has a surface area. The ream of paper can cover different amounts of the desk's surface, depending on how the ream is placed on the desk. The amount of 3-dimensional space that the ream takes up remains the same, no matter which way we turn it or how much of the desk's surface area the ream covers.

Show the two containers that hold different volumes of water.

*How do the volumes of water in these two containers compare?*

Show the container filled with sand and the container filled with organic soil.

*How do the volumes of sand and organic soil compare?*

*Which one weighs more? How can we tell?*

### Introduce the investigation question

Today's investigation question is:

*Same volume, same weight?*

Show the class two containers, one holding 40 cc's of sand and one holding 40 cc's of organic soil.

*What do you think? If samples of different materials have the same volume, do they have the same weight?*

## 2. Compare the weights

Small Groups | 20 Mins | Notebook

### Introduce the electronic scales

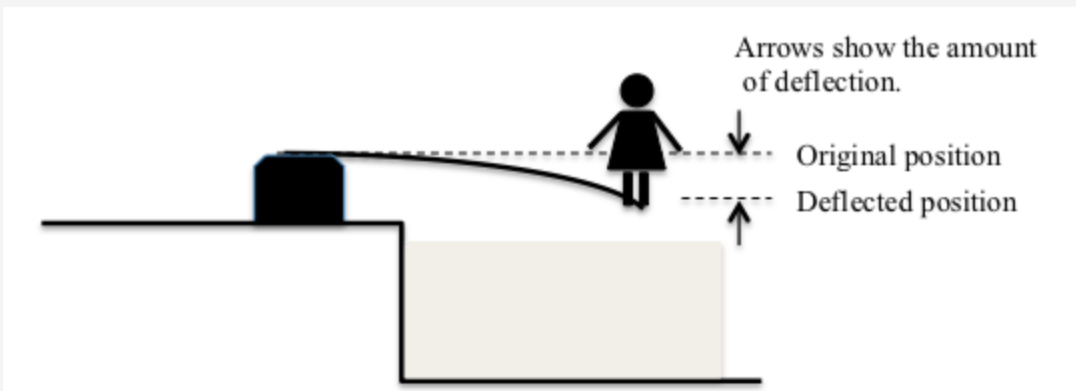
Distribute the electronic scales that students will be using in this unit. Explain that that scales have been made specifically for weighing objects that are light. They could weigh a couple of apples, but not a brick. The class will be using just light objects in the science unit. Students should handle the scales carefully and not press down on them or place any heavy objects on them.

***Letter from the Engineer***
***A better way to weigh***

*This scale you are about to use looks very different than the pan balances you may have used in the past to weigh things. Do you remember how to weigh things using a double pan balance? You place an object you want to weigh in one pan and add weights to the pan on the opposite side until the two pans are level.*

*Engineers know that a pan balance is difficult to use. Sometimes the weight you add is too heavy or too light and nothing seems to make the pans balance perfectly. Sometimes the weight you need can get lost. And even when you can balance the pans perfectly, it can take a lot of time. Engineers saw these problems and asked, ‚ÄúHow can we improve this instrument? Can we make a scale that is easier and faster to use, is accurate, and that does not need a set of weights to balance an object. One solution they came up with is the electronic scale, which is the kind of scale you are about to use.*

*How does the electronic scale work? It depends on the fact that placing weight on something causes it to bend or change its shape. Sometimes you can see this very clearly: Think about a diving board. Once someone walks out to the end of the diving board, it bends to a new position. The change in shape or position is called a "deflection". After the person leaves the diving board it returns to its original position and the deflection that was caused by the weight goes away.*




*Even when the weight is very small, deflection happens, although it can be too small for your eyes to notice. If a small bird landed on the end of the diving board, the board would deflect a very tiny amount but no one would notice it.*

*When we place an object on the top of an electronic scale, we are causing a small piece of metal inside the scale — you can think of it as a tiny diving board — to bend or deflect; the heavier the object, the more the piece of metal deflects. Engineers had to study how different materials deflect or bend when weight is put on them; some deflect much more than others. They have designed a way to measure that deflection, and to have batteries send a certain amount of electricity to the LCD (screen that shows the weight) depending on how much the metal deflects. More deflection means more weight. Both the pan balance and the electronic scale are examples of technology that help us to weigh things, and the electronic scale is a good example of how engineers have developed a new technology to solve a problem.*

Demonstrate how to turn the scale on and have students turn on their scales.

Some scales can be set to measure either in grams or in ounces. For all work in this unit, students should check the units each time before they start to use the scale, and use the switch or button to reset it to *grams* if that is necessary.

Finally, a scale will sometimes indicate a weight, or even a minus number, when nothing is on it. This would result in an incorrect measurement. Show students how to reset the scale to zero; they should always be sure the scale reads zero before they weight anything.

Have students place a pencil or other small object on the scale and observe the way in which the scale displays the weight.

### Compare two liquids

Distribute a tray of materials to each group and identify the four earth materials: water, mineral oil, organic soil, and sand.

Hold up the containers of water and mineral oil and confirm that they hold the same volume of liquid. It is not necessary to measure the volumes, just ask the class to compare them "by eye."

> *Before you weigh the two samples, make a prediction: How do you think the weights compare?*

Listen carefully to the reasoning. Do students think the weights will be the same "because the volumes are the same"? Do they think they'll weigh the same "because both materials are liquids"? Or maybe they think the weights will be different because the liquids have different properties, perhaps "because one liquid is thick and the other is thin." Acknowledge all answers and theories.

> *How can we find out for sure?*
>
> - By weighing the samples

If students don't raise the question themselves, ask how they can measure the weight of only the liquid

> *How can we weigh just the water, or just the mineral oil?*

Listen for a suggestion to subtract the weight of the empty container from the total weight of the sample. Introduce the term *tare weight*, which is the weight of just the container.

Have groups weigh an empty container and record that weight (approx. 26g) in all four rows of the data table their Science Notebooks *[Observations of weights and volumes]*. Next have them weigh the two liquid samples, calculate the weight of just the liquids, and enter their data in their notebooks. Make sure they specify that the unit of weight is grams.

When all the groups are finished, ask for their results and record them in the table you prepared before class. *Do not try to reconcile differences at this point.*

Example of a class data table.

| Material | Volume or Bulk Volume | Weight (g) Material | Class Agreement Weight (g) |
|---|---|---|---|
| **Water (liquid)** | 40cc | 40g; 40g; 39; 40g; 41g; 39g | |
| **Mineral Oil (liquid)** | 40cc | 32g; 31g; 31g; 32g; 33g; 33g | |
| **Sand (granular solid)** | 40cc | 78g; 76g; 77g; 77g; 78g; 78g | |
| **Organic (granular solid)** | 40cc | 17g; 16g; 15g; 16g; 16g; 20g | |

### Compare two solids

Have students pass around the containers of sand and organic soil.

> *Do the samples seem to have the same volume?*
>
> *Do you think they have the same weight?*

Have students weigh the samples as before, subtracting the tare weight and recording the data in their notebooks. Make sure they label their measurements in grams.

The procedure is exactly the same as before, but this time there’s a wrinkle — there are empty spaces between the grains of soil.

> *Are the empty spaces parts of the volume?*

Yes. Sand and organic soil belong to a group of materials called *granular materials*. Cheerios, sugar, gravel, and peanuts are also granular materials. Granular materials are made up of many smaller pieces that are about the same size and that have spaces in between them. The volume of a granular material is the sum of two smaller volumes: 1) the volume of all the individual pieces, and 2) the volume of all the small spaces. This combined volume has a special name: it is called *bulk volume*. Bulk volume is measured the same way that the volume of a liquid is measured, but the name bulk volume lets everyone know that the volume is a combination of the individual pieces and the spaces between them.

Once students have weighed the samples and entered the data in their notebooks, enter their data in the class table.

Allow time for students to briefly discuss the reflection questions in their small groups and write responses in their notebooks before moving on to the class discussion *[Reflections on weights and volumes]*.

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## 3. Make meaning

Discussion 15 Mins

There are two layers of data to grapple with in this discussion:
(1) establishing a single weight for each of the four samples, since it's unlikely that all groups found identical weights for a sample;
(2) once the weight of a 40cc sample is established for each material, using the data to address the investigation question: Same volume, same weight?

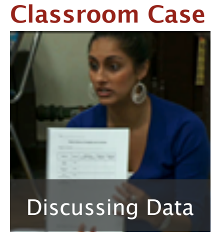
### Purpose of the discussion

The purpose of the discussion is for students to

1. connect the investigation question and their data.
2. wrestle with discrepant data.
3. make claims and describe the supporting evidence.
4. suggest explanations.

Again, the discussion focuses on the investigation question.

**Classroom Case 2**




The Role of a Data Discussion

Available online at inquiryproject.terc.edu

### Engage students in the focus question

Remind students that the purpose of collecting the weight data was to answer the investigation question:

*Same volume, same weight? If samples of different materials have the same volume, do they have the same weight?*

> *Do we have data that we can use to answer this question?*

As you listen to student responses, check to be sure everyone knows what information is contained in each of the three columns in the class data table. The class table is a simplified version of the one in their notebooks.

**How can we reconcile discrepancies in the data?**

> *Not all groups found the same weight for 40cc of water (oil, sand, organic soil). Why do you think that is and what number should we use for the weight?*

Listen to students' ideas about why their weight measurements vary and how they can decide on a "class" value for the weight of 40cc of water.

**Some possible student ideas**

**Explanations for small differences**

- There may be tiny differences in the amount of sand (water, oil, organic soil) in the containers.
- There may be tiny differences between the scales.
- The scales round the actual weight to the nearest gram, so tiny differences in actual weight can appear to be larger on the scales.

**Explanations for large discrepancies**

- We forgot to include the weight of the container cap.
- We made a subtraction error.

**Strategies for coming up with a weight the class can agree on**

- Use the weight that appears most often.
- Pick a round number that seems an appropriate middle point.
- Make a new 40cc sample and weigh it.

Once a typical weight for each material has been established, ask someone to make up a sentence that describes the data in each row of the table. For example:

> The top row tells us that a forty cubic centimeter sample of water weighs forty grams.

**What claims can we make and what is the supporting evidence (data)?**

Now that the data has been "cleaned up", ask:

> *Let's return to the investigation question: Same volume, same weight? If samples of different materials have the same volume, do they have the same weight?*
>
> *What claims can you make, and what evidence can you point to that supports the claims?*

The cleaned-up data should be clear:  equal volumes of different materials can have different weights. Encourage students to describe the data they use as evidence for a claim.

**What is a possible explanation?**

Ask the group to explain why they think same-sized samples of earth materials have different weights.

> *What might be a possible explanation for why, when the volumes are the same, the weights of different materials are different?*

Listen to students' ideas. If they don't suggest that each kind of material has its own properties, you might remind them of their prior experience with properties of materials. In addition to properties such as color or texture, materials can have different weights even when they have the same volume (take up the same amount of 3-D space). We call this property "heavy for size". The sand is heavy for its size compared with the same volume of water, mineral oil, or organic soil.

### Summarize the discussion and recap the investigation

Here is what I think I heard you say about the data we collected...

> *In your summary, include the two main parts of the data discussion (1) ideas about how to explain the fact that different groups got different results and how to come up with a single weight, and (2) once they have a single weight for 40cc of each material, ideas about how to answer the investigation question.*

Here are some of the things we discussed and explored today:

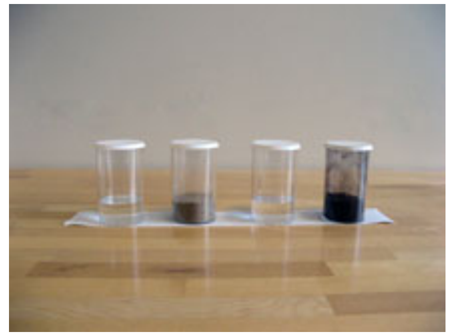
- Volume is the amount of 3-D space an object takes up.
- We measured the weights of equal volumes of sand, organic soil, water, and oil.
- We think we got slightly different weights for each type of material because we used different scales and there may be small differences between the scales.
- Even though we got slightly different measurements, we agreed that 40cc's of water weigh 40g, etc. (read the values from the table).
- We answered the investigation question using the data we collected: equal volumes of different materials do not have the same weights. So some materials are heavier for their size than other materials.

Save the class data chart for Investigation 2.4.

2. Heavy for Size: Investigation 2.2

# *What makes a good weight line?*

## Plan Investigation 2.2



Scientists often use tables (as we did in the last investigation) to organize and represent the data they collect. However, there are other ways to represent data, and some representations are better than others for highlighting different aspects of the very same data set. In this investigation, we look again at our "equal volumes of different materials" data but this time using a measure line (weight line) instead of a table.

Students study a set of weight lines, some of which are poorly constructed. Through their analysis of these lines they discover the essential characteristics of a good weight line: these include appropriate starting and ending points and a regular pattern of line spacing and number progression. These characteristics allow our eyes to make sense of the relationships between objects on the line. The weight line is an explicit representation of the closeness or distance between the weights of a set of objects; its geometry plays an essential role. Careful work with weight and volume measure lines lays a foundation for later understanding of information displayed in conventional graphs.

**Formative Assessment**

*Do students understand the basic characteristics of a "good" weight line?*

Available online at inquiryproject.terc.edu

By the end of the investigation students will be able to construct their own weight lines for their earth materials — a challenge they will undertake in the next session.

### Learning Goals

- Understand what makes a good weight line

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 15 Mins |
| 2. Explore weight lines | Individual | 15 Mins |
| 3. Develop rules for weight lines | Discussion | 15 Mins |

### Materials and Preparation

For the class:


- Post the investigation question in a place where all students can see it.
- Begin a class list with the title "Rules for a Good Weight Line" and post it where everyone can see it.
- Class data table for earth material weights (from the last investigation)
- 1 strip of adding machine tape
- 1 capped 150cc container with exactly 40cc of fresh water (from the last investigation)*
- 1 capped 150cc container with exactly 40cc of mineral oil (from the last investigation)*

- 1 capped 150cc container with 40cc of sand (from the last investigation)*
- 1 capped 150cc container with 40cc of organic soil (from the last investigation)*

* These 4 containers will also be used in the next investigation.

### Concept Cartoon

The Weight Line Concept Cartoon is part of this investigation and is in the student science notebook.

## 1. Ask the question

All Class 15 Mins Notebook

Hold up the four containers of earth materials. Recall the last investigation, and establish that the containers hold the same volume of four different materials.

*Were the weights the same?*

Confirm that one of the materials was much "heavier for its size" than the others.

*Which of the earth materials was heaviest*

- sand

*Which was lightest?*

- organic soil

*And the two in the middle?*

- mineral oil and water

As the students answer, place the materials in a line on the blank strip of paper. Put them in weight order, *an equal distance apart*. Encourage students to consult the data from their notebooks or class chart to determine "how much heavier." Discuss the way the containers are arranged and the way the data are represented in the class table.

*Right now the containers are arranged to show their weights from lightest to heaviest. But does this arrangement show how much heavier some containers are than others?*

*Can you think of a way to arrange the containers differently, so that someone could tell, just by looking, which materials are close in weight and which are much heavier or much lighter than others?*

Ask a volunteer to spread the containers along the paper strip to show how the weights of the materials actually compare. Do students agree with the result? Do others have different suggestions? Let them know that the data display they are creating is called a weight line.

*Is there anything we can do to show the data even better?*

- write down the weights, mark intervals on the line, etc.

Introduce the investigation question:

*What makes a good weight line?*

## 2. Explore weight lines

Individual | 15 Mins | Notebook

Students evaluate four weight lines in their science notebooks *[Which weight line?]*. The work is presented through a concept cartoon involving five characters. One of them, Darwin, a dog, has four dog biscuits. The biscuits are all the same size but have different weights: 5 grams, 10 grams, 20 grams, and 100 grams. Darwin wants to arrange the biscuits on a weight line so he can see how the weights compare. In the cartoon, four characters show Darwin their weight lines.

Ask students to place the four biscuits on each character's weight line. When they are done, have them talk in their groups about the strengths and weaknesses of each weight line and then write a letter about them in the notebook *[Dear Darwin]*.

In fact, three of the weight lines are problematic; only Fern's is well constructed. As you circulate among the students, see if they are noting some of the difficulties — improper endpoints, erratic intervals, missing units of measure, etc. — but do not comment on them at this time.

*What makes a good weight line?*

## 3. Develop rules for weight lines

Discussion | 15 Mins | Notebook

### Purpose of the discussion

The purpose of the discussion is for students to consolidate their ideas about what makes a good weight line and to recognize the importance of consistent measurement. Return to the investigation question for the discussion.

Talk Moves

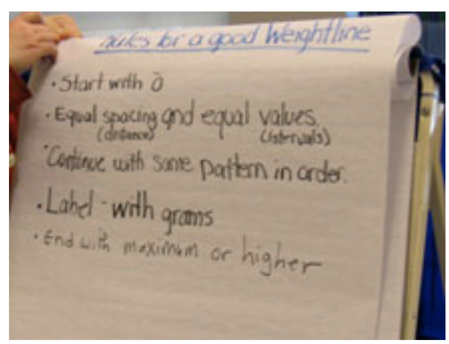
Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage students in the focus question

Students' initial discussion of the concept cartoon sets the stage for consolidating ideas about the investigation question:

*What makes a good weight line?*




Ask students to share their thoughts about the four weight lines in the concept cartoon, and then pose a challenge:

*Could we make a list of rules for good weight lines?*

Help specify students' thinking. Why do they think this is a good rule? What would happen if the rule was not followed? In particular, help students understand that a good weight line will accurately represent the "closeness" or "distance" that the weights have each to each. That way our eyes can make sense of their *relative weights*. In other words, a good weight line will show *how much more* one thing weighs than another.

As the class agrees on some rules, record them on the list you prepared before class and have students copy them into their notebooks *[Rules for good weight lines]*.

**Some rules for good weight lines:**

- The line should start at zero.
- The line should end at a value higher than the heaviest object that will be placed on it, but not much higher; this is called giving an appropriate range.
- The unit of measure should be clearly indicated.
- The line should include some weight marks showing some values between zero and the end value.
- The weight marks should be evenly spaced, and the distance between marks should represent the same amount of weight each time; the distance between the marks is called the interval.
- The interval doesn't have to be 1 unit; it could be any regular increase, e.g., 2g or 10oz or 50lb — whatever best suits the purpose of the line.
- The line should be long enough to show the information clearly.

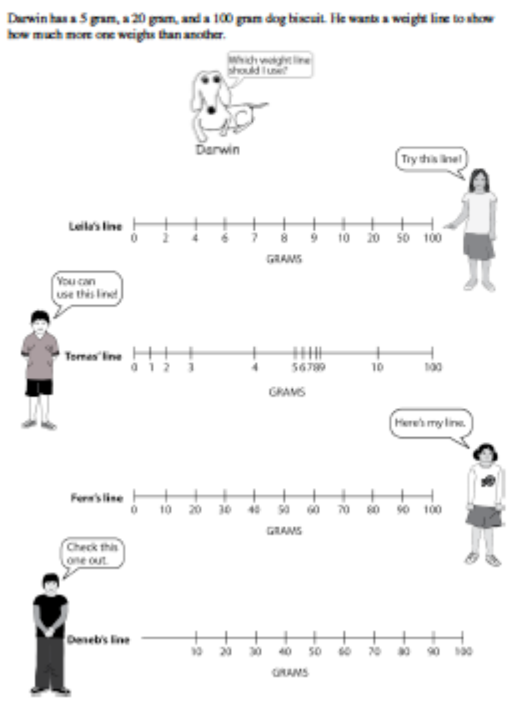
### Summarize the Discussion

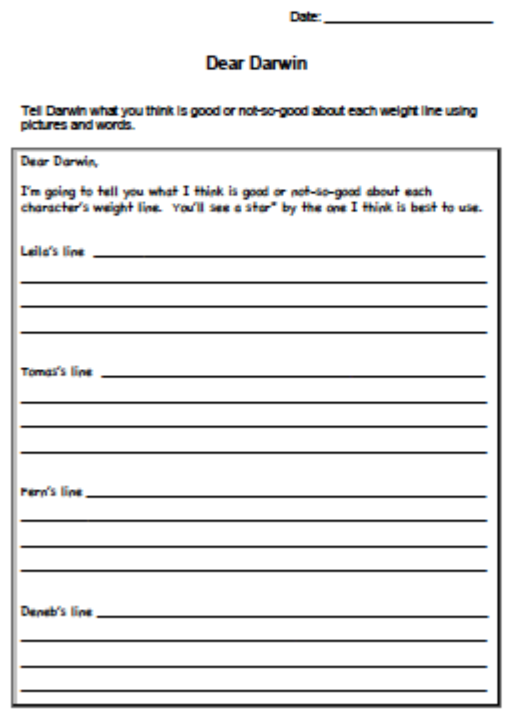
Leave them with this thought:

> *Now we have some rules for good weight lines. Do you think you can make a good weight line that can show how the weights of sand, soil, water, and mineral oil compare — that can show how much heavier one is than another? In what ways would your weight lines be the same?*

Save the class list for the next investigation.

# Weight Line Concept Cartoon



Date: ____________________

Dear Darwin

Tell Darwin what you think is good or not-so-good about each weight line using pictures and words.

Dear Darwin,

I'm going to tell you what I think is good or not-so-good about each character's weight line. You'll see a star* by the one I think is best to use.

Leila's line ____________________

Tomas's line ____________________

Fern's line ____________________

Deneb's line ____________________

This cartoon was developed to assess students' ability to:

- Understand that on a measure line the numbers represent units of measure (weight in grams)
- Identify the characteristics of a weight line for accurately displaying the differences in the weights of objects

This cartoon is part of Investigation 2.2, *What makes a good weight line?*

Students become more aware of the pros and cons of each weight line when they try to locate all four dog biscuits on each of the lines.

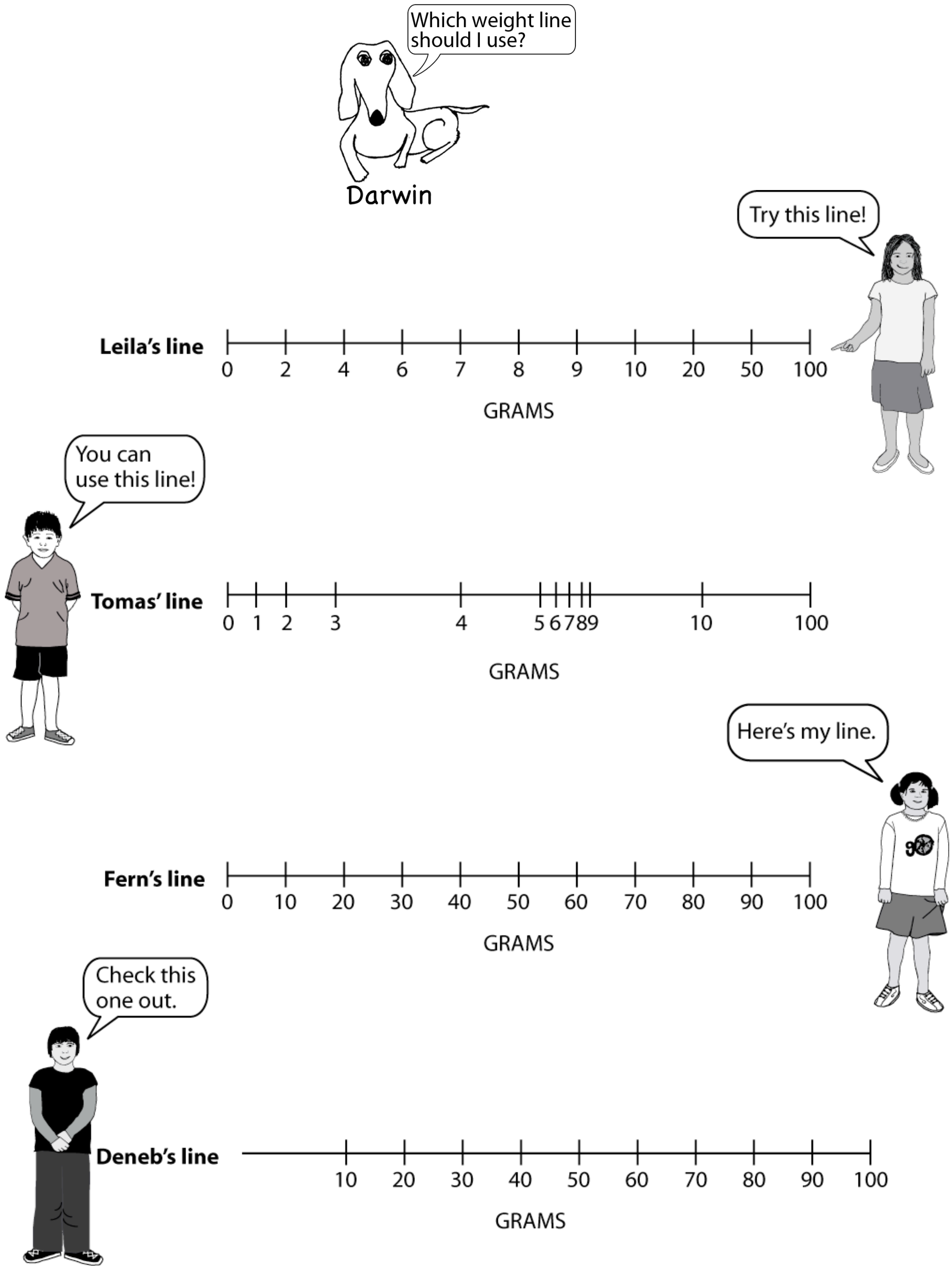
## Things to look for in student responses

Do students recognize the characteristics of a useful and accurate weight line?

- Most students will tell Leila that the increments marked off on her weight line do not represent equal amounts of weight. The same distance between two marks may equal 2g or 1g or 10g, 30g, or 50g. On this line a 100g dog biscuit looks just a bit heavier than a 20g biscuit when it is actually five times heavier.
- Students are likely to explain to Tomas that his line is not divided into equal increments and that spaces between one "tick mark" and another vary in size and it's therefore hard to compare weights.
- Students are likely to explain to Fern that they like her line best. They may note that it starts with a zero, has a spot for all the data including the heaviest dog biscuit (100g), is divided into equal increments, and each segment equals the same amount – 10g.
- Students may tell Deneb that his line has all the attributes of Fern's only it lacks a zero. Without the

zero, it is hard to locate the 5g biscuit on the line. When they add a zero, students may place the mark at the start of the line, making the distance between 1-10 greater than all other 10g lines segments. Or, they may locate the zero so the distance from 0-10 is equal to the other 10g segments (with Fern's line as a model!)

Darwin has a 5 gram, a 20 gram, and a 100 gram dog biscuit. He wants a weight line to show how much more one weighs than another.



Date: ______________________

# Dear Darwin

Tell Darwin what you think is good or not-so-good about each weight line using pictures and words.

Dear Darwin,

I'm going to tell you what I think is good or not-so-good about each character's weight line. You'll see a star* by the one I think is best to use.

Leila's line ______________________________________________

______________________________________________

______________________________________________

______________________________________________

Tomas's line ______________________________________________

______________________________________________

______________________________________________

______________________________________________

Fern's line ______________________________________________

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______________________________________________

______________________________________________

Deneb's line ______________________________________________

______________________________________________

______________________________________________

______________________________________________

# 2. Heavy for Size:  Investigation 2.3

## *What can a good weight line show us about our earth materials?*

## Plan Investigation 2.3

Students now have some weight data, and they have some rules for making a good weight line. They are ready for the next challenge: Construct a weight line that will help them see — *really see* — how much heavier some earth materials are than others.

As they work through the challenge, students apply their rules, grapple with some geometry and arithmetic, and consider what their weight line shows them about their earth materials. They then compare the two ways they have represented their data: in the data table and on the weight line. Then also try to solve some weight line puzzles. By the end of the investigation, students will have a better visual understanding of what it means to be "heavy for size."

**Formative Assessment**

*Do students understand that a table and a weight line can represent the same data set?*

Available online at inquiryproject.terc.edu

### Learning Goals

- Recognize that data tables and weight lines can both display weight data
- See that a weight line is a good way to show how much more one thing weighs than another

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 5 Mins |
| 2. Build weight lines | Individual | 20 Mins |
| 3. Reflect | Discussion | 10 Mins |
| 4. Weight line puzzles | All Class | 10 Mins |

### Materials and Preparation

For the class:


- Post the investigation question in a place where all students can see it.
- Class data table for earth material weights (from the first investigation)
- Class list of rules for a good weight line (from the last investigation)

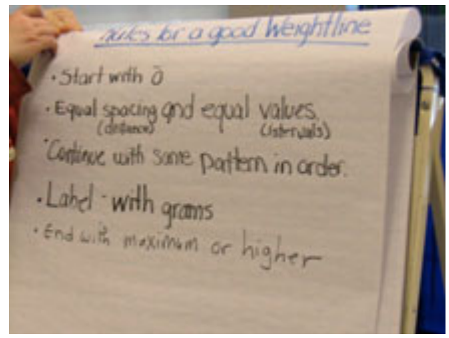
For each tray:

- 1 capped 150cc container with exactly 40cc of fresh water (from the last investigation)*
- 1 capped 150cc container with exactly 40cc of mineral oil (from the last investigation)*
- 1 capped 150cc container with 40cc of sand (from the last investigation)*
- 1 capped 150cc container with 40cc of organic soil (from the last investigation)*
- 4 strips of adding machine tape; strips can vary in length from 40-60 cm.

** These 4 containers will also be used in the next investigation.*

## 1. Ask the question

All Class 5 Mins




Recall the last two investigations. In the first one, students weighed four samples of earth materials and entered the data in a class table. In the second one, they thought of some good rules for weight lines.

Today, they will make their own weight lines and use them to plot their data. Ask students to imagine how the project will go. If they need help, refer them to the class list of rules from the previous investigation.

*Where will you find the weight data?*

*What will you do first? Then what?*

*What do you think will be the hardest part?*

*What do you think you might learn?*

Introduce the investigation question:

*What can a good weight line show us about our earth materials?*

## 2. Build weight lines

Individual 20 Mins

Distribute a tray of materials to each group and remind students of the contents of the containers: equal volumes of water, mineral oil, sand, and organic soil. Ask them to open their notebooks and locate their weight data and their rules for good weight lines.

The hardest part of building the weight line will be determining the interval to use between weight marks, and then to ensure that the intervals are evenly spaced on the line. The interval must be large enough to accommodate the necessary range on the strip of paper, and it must also be easy to work with. Some students may arrive at a good interval through trial and error. Others may use a folding technique, or arithmetic, or some combination of these (see box). As you circulate among the groups, listen to their strategies and head off any serious errors.

When students are satisfied with their weight lines, have them place the containers of materials in the appropriate places.

**Geometry, arithmetic, trial and error: three good strategies.** A simple way to ensure that the intervals are reasonable and evenly spaced is to use geometry. Fold the paper strip in half to find the middle, fold again to find the quarter points, and continue halving by folding until there are intervals of reasonable size. With fourth graders, it's important to have a range that can be halved several times before getting fractions. If the range is 0 to 70 grams, the first fold will mark 35g, but the second fold will create intervals of 17.5g — not very helpful! If you use a range of 0 to 80 grams instead, successive folds will create intervals of 40g, 20g, 10g, and 5 g before running into fractions.

Another approach involves more planning, some arithmetic, and a measuring tape or ruler. If the paper strip is 40cm long, and the range is 0 to 70 grams, and the goal is to have a mark every 5g, you will need 14 intervals (70/5=14) of 2.85cm each (40/14=2.85). Round down to 2.5cm to simplify the measuring, then space the 5g intervals 2.5cm apart. The resulting weight line will use less than the full length of paper, but it will be manageable.

Students may arrive at some combination of these approaches, e.g., they could start by folding once or twice and then measure or make estimates to create smaller intervals. They could also use a ruler and a trial-and-error approach to creating the equal intervals.

## 3. Reflect

Discussion 15 Mins

### Purpose of the discussion

This discussion has two purposes: first to use the weight line data to make claims about how the weight and volume of the four materials compare, and second to compare the information revealed by two different representations of the data, the weight line and the data table.

Talk Moves

Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage students in the focus question

Return to the investigation question with one or more of the student weight lines visible for all to see.

*What can a good weight line show us about our earth materials?*


Students should be able to see clearly that some materials are much heavier than others, while others are nearly equal in weight. Perhaps someone will notice that weight seems to be independent of whether the material is a solid or a liquid (i.e., the two liquids fall between the two solids on the weight line). Some students might observe that when they place the containers on the weight line, they can see that the volumes are the same but the weights are different. This can help confirm that some materials are "heavy for size."

Give students some time to compare the two representations of their weight data, i.e., the class data table that they created in the first session, and the weight lines they just built, which are holding the containers of earth materials.

*What is the same about a data table and a weight line?*

- One example: Both show that earth materials of the same volume have different weights. Both show that sand is heaviest for its size, followed by water, mineral oil, and then organic soil.

*Can the weight line reveal information we can't see in a table?*

- One example: When we put the containers on the weight line, we can actually see that they are all filled to the same level, which shows the volume of the material, and see the distances between the containers on the weight line, which show how their weights compare.

*Does the table reveal information we can't see in the weight line?*

- One example: It's easier to see the actual weights in the table, and to compare them to one another.

### Summarize the discussion

In summarizing the discussion emphasize two points:

1. The weight line is a tool that not only helps us to make measurements, but to make comparisons.
2. Both the weight line and the data table are important ways to represent the data. Each has its own advantage.

## 4. Weight line puzzles

All Class 10 Mins Notebook

Ask students to try the weight line puzzles in their notebooks *[Weight line puzzles]*. The puzzles will give them a chance to practice putting the rules to use. Try solving the first two puzzles together as a class and then have students work on the rest individually or in pairs.

# *Same weight, same volume?*

## Plan Investigation 2.4

By now students are aware that materials having the same volume can have different *weights*. But do they understand that the reverse must also be true? In this investigation they confirm that materials having the same weight can have different volumes.

Students review the weight data for the materials they have studied so far — sand, water, mineral, and organic soil. Then they predict how the volumes of these materials will compare if the weights are held constant. They also consider a new material: gravel. They check their predictions by measuring out equal weights of the materials and comparing the volumes.

By the end of the investigation, students will have a clearer understanding that weight and volume are different properties of earth materials. They will also have a deeper understanding of what it means to say that a material is "heavy [or light] for its size."

### Learning Goals

- See whether equal weights of different materials have the same volume
- Distinguish weight and volume

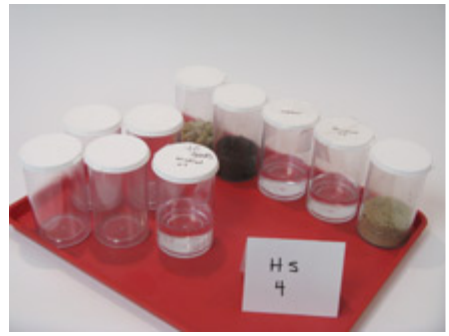
| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 10 Mins |
| 2. Predict volumes | Small Groups | 10 Mins |
| 3. Test predictions | Small Groups | 15 Mins |
| 4. Discuss the results | Discussion | 10 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Post the investigation question for Investigation 2.1., i.e., “Same volume, same weight?”
- 4 classroom weighing stations:
-
    - 1 water weighing station:
        - 1 pitcher of water
        - 2 pipettes
        - 1 digital scale
    - 1 gravel weighing station:
        - 1 container of gravel
        - 2 spoons
        - 1 digital scale
    - 1 organic soil weighing station:
        - 1 container of organic soil
        - 2 spoons
        - 1 digital scale
    - 1 sand weighing station:
        - 1 container of sand
        - 2 spoons
        - 1 digital scale

For each tray:



- 1 capped 150cc container with exactly 40cc of fresh water (from the last investigation)*
- 1 capped 150cc container with exactly 40cc of mineral oil (from the last investigation)*
- 1 capped 150cc container with 40cc of sand (from the last investigation)*
- 1 capped 150cc container with 40cc of organic soil (from the last investigation)*
- 1 capped 150cc container with 40cc of gravel*
- 1 capped 150cc container with exactly **40 grams** (*not 40cc*) of mineral oil **
- 4 capped 150cc containers, empty

* One set of these 5 containers is used in the next investigation.
** The mineral oil containers are used again in Investigation 3.3.

## 1. Ask the question

All Class 10 Mins

Introduce the investigation question:

*Same weight, same volume?*

Wait — that question seems very familiar. Hasn't the class already done this investigation? No, not exactly. Draw attention to the investigation question for the first session of this unit:

*Same volume, same weight?*

Is this the same question? How is it different? Can the class guess what today's investigation will be?

Ask a volunteer to summarize the investigation the class has already done weighing samples of earth materials that have the same volume. As a reminder, show one set of the containers holding equal volumes of sand, organic soil, water, and mineral oil.

*What did we discover?*

- When volumes are the same, different materials can have different weights.
- Some materials are heavier for their size than others

Explain that today the class will explore the opposite question.

*When **weights** are the same, how do the volumes compare?*

*How might we go about finding out?*

Listen carefully to the answers. Make sure students are clear on the difference between weight and volume, that they can imagine how to turn the previous experiment around, and that their preliminary thinking is on track.

## 2. Predict volumes

Small Groups 10 Mins Notebook

Distribute a tray of materials to each group, but hold back the empty containers and the second container of mineral oil (the one containing **40 grams** of oil) for now. Draw attention to the new material — the gravel — and point out that all the materials take up the same amount of space. Check for understanding:

> *Do these materials have the same weight or the same volume?*
>
> - the same volume

Students will fill containers with equal weights (40 grams) of these same materials. Then they will see how the volumes compare. But first you want them to predict what the results will be, and how the materials will line up in volume order.

> *How do you think the volumes will compare when every container has 40 grams of material?*
>
> *What will the order be, from least volume to most volume?*

Ask students to take five minutes to record their thoughts and predictions in their science notebooks *[What is the volume of 40 grams of an earth material?]*. If they are stumped, suggest that they go back to their weight data recorded earlier in their notebooks.

You may need to remind students that they are working with the bulk volumes of the granular materials. The volume will include the air between the grains of sand, organic soil, and gravel.

**What is bulk volume?** Bulk volume is a term used to define the amount of space taken up by a granular solid like soil. In these materials, there are actually *three* volumes: the volume of the grains; the volume of the spaces between the grains; and the total volume, or *bulk volume*, which is the sum of both. Bulk volume can change. For example, when soil is compressed, the volume of air is reduced.

## 3. Test predictions

Small Groups 15 Mins Notebook

Distribute four empty containers and a container holding 40g of mineral oil to each group. Then have the students test their predictions by filling the containers with a measured amount — 40 grams — of each of the other four earth materials (sand, water, organic soil, and gravel), which they will find at the weighing stations. Students may divide up the work.

As you circulate among the groups, check that they remember to allow for the weight of the empty container and its lid (approx. 26g). The total weight of the sample should be 40 grams plus the weight of the container.

Provide time for students to record their observations in their notebooks using labeled drawings *[What is the volume of 40 grams of an earth material?]*.

**Too much soil?** Forty grams of organic soil may not fit into one container. Have additional empty containers available for students to use if they need them.

Once the containers have 40g of material, students can tap them a few times to settle the contents, but they should not compress the materials directly by pushing down on them. They should then place the materials in volume order, from least volume to most volume.

## 4. Discuss the results

Discussion | 10 Mins | Notebook

### Purpose of the Discussion

The purpose of the discussion is for students to use data to answer the investigation question, *Same weight, same volume?*. They make claims and describe their supporting evidence. Their discussion helps them to solidify the difference between weight and volume and to recognize that some materials are heavier for their size than others.

Talk Moves

Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage Students in the Focus Question

*All five containers weighed 40 grams. Were their volumes the same? How did they compare?*

Have the groups share their results. Do all groups agree on the order of the materials? When there is consensus, write the order on the board or post a sketch of the five labeled containers, arranged from least to most.

The order is: sand or gravel, water, mineral oil, organic material. The sand and gravel are very close in volume; groups may differ on which material takes up more space.

Do the results match the students' predictions? Are there any surprises?

Did students expect gravel and sand to be similar? Did anyone think the gravel might take up more space because the spaces between the pieces are so big?

### Summarize the Discussion

Reinforce the idea of heavy for size by asking some probing questions:

*Would the order change if we had just 5g of each material? What if we have 500g of each material? Why not?*

*Do any of these earth materials have similar volumes for equal weights?*

- yes, gravel and sand

*Do you think this is a coincidence, or might there be a reason why sand and gravel are similar?*

- Sand and gravel have different grain sizes but the minerals of which they are made are very similar.

Allow time for students to write responses to the reflection questions in their notebooks *[Volume reflections]*.

### Recap the Section

Wrap up this section of the curriculum by returning to the investigation questions that began and ended this unit:

*Same weight, same volume?*
*Same volume, same weight?*

Students have seen, with their own eyes, that materials that have the same weight can have different volumes — just as materials that have the same volume can have different weights.

Check that students are taking away the important points of this unit:

- Weight and volume are not the same thing.
- Weight and volume are different properties of a sample of earth materials.
- Some earth materials are heavy for their size, while others are relatively light for their size.
- Earth materials that are heavy for their size take up less space than materials that are light for their size, for an equal weight.

**Cleanup:** When finished, students may return the 40g samples of water, gravel, sand, and organic material to their original containers. All the 40cc samples and the 40g container of mineral oil should be saved.

# 3. Liquid Materials

Salt water … Oil… Rain water … Melting ice caps. Much of planetary life depends on liquid materials.

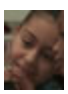
In these investigations we return to our two liquid earth materials — mineral oil and water — to find ways to measure and compare liquid volumes. Liquids take the shape of their containers, and when the containers vary in shape and or size, it's hard to tell with our senses how much more space one sample of liquid takes up than another. Confronted with this dilemma, students see a need for a standard unit of volume measure that they can use to measure liquids. They use centimeter cubes to calibrate containers and then carefully measure the volumes and weights of different-sized samples of the liquids. Students then compare the results and consider some of the properties of the two materials.

As they investigate the liquids, students become familiar with a new unit of measure (cubic centimeters) and discover that "heaviness for size" — our preliminary understanding of *density* — is a property of materials that is independent of sample size.

### Investigations:

- 3.1 How can we compare the volumes of liquids?
- 3.2 How can we measure the volume of a liquid?
- 3.3 How do oil and water compare?

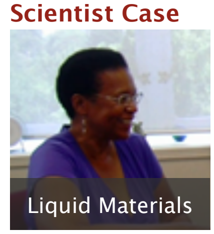
### The Child and the Scientist



**The Child:**
The Challenges of Learning About Liquid Materials

**The Scientist:**
What's important about liquid materials?

**Scientist Case**




Watch Linda Grisham doing the Liquid Materials investigations

Available online at inquiryproject.terc.edu

# The Challenges of Learning About Liquid Materials

> *one of the main challenges in teaching children about liquid materials is to help them begin to appreciate some of the deeper similarities they share with solid materials*

Since infancy, children have had extensive experience with one important class of liquid materials—drinks—that are essential to their health and well-being. Some of the first names they learn for specific materials are names for such liquids as water, milk, and juice—and they have rich knowledge of their sensory-motor affordances. They know that you need to pour drinks into containers that hold them, that drinks can move from their container to your mouth if you tip them at the right angle but also can slosh around or spill if you are not careful, and that different drinks have different characteristic colors, textures, odors, and tastes. For example, water is colorless, runny, and clear; milk is white and creamy; juices can be different colors, are sweet tasting and sticky to touch. Water, of course, can be found not only in glasses and containers, but outside in puddles, swimming pools, streams, and lakes. Children have still further sensory-motor experiences with this special liquid—immersing themselves in water when they take a bath or swim, or being drenched when outside in a cloudburst. These give rise to their knowledge of another characteristics of water—that water can make them wet.

All of these experiences highlight the *distinctive* properties of liquid materials—the myriad ways they are different from the more stable, rigid, everyday objects (toys, furniture, cars, trees) that also inhabit their universe. Hence, one of the main challenges in teaching children about liquid materials is to help them begin to appreciate some of the deeper *similarities* they share with solid materials—that they occupy space, have weight, and can be distinguished by their densities. Such understanding is entrÈe for helping them to develop a more abstract concept of matter (that includes both solid and liquid materials) and of material itself (that can be in both solid and liquid forms).

Because liquids are so fluid and changeable, they don't appear to have those constant properties as long as children rely on their perceptual experiences rather than formal measurement in interacting with them. For example, because liquids slip through your fingers when you attempt to hold them, they appear to have no weight. Because liquids change shape so easily as they slosh around or as you pour them from one container to another (which does greatly change the area the liquid covers), it is not obvious that they take up a fixed amount of space across those transformations. Similarly, because objects can be easily immersed in water, it is not obvious that the water itself is taking up space; children tend to think of themselves as simply going *into* the water rather than the water being displaced.

Still another challenge children confront in learning about liquid materials is more clearly differentiating their concept of *liquid* from their concept of *material*. Most everyday liquids that children encounter are water-based drinks, which although they can vary in taste, are similar in their densities and other behavioral properties. Hence, water is the prototypical liquid for children, and it is easy for them to think of water and liquid as synonymous. As they extend their range of experiences—encountering such liquids as oil, alcohol, glycerin or molasses that are not water-based—they strengthen making this fundamental differentiation. Further, as they explore what happens when you cool these materials, they come to the astounding realization that the *same material* can be in solid or liquid form. Thus, there is an even deeper similarity between solids and liquids—both can literally be the same stuff! Indeed, when material is defined at this abstract level, water (or more properly the H2O molecules that comprise water) isn't even wet!

—Carol L. Smith

**The Scientist's Essay for *3. Liquid Materials***

# What's important about liquid materials?

> *The solid and liquid states are far more like one another than either is like a gas. Physicists often lump the two together as "condensed matter".*

Arguably the most important material to us humans is water. It is also just about the only common material that exists in all three phases ‚Äì solid, liquid and gas — within the range of temperatures and pressures that we commonly experience. Most of the time, though, it's liquid. Of course it's not the only liquid. A lot of the liquids around us that we give names — milk, beer, soda, juice, detergent, even blood — are really just water with some stuff added. But some common liquids are really entirely different substances: gasoline, rubbing alcohol, molten wax. Moreover, under extreme conditions, most materials can become liquid — metals, rocks, natural gas, air. So there's more to liquids than just water and its relatives.

In many ways the liquid form of a material is a lot like its solid state. Its density is usually not very different (for most materials — water being the important exception — the liquid is slightly less dense than the solid, but the differences are generally small) and it often looks much the same. Molten metal looks shiny, ice (if you make it without bubbles) is clear and colorless like water. On a microscopic level the molecules in the liquid state are bound together and strongly coupled, as in the solid. As a result liquids, like solids, are nearly incompressible — if you push on them they may deform or move around, but the volume doesn't change. The solid and liquid states are far more like one another than either is like a gas. Physicists often lump the two together as “condensed matter”.

But of course solids and liquids differ in one crucial respect: liquids flow, and fill a container, while solids are rigid and retain their shape. On a microscopic level, the molecules in a liquid have enough heat energy to be able to move around and rearrange themselves, but still not enough to actually pull apart from one another.

A very useful practical consequence is that it's much easier to measure the volume of a quantity of liquid than that of a solid object — you just pour the liquid into a measuring cup or graduated cylinder and read off the volume. (Of course it's a little harder to measure the weight of the liquid, since you have to worry about the weight of the container, but that's a small price to pay.) We will exploit that property both to investigate density in some detail, and also to provide an indirect means of measuring the volumes of solids.

—Roger Tobin

## 3. Liquid Materials: Investigation 3.1

# *How can we compare the volumes of liquids?*

## Plan Investigation 3.1

Water in a round container … Water in a square container … Water in a curvy container … How can we compare the volumes when the shapes keep changing?

Students consider three containers of water and compare the volumes using only their senses. They predict the volume order then check it using strategies they devise themselves, e.g., transferring the liquids to three identical containers, or marking the level of each liquid in a fourth container. They consider whether liquids keep their volume as they change containers.

By the end of this investigation students will understand that liquids take the shape of their containers, that a standard-sized container makes it easier to compare volumes, and that volume is conserved no matter what container holds the liquid.

**Formative Assessment**

*Do students understand that the volume of a liquid stays the same no matter what container holds the sample?*

Available online at inquiryproject.terc.edu

### Learning Goals

- Recall that volume is the amount of three-dimensional space a material takes up
- See that liquids take the shape of their container
- See that the volume of liquids does not change with the shape of the container

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | Discussion | 10 Mins |
| 2. Predict volume order | Small Groups | 10 Mins |
| 3. Test predictions | Small Groups | 10 Mins |
| 4. Make meaning | Discussion | 15 Mins |

### Materials and Preparation

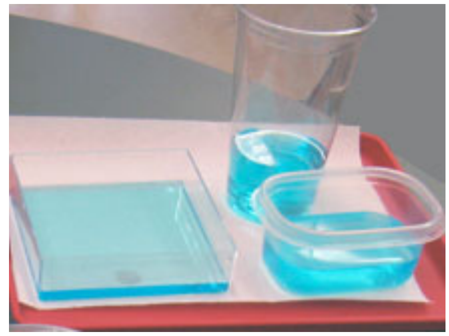
For the class:

- Post the investigation question in a place where all students can see it.
- Prepare a class table for recording the groups' predicted volume orders; an example is found in Step 2.
- 1 capped 150cc container with exactly 40cc of fresh water*
- 1 capped 150cc container with exactly 40cc of mineral oil*
- 1 capped 150cc container with 40cc of sand*
- 1 capped 150cc container with 40cc of organic soil*
- 1 capped 150cc container with 40cc of gravel*
- blue food coloring

** These 5 containers of materials were also used in the last investigation.*

For each tray:

- 1 set of 3 containers, each filled with 250cc of blue-tinted water
    - 1 wide, shallow rectangular container, marked "A"
    - 1 narrow, tall rectangular container, marked "B"
    - 1 20oz cup, marked "C"
- 2 additional 20oz cups, empty (if the group asks for these)



## 1. Ask the question

Discussion 10 Mins

Meet for an all class discussion. Set out the containers of earth materials: water, mineral oil, gravel, sand, and organic soil.

Take a minute to revisit how the unit has unfolded so far: students first investigated solid materials (rocks and minerals), then they investigated granular materials (gravel and sand). Let students know they will now investigate two liquids — mineral oil and water — starting where they left off in the last investigation, with volume.

Show the containers of oil and water, and introduce the investigation question:

*How can we compare the volume of liquids?*

Listen for comments about seeing the "amount of 3-D space" the liquids take up, or "how high they go" in their containers. Agree that this strategy works if the containers are the same size and shape, but what if they are different?

Show the class the three containers holding the blue-tinted water. Point out the labels — A, B, and C — and explain that the liquid is water tinted with food coloring. Now issue a challenge:

> *Can you put these liquids in volume order using only your senses? No rulers, no scales, no measuring cups, no numbers — just your eyes and your hands and your brains?*

Encourage students to model the volumes with their hands and to offer strategies for comparison. If they hazard guesses, ask them to justify their predictions. As students think out loud, listen for an understanding of the difficulties of the task— the containers have different shapes, we do not know the weights of the samples, there are no volume markers, and so on.

> **Talk with your hands!** When talking about volume, it is often useful to "talk with your hands." In fact, hands can often describe 3-dimensional spaces better than words can. For practice, ask students to use their hands to indicate the volume of some common objects such as an orange, a watermelon, or a desktop computer. Then have them model the volumes of the water they see in the containers. Are they capturing all the dimensions: length, width, and height?

## 2. Predict volume order

Small Groups | 10 Mins | Notebook

Distribute a tray of materials to each group.

Encourage students to discuss the challenge in their groups and brainstorm strategies. They can use any strategy they want as long as they keep the liquids in their original containers.

As you circulate among the groups, ask students explain their strategies. Model three-dimensional thinking whenever you can, e.g.,

- So, you're thinking that because this container is wider than the others, it might hold more water, even though the height of water in the other containers is a bit higher.
- You're going to wrap your hands around the containers to get a sense of how much space the water takes up. Is that right?

As students arrive at their predicted volume order, they should record it in their notebooks *[Which water sample takes up more space?]*, using the letters on the containers. Record the volume orders in the class table you have prepared.

| Group | How do the three volumes compare?<br>Least Volume ----- Greatest volume |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| etc. | |

Is there agreement about the volume order or are the results quite varied? It is not necessary to come to consensus now; students will determine the true volume order in a minute.

**Height isn't everything.** Volume is a three-dimensional measurement, but when containers are identical, we need only look at height to compare volumes. This habit can be hard to break, and students may need to be reminded: *Volume is space in every direction; volume is 3-D space.*

## 3. Test predictions

Small Groups | 10 Mins

Typically, the predicted orders vary. This indicates that it's hard to compare volumes when the containers aren't the same. Have students brainstorm ways to test their predictions.

*How can we check our predictions?*

*Can we think of a fair test to compare the volumes of water in the three containers?*

Someone might suggest putting the three samples into identical containers so students can compare volumes — just as they did in earlier investigations. Alternatively, someone might suggest pouring the water from cups A, B, and C into a fourth container, one by one, and marking the level of each sample.

Distribute any necessary materials to the groups (e.g., some 20oz cups) and let them conduct their tests. Be sure students keep track of sample labels ("A," "B," or "C") and that they record their findings in their notebooks.

The volumes are the same. As students report their findings:

*Are the results surprising? How do you explain them?*

*Which estimation strategies were successful and which were not?*

Before moving on, get consensus on the following point:

- When the containers vary in shape or size, it's hard to tell with our senses how much more space one sample of water takes up than another.

## 4. Make meaning

Discussion 10 Mins Notebook

### Purpose of the discussion

The purpose of the discussion is to review the investigation and consolidate students' understanding of key ideas. Focus the discussion on the investigation question.

**Classroom Case 3**


The Role of a Consolidation Discussion

Available online at inquiryproject.terc.edu

### Engage students in the focus questions

Write the four focus questions on the board:

- How did you compare the volumes of liquids?
- What did you do? (What strategy did you use?)
- Why did you do it?
- What did you find out?

The session began with a challenge: to compare the volumes of three samples of water that were in containers of different shapes and sizes.

In this discussion we'll review *what* the different groups did, *why* they did it, and *what* they found out. Refer to the discussion question and open the discussion.

As students describe the steps in their procedures and why they took them, encourage others to:

- listen carefully (as always!)
- ask for clarification or ask questions when something isn't clear.
- think about how this procedure is the same or different from the one they used

### Summarize the discussion

Summarizing this **consolidation discussion** will also serve as a re-cap of the investigation.

> *Our challenge was to find a reliable way to compare the volume of water in three different containers.*
>
> *We used different strategies to answer the investigation question. (Review strategies that students presented.)*
>
> *No matter which strategy we used, we found that the volumes of water in the three containers were equal.*
>
> *We know from the predictions we made that it can be really difficult to compare the volumes of liquids if the containers are not the same size and shape.*

Students may complete the optional assessment in their notebooks *[What is the volume?]*.

**Conservation of volume and the literal-mindedness of children.**

The volume of a liquid is conserved — *i.e., it remains the same* — no matter what container you pour it into. As you present this fundamental law of nature, some students may become distracted by the possibility of irregularities in the procedure. They may object, for example, that the volume cannot remain the same because tiny drops will cling to the container being emptied. This is true and it's good that students realize it, but it is beside the point. Acknowledge the truth of objections of this kind, then make your case theoretical by asking:"If we pour *every little bit of the water* into a different container, will the volume remain the same?"

Literal-mindedness is common in children this age. You can help them move past tiny distractions by pointing out that, we can *imagine* moving every last bit of water from one container into another.

## 3. Liquid Materials: Investigation 3.2

# *How can we measure the volume of a liquid?*

## Plan Investigation 3.2


Minutes … Inches … Grams … Square feet … Most fourth graders have a passing familiarity with measures of time, length, weight, and area. But cubic centimeters? What are those?

In the last session, students discovered that they can't reliably compare liquid volumes using only their senses. In this investigation they get a hands-on introduction to cubic centimeters, a common unit of volume used by scientists. They then make and calibrate their own measuring cups and use them to measure some water volumes.

By the end of this investigation students will appreciate the usefulness of a standard unit of volume, become familiar with centimeter cubes, begin to associate these objects with equivalent amounts of space, and be able to compare liquid volumes with accuracy.

### Learning Goals

- Become familiar with the volume of a centimeter cube
- Figure out how to make a measuring cup for liquids
- Begin to estimate volume in cubic centimeters

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 5 Mins |
| 2. Explore centimeter cubes | Small Groups | 10 Mins |
| 3. Make a measuring cup | Pairs | 20 Mins |
| 4. Make meaning | Discussion | 10 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- 20-25 centimeter cubes for your class demonstration

For each tray:

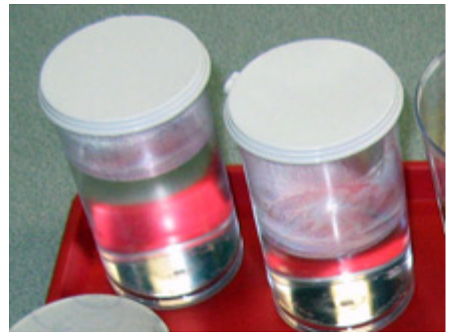

- 1 capped 150cc container approximately 1/2 full of water
- 1 capped 150cc container approximately 3/4 full of water
- 2 empty 150cc containers with a vertical strip of masking tape applied to the outside *
- 2 small rectangular plastic containers
- 2 pipettes
- 2 20oz cups approximately 1/2 full of water
- 1 fine tip permanent marker
- 1 cup holding approximately 75 centimeter cubes (these cubes will be handed out separately, before the rest of the tray)

**Student-made graduated cylinders will be used again Investigation 4.3.*

## 1. Ask the question

All Class · 5 Mins

Show the class the two covered containers that are filled to different levels with water.



> *Which container has a greater volume of water?*
>
> ***Exactly** how **much** greater is the volume of water in one container than another?*

Listen to how students compare the volumes in the absence of units of measure. They may say things like "Only a little more," "About an inch more," "Maybe three bottle caps more," "Half again as much."

As students wrestle with the need for a standard unit of measure, introduce the investigation question:

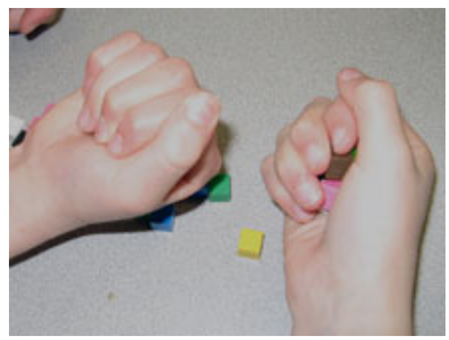
*How can we measure the volume of a liquid?*

Let students brainstorm ideas then, as the ideas run out, give each student a centimeter cube.

## 2. Explore centimeter cubes

Small Groups · 10 Mins

As students explore the centimeter cubes, explain that scientists have designed a way to measure how much space something takes up. They use a unit of measure called a cubic centimeter, which takes up exactly as much space as the cube they hold in their hands. Point out that every edge of the cube is exactly one centimeter long.



> *Can you show me with your fingers how much space a cubic centimeter takes up? Be sure you think 3-D!*
>
> *Can you think of something that has a volume of just 1 or 2 or 3 cubic centimeters?*

One M&M candy has a volume of less than 1 cubic centimeter; a large blueberry, a tooth, or a pencil eraser can have a volume close to 1 cubic centimeter. A marble may have a volume of close to 2 cubic centimeters.

Demonstrate how you can use centimeter cubes to measure and describe the amount of space something takes up. For example, you can get an approximate measure of the amount of space inside your closed hand by scooping up cubes and counting. Keep adding cubes until you can no longer wrap your fingers around them without some of them showing, then let the class know the results.

> *It looks like my hand can hold about [XX] cubic centimeters of stuff.*

Students may point out that the volume is actually greater because there are spaces between the cubes in your hand. Acknowledge this observation.

Distribute a cup of centimeter cubes to each group and ask each student to measure the volume of their own closed fist in the same way. When students finish, do a quick "show of hands" survey of the results.

*How many people had more than 10 cubic centimeters of space inside their closed fist? How many had more than 15 cubic centimeters of space inside their closed fist?*

Have students use the cubes to estimate the volumes of some other solid objects nearby, perhaps a pencil, or a whiteboard eraser, or an apple. Continue to ask for estimates throughout the lesson, so students can get practice with the new unit of measure.

**Centimeter cubes and cubic centimeters:** Students may be confused at first about the difference between centimeter cubes and cubic centimeters. Centimeter cubes are the physical cubes, often made from wood or plastic; they have a dimension of one centimeter along each edge. A cubic centimeter is the amount of space that a centimeter cube takes up; it is a standard measure for volume.

If you sense confusion, ask, "Are you talking about the object, or are you talking about the volume (or, the amount of space it takes up or, the unit of measure)?"

## 3. Make a measuring cup

Pairs 20 Mins Notebook

Distribute a tray of materials to each group of students and point out the two containers of water.

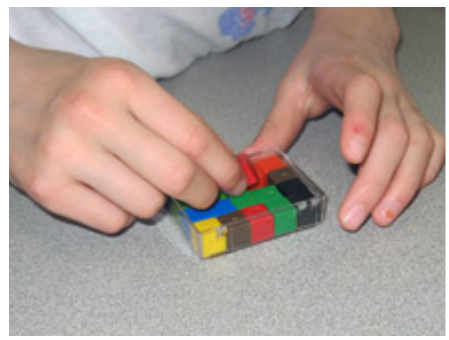
*How could we use our centimeter cubes to measure these two volumes of water?*

As the students brainstorm some ideas, they may suggest stacking the cubes next to the containers. Good idea — but the measure will be approximate, like the measure of the space inside their hand.

*How can we get an* ***exact*** *measurement?*

*Could we make some sort of measuring tool that will help us measure the volume of the liquid?*

If anyone has ever used a recipe to bake cookies or cook a meal, they have probably used a measuring cup, a cup with marks on it that allows them to pour the exact amount of water or milk or oil that's needed. Let students know they will now make their own "measuring cups," using the centimeter cubes to help them. Ask them to open their science notebooks, and point out the steps outlined there *[Challenge: Build a measuring cup!]*.



***Letter from the Engineer***
*The measuring cups you are about to build are really scientific instruments. They are important to have in the kitchen when you need to measure a certain volume of milk or water for a recipe, and they are important to scientists and engineers when they need to carefully measure the volume of liquids. But a measuring cup will not help you to bake good cookies or make accurate scientific measurements unless it has been built very carefully. What makes a measuring cup accurate? There are certain important features or standards — also called criteria — that make a measuring cup accurate. Here are some of those criteria. See if you agree that each one is important.*

- *The lines need to be in the right places.*
- *The lines need to be "level" or horizontal, not wiggly or slanted.*
- *The lines need to be thin but also easy to see. (What's the problem with a thick line?)*
- *The lines need to be labeled with volume measurement units (for example, cubic centimeters)*

*Whenever engineers design anything, they need to identify the important criteria that allow them to know if the design is a success.*

After they finish making their measuring cups, students use them to measure the volumes of the two water samples. They enter the volumes in their notebooks, compare them, and answer three reflection questions *[Using our measuring cup]*.

**What about liters?** Some students may be familiar with liters, another metric unit of volume, which is used for containers of water and soda sold in grocery stores. Liters and cubic centimeters are related like this:
1,000 cubic centimeters = 1 liter
1 cubic centimeter = 1 milliliter

We use cubic centimeters for our units in this curriculum because we have a concrete, tangible way to represent the volume — our centimeter cubes.

## 4. Make meaning

Discussion 10 Mins

### Purpose of the discussion

The purpose of the discussion is to replicate what was done in words, including giving a rationale for the methods used to build a measuring cup. This will help students consolidate their learning and you will gain insight into what they are taking away from today's investigation. Return to the investigation question for discussion: *How can we measure the volume of a liquid?*

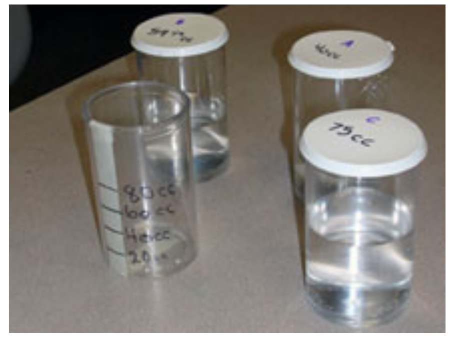
Talk Moves

Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage students in the focus question

> *This was a busy investigation with lots of steps. Does it all make sense to you? Pretend a visitor has come into the room and has no idea what you just did. How would you explain today's work?*



Do students touch on all the following points as they describe their work:

- In science, a standard unit of measure for volume is cubic centimeters.
- We can use centimeter cubes to help us measure or estimate volume.
- We can use a measuring cup to measure liquid volumes.

Are they able to answer the investigation question:

*How can we measure the volume of a liquid?*

### Summarize the discussion and recap the investigation

Let students know that as they work with more liquids, they'll be able to use the measuring cup they made and will get better at estimating volumes. For example, imagine a can of soda. Is it more or less than 140 cubic centimeters (the capacity of the measuring cups they just made?) Based on today's experience with cubic centimeters, what do they think the volume of a can of soda might be?

> **Cubic confusion?** Some students may be having trouble making the mental transition from centimeter cubes, which are solid physical objects, to cubic centimeters, units that can be used to measure liquid volumes. It might help to explain it this way: We describe the volume of things using the words *cubic centimeters* even when we can't see cubes at all. If we have a good measuring cup, and we pour juice into it, and see that it reaches the level of 60 cubic centimeters, we know we have 60 cubic centimeters of juice, because *its volume is the same as 60 of those centimeter cubes*, and not because the juice looks at all like a cube.

3. Liquid Materials: Investigation 3.3

# *How do oil and water compare?*

## Plan Investigation 3.3

Mineral oil and water — they are alike in many ways. But their differences may tell us more about the nature of Earth's materials. In this investigation, students explore some differences between oil and water as they make their way toward an understanding of density.

First students compare some properties of oil and water by sight, then they measure volumes of oil and water at three different weights. They find a relationship between the weights and volumes and consider whether the relationship holds true for all weights of these materials.

By the end of this investigation students will understand that oil will always have more volume than water when their weights are equal. With this they have the beginnings of an understanding of density as the amount of space a material takes up per unit of weight.

**Formative Assessment**

*Do students understand that when the weights of oil and water are equal, the oil will always occupy more space?*

Available online at inquiryproject.terc.edu

### Learning Goals

- Observe some differences between oil and water
- Compare the amount of space a gram of water and oil take up
- The volume of one gram of a particular liquid is a property of that material

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 10 Mins |
| 2. Explore oil and water | Small Groups | 10 Mins |
| 3. Share weight and volume data | All Class | 15 Mins |
| 4. Make meaning | Discussion | 10 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Make an overhead transparency of the notebook page titled "Observations about oil, water, weight, and volume," or copy it onto a class chart for everyone to see (optional).
- 1 classroom weight line (see kit for instructions)
- Blue food coloring

For each tray:
Different groups work with different-sized samples; you will prepare 3 sets of trays, one with 20g of oil, another with 40g, and a third with 80g.

- 1 index card labeled "20 grams" or "40 grams" or "80 grams"
- 1 capped 150cc container with exactly 20 or 40 or 80 grams of mineral oil *
- 1 empty 150cc covered container *
- 1 20oz cup approximately half filled with blue-tinted water
- 2 paper towels
- 1 pipette
- 1 digital scale
- 1 fine tip permanent marker

** The containers with 40g of mineral oil were used in Investigation 2.4; the others are new. All containers should have a vertical strip of masking tape applied to the outside for marking volumes.*

## 1. Ask the question

All Class 10 Mins

Review with the class what we've learned about liquids so far in this unit. We know that liquids flow and take the shape of their containers. We know that we can measure their volume "by eye," or by using cubic centimeters, or with a measured cup. Point out that this is true for all liquids.

But are all liquids alike? Take mineral oil and water, for example. Would you use water to grease a pan? Would you use oil to put out a fire?

Share today's investigation question:
*How do oil and water compare?"*

Begin a discussion of what students already know about the properties of oil and water:

*What are some properties of water that you have noticed?*

- e.g., water is clear, "wet," "thin," and "splashy"

*What are some properties of oil that you have noticed?*

- e.g., oil is "sticky," "slippery," "thick," and pours slowly

Remind students that they know something else about oil and water. Ask them to look back at the data they collected when they compared the volumes of 40 grams of water, oil, sand, and soil (Heavy for Size, Investigation 2.1, Observations of Weights and Volumes).

*How did the volumes of oil and water compare?*

- the oil had a greater volume

*What if, instead of 40 grams of oil and water in the container, you had only 20 grams of each. Try to picture it. How would the volumes compare? Would there be a greater volume of oil or a greater volume of* *water? Or would they be the same?*

*What if you had 80 grams each of oil and water? How do you predict the volumes would compare?*

As students share their ideas, let them know they are about to find out if their predictions are correct.

## 2. Explore oil and water

Small Groups 15 Mins Notebook


As you distribute a tray of materials to each group, explain that groups will get 20 grams or 40 grams or 80 grams of oil. They will measure out equal amounts of water in a moment. At the end of the investigation, they will share their results and compare them.

Students fill the empty container with their assigned weight of water — 20 grams, 40 grams, or 80 grams. You may need to remind them to allow for the weight of the container (26g). Students then double-check that the weight of their two samples is the same; if it's not, they can add or remove some water using the pipette.

When they have equal weights of oil and water, students measure the volumes of the two samples using a measuring strip that they cut out of their notebooks. They record the volumes on the containers and make labeled drawings of the containers in their notebooks *[How do oil and water compare?]*.

As students finish up their measurements, ask them to compare the way oil and water move by holding a container upright in each hand and gently swirling the liquids — no shaking or splashing! Have them record and share their observations.

*What property of oil or water do you think explains the difference in the way these two liquids move?*

**No oil spills!** Though the containers of oil are capped and taped shut, students should keep them top-up at all times to prevent oil from leaking out. This is especially true when they are investigating the way the liquids move — no shaking!

## 3. Share weight and volume data

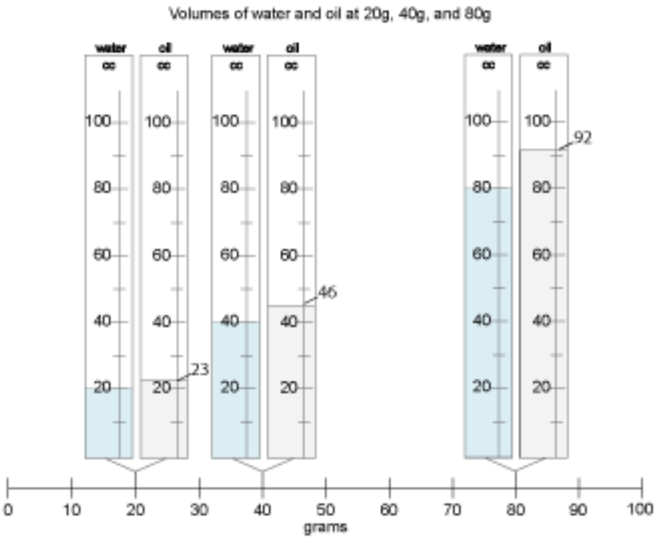
All Class 15 Mins Notebook

Ask the students to come to the class weight line with their notebooks and their containers of oil and water. Have each group place their containers at the appropriate point on the line (there will be duplicates).

*What do you notice?*

Students may struggle a little to see the weights and volumes, but there should be consensus that the volumes are increasing as the weights increase. They may or may not be able to tell much about how the volumes of the oil and water samples compare.

**Chart data (optional)**




Let's look at the data another way. Let's take the weight and volume data from your notebooks and put it on a class chart.

Have students open their notebooks *[When weights are equal, what's the volume?]*. Point out that this is the same chart as the class chart, only sideways.

> *How does this chart work?*
>
> *Where should we put the volume data for the 20 grams of water?*

Record data for all the samples on the chart, resolving any disputed findings as you go along. Have students record the data in their notebooks. The chart will look much like this.

## 4. Make meaning

Discussion 10 Mins

### Purpose of the discussion

The purpose of the discussion is for students to use the data they've collected to make and support claims about the investigation question. Return to the investigation question for discussion.

### Engage students in the focus question

Now we can see the data more clearly. What claims can we make that the data support?


Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

*How do oil and water compare?*

> *Look carefully at the differences in weights and in volumes. What do you notice?*

- If the weights are the same, oil has greater volume than water in every case.
- The heavier the samples, the greater the difference between the volumes.
- As the weight doubles, the volume difference doubles.

**Supporting questions**

*What do you think the volume difference for oil and water would be if you had 160 grams of each liquid?*

*How do you think the volumes would compare if you had 5 grams of each? Or just 1 gram of each? Or if the samples weighed tons and tons*

*If instead of starting with equal weights you started with equal volumes: how do you think the weights would compare?*

- If the volumes are the same, oil will weigh less than water.

*What property of oil or water do you think explains why equal weights of oil and water have different volumes?*

**Note:** The relationship between a material's weight and its volume stays the same no matter how big or small the sample is. It is a property of the material called density. Density is a term we are not introducing to students in this curriculum.

The class knows this property from earlier investigations as "heavy for size." We can also say "heavy for volume." Water is heavy for its volume compared with oil, just as sand is heavy for its volume compared with soil.

### Summarize the discussion and recap the investigation

Use the same language that students have used to summarize the discussion. Include student comments that address claims and evidence about how oil and water compare.

As you recap the investigation, be sure there is understanding of these two points:

- If the weights of oil and water are equal, oil will always have a greater volume than water.
- The amount of space a liquid takes up compared to its weight is the property we call "heavy for size."

**Not too small to matter.** Heaviness for size is a property of all materials, independent of sample size. Although it is not very obvious, a single gram of oil has a greater volume than a single gram of water, and 0.1 grams of oil will have greater volume than 0.1 grams of water. If students doubt this, ask if they are saying we might not notice the volume difference any more, or if they think the difference really ends once we reach 1 gram. While our senses are very important in helping us learn about the world, there are times when our senses — or even scientific instruments — cannot detect something, and we have to rely on our understanding. Does it make sense that the pattern we see would suddenly stop being true at 1 gram? No, there is no logical reason for that, so we must rely on our understanding.

# 4. Mineral Materials

It's easy enough to measure the volume of a liquid if we have a measuring cup, but how do we measure the volume of solid materials — especially if they are oddly shaped, like a rock or a handful of soil? It's an ancient problem, and one that students examine first, like the ancient Greek mathematician Archimedes, through a consideration of water displacement.

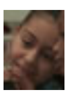
Students first investigate what happens when a rock is submerged in water, and determine that it is volume, not weight, that causes the water level to rise. Then, through a series of hands-on investigations, they find ways to measure the volumes of rocks, gravel, and sand.

As the investigations unfold, students come to understand that two objects cannot occupy the same space at the same time. They discover that the volume of a solid object can be found by water displacement, observe that the volumes of objects can be added, and consider how the volumes of granular materials are different from the volumes of liquids and solids.

### Investigations:

- 4.1 What causes the water level to rise?
- 4.2 How can we measure the volumes of rocks?
- 4.3 What happens when we add earth materials to water?

### The Child and the Scientist



**The Child:**
The Challenges in Learning about Water Displacement

**The Scientist:**
What does "Eureka" mean? Displacement of liquids

### Concept Cartoon

The Volume Concept Cartoon is typically used after Investigation 4.3, *What happens when we add earth materials to water?*.

**Scientist Case**


Watch Roger Tobin doing the Mineral Materials Investigations

Available online at inquiryproject.terc.edu

**The Child's Ideas for *4. Mineral Materials***

# The Challenges in Learning about Water Displacement

> *most children think about what happens when objects are placed in water in dynamic terms—the object, because of its heft, pushes down on the water, causing the water to rise*

Students are typically taught to use water displacement as a method of determining the volume of an irregularly shaped object, without considering whether students have any real understanding of what they are doing when using this method. What is the volume of an object? And why is putting objects in water relevant?

Answers to these questions are by no means initially obvious to children for two main reasons. First, the vast majority of children do not have a concept of volume (as occupied three-dimensional space) that is differentiated from other measures of spatial extent (length and area) and linked to amount of material. For example, when children are asked to measure how much space two different shaped objects fill up, they overwhelmingly focus on measuring the length or areas of the two objects. Further, when they watch as a clay ball is flattened into a pancake and are asked to compare how much space the ball and pancake fill up, they overwhelmingly say that the pancake fills up more space because it is longer or more spread out, rather than reasoning they both fill up the same amount of space because they have the same amount of material, just arranged in a different shape, or noting the compensation among dimensions (e.g., although the pancake is much longer and wider, it is also much thinner).

Second, most children think about what happens when objects are placed in water in *dynamic terms*—the object, because of its heft, pushes down on the water, causing the water to rise. It follows from this dynamic analysis that they think that weight is the relevant factor for the rise in water: heavier objects should push down with greater force, resulting in a greater rise in water. Thus, almost all children, when shown two equal size (and shape) cylinders of very different weight (e.g., one made of aluminum, one made of brass), confidently predict that the heavier cylinder will make the water rise up higher.

Note that in this dynamic analysis, children are not yet thinking that the water rises because the object has *displaced* the water. Seeing the situation as one of "water displacement" calls for students to construct a deeper model of what happens that "goes beyond the information given perceptually." More specifically, they must combine the belief that "two things can't occupy the same space at the same time" (a deeply held physical principle since infancy) with their newly developing ability to attend to the volume in this situation (rather than weight) and to think of the volume compositionally (i.e., the volume of the whole system is the sum of the volume of the parts—the liquid and the immersed object). In so doing, they can mentally imagine that when the object is immersed in the water, it must "push away" an amount of water equal to its volume. Hence, if one were to capture the water that was "pushed aside," it would have a volume exactly equal to the volume of the object.

—Carol L. Smith

**The Scientist's Essay for *4. Mineral Materials***

# What does "Eureka" mean? Displacement of liquids

Legend has it that the Greek philosopher Archimedes was tasked with figuring out whether an allegedly gold crown was adulterated with cheaper metals. He knew that gold is denser than the baser metals, so he could tell if the crown was really gold if he could measure its density. Measuring its weight was no problem, but how to measure the volume of such a complicated shape?

> "*...the total volume occupied by the submerged solid and liquid together is exactly equal to the volume of the solid plus the volume of the liquid.*"

If a solid is submerged in a liquid, the liquid cannot occupy the same space as the solid, so it is forced out of the way. At the same time it flows, so it fills in all the holes, crevices, nooks and crannies, leaving no gaps. And since it's incompressible, the volume occupied by the liquid itself doesn't change. Therefore the total volume occupied by the submerged solid and liquid together is exactly equal to the volume of the solid plus the volume of the liquid. So if you measure the apparent "change" in the volume of the liquid, that's just the volume of the submerged solid object. Since measuring the volume of a liquid is pretty easy, the problem is solved: you now have an accurate way to measure the volume of any solid object, no matter how complicated its shape.

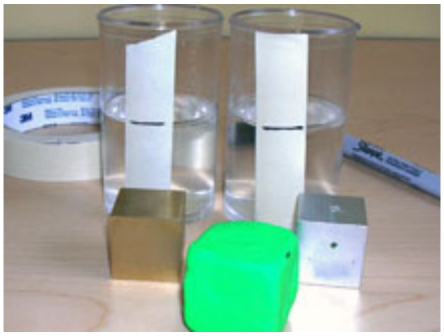
According to the story, Archimedes arrived at this insight while bathing, and was so excited that he jumped from the bath yelling "Eureka!" ("I found it!") and ran home naked through the streets of Syracuse. Dubious story, but sound physics.

—Roger Tobin

## 4. Mineral Materials: Investigation 4.1

# *What causes the water level to rise?*

## Plan Investigation 4.1



What makes the bathtub overflow when a person settles in for a bath? Is it weight or volume? It's the volume, but children often believe it is weight that "pushes the water out of the way." In this investigation, students confront this idea head on.

Today, students gather evidence to decide if weight or volume is the determining factor in the displacement of water.

By the end of this investigation students will understand that objects submerged in water will always change the water level, and that it is *volume*, not weight, that determines how much water will be moved aside.

**Formative Assessment**

*Can students use evidence to reason that volume, not weight, determines how high the water level will rise?*

Available online at inquiryproject.terc.edu

### Learning Goals

- Discover what property of a sunken object makes the water rise
- Understand that two objects cannot occupy the same space at the same time

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 10 Mins |
| 2. Explore water displacement | Small Groups | 15 Mins |
| 3. Share data | All Class | 5 Mins |
| 4. Make meaning | Discussion | 15 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Prepare two class data charts, one for weight, another for volume; examples are shown in the notebooks and in Step 3.

Have the following materials ready for a demonstration at the start of class:

- 2 150cc containers with a vertical strip of masking tape applied to the outside, each approximately half full of water
- 2 rocks or minerals, one visibly larger than the other (each must fit in 150cc container)
- 1 aluminum cube (44g)
- 1 copper cube (147g)
- 1 44g cube of plastic modeling clay (same weight as aluminum cube)

- 1 3oz cup of water
- 1 pipette
- 1 plastic fork
- 1 fine tip permanent marker
- 1 paper towel

For each tray:

- 3 150cc containers with a vertical strip of masking tape applied to the outside, each approximately half full of water
- 1 aluminum cube
- 1 copper cube
- 1 piece of plastic modeling clay weighing approximately 50g
- 1 pipette
- 1 3oz cup of water
- 1 fork
- 1 fine tip permanent marker
- 2 paper towels
- 1 digital scale

## 1. Ask the question

All Class 10 Mins

Show the students the two containers of water and the two rocks.

*What do you predict will happen when I add this larger rock to this container of water?*

As students predict, ask them to explain their reasoning.

Before placing the rock in the water, show students how to draw a line to record the initial water level. Demonstrate lowering your eyes to the level of the water to accurately see its level and then draw a line on the masking tape. Next, use a fork to lower the rock into the container. Explain that you don't want any water to splash out because that would change the amount of water in the container. When students have confirmed that the water level has risen:

*What do you think caused the water to rise?*

Students may say, "The rock pushed the water away," or "The rock is heavier than the water so the rock went down and the water went up." Some may suggest "size" or "volume" is responsible, or maybe "pressure" or "gravity." Accept all suggestions without comment for now.

Show students the smaller rock.

*What will happen when I put this smaller rock into the second container? Will the water level rise the same amount? More? Less? Why do you think so?*

Before lowering the smaller rock into the second container, make sure the water level matches the starting level marked on the first container. Use the pipette to add or remove enough water to get them exactly equal, then mark the container. Use the fork to lower the smaller rock into the water without splashing.

*What do you notice?*

**Displacement:** When an object is submerged or partially submerged in water, the object displaces, or "puts out of place" the water originally in the space now occupied by the object. This happens because two objects cannot occupy the same space at the same time. Scientists call this phenomenon water displacement. Water leaves no space between itself and a submerged object, so when an object is added to a container of water, the volume of stuff below the water line increases from the volume of just the water to the volume of the water plus the submerged object.

Students should see that both rocks caused the water level to rise, and that the larger rock raised the water level more than the smaller rock. Let students know that the scientific term for this change in water level is *water displacement*. The water moves away because the rock has taken its place.

*Why do you think one rock displaced more water than the other?*

*Is it the weight of the bigger rock or its volume? How can we find out?*

Have students brainstorm among themselves, then ask them to share their thoughts with the class. Listen for a suggestion of a *controlled comparison* or "fair test", i.e., to test two objects with the same volume but different weights — or the same weights but different volumes — and observe the difference in the amount of water that is displaced.

## 2. Explore water displacement

Small Groups 15 Mins Notebook

Return to the investigation question:

*What causes the water level to rise?*

Explicitly point out that we are trying to determine if volume or weight is the cause.

Distribute a tray of materials to each group. Ask students to examine the two cubes to see how they compare. Do they agree that they have the same volume? Can they tell that the copper cube is much heavier than the aluminum cube?

Point out the plastic modeling clay and the scale. Let students know they can cut and form the plastic modeling clay into a third cube having the same weight as the aluminum cube.

Ask students to help you list the steps for a fair test that will answer the investigation question. An example is given below.

**Steps for a Fair Test:**

1. Equalize the starting water levels and mark them on the containers.
2. Weigh the 2 cubes.
3. Compare the volumes of the 2 cubes.
4. Carefully place the cubes in the containers of water.
5. Compare the water levels in the containers.
6. Compare the water levels of the two cubes that have *the same weight* (i.e., the aluminum cube and the plastic modeling clay cube).

Have students open their science notebooks and record their predictions, then set the groups to work. Students should first compare the aluminum and copper cubes and then work on comparing the aluminum and plastic modeling clay cubes.

As you circulate among the groups, confirm that the volume of the plastic modeling clay cube is greater than the volume of the aluminum cube. Make sure students are recording their predictions and their data in their notebooks *[How much will the water level rise?]*.

Let students know that the only *quantitative data* they will record is the weight of the cubes (in grams); the volume data and the water levels will be *comparative data*, e.g., " volume is greater than the other." or "the water rose higher."

## 3. Share data

All Class 5 Mins

Ask students to help you fill in the class data charts. The data will look something like this.

**Comparing Aluminum and Copper Cubes**

| | Volume | Weight | Water level |
|---|---|---|---|
| **Aluminum cube** | Same as copper | 44 grams | Same as copper |
| **Copper cube** | Same as aluminum | 147 grams | Same as aluminum |

**Comparing Aluminum and Plastic Modeling Clay Cubes**

| | Volume | Weight | Water level |
|---|---|---|---|
| **Aluminum cube** | Smaller than plastic modeling clay | 44 grams | Lower than plastic modeling clay cube |
| **Plastic Modeling Clay cube** | Larger than aluminum | 44 grams | Higher than aluminum cube |

Resolve any conflicts in the data before moving on to the discussion.

## 4. Make meaning

Discussion 15 Mins

### Purpose of the discussion

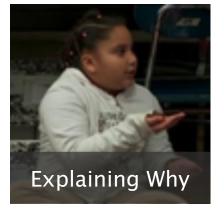
The purpose of the discussion is to construct an explanation together of what causes the water to rise. The resulting explanation should be consistent with observations and evidence. Begin the discussion by returning to the investigation question.

### Engage students in the focus question

*Weight or volume, which causes the water level to rise?*

Engage students in the topic by asking them to talk a couple of minutes to talk with a partner about their claims and the evidence that supports their claims. Provide three 150cc containers with equal volumes of water and an aluminum, copper, and plastic modeling clay cube for students to refer to during their discussion, as well as the data they recorded in their notebooks.

**Classroom Case 4**




The Role of Explanation Discussions

Available online at inquiryproject.terc.edu

Open the full-class discussion with the focus question.

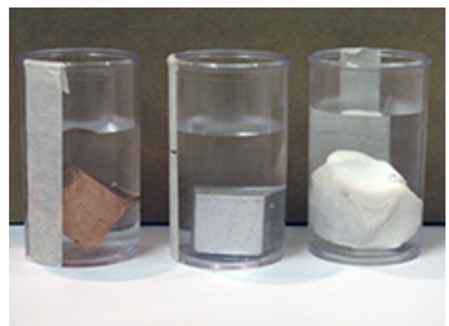
*Is it weight or volume that causes the water level to rise?*

#### Supporting questions

*What do the data tell us? (Refer to the class data chart.)*

*What claim can you make: can you claim it's the volume that causes the water to rise? Or do you claim it's weight? What is your evidence that supports your claim? And what is your reasoning?*

*How do you explain the results?*



**Note:** From their investigation, students have evidence to reason that *weight* is *not* a factor in raising the water level.

The aluminum and copper cubes weigh different amounts but the water levels rose equally.

The aluminum and plastic modeling clay cubes weigh the same but the water levels rose unequally.

Students also have evidence to reason that *volume is* a factor in raising the water level.

The aluminum and copper cubes have equal volumes and the water levels rose equally.

The aluminum and plastic modeling clay cubes have different volumes, and the water levels rose unequally.

The underlying reason — *the explanation* — why the water rises is because two objects cannot occupy the same 3-D space at the same time. *Volume*, and not weight, is the property of an object that describes the amount of 3-D space an object takes up.

Students may not be able to clearly articulate this explanation; they may say the rock “pushed the water out of the way”. In response, you may ask, “Why? Why couldn't the water just stay in the same place after the rock was dropped in?”

Support the discussion with "moves" such as:

*Who wants to repeat (student A)'s explanation using different words?*

*Do you agree or disagree? Does that reasoning make sense to you?*

When you think the group is convinced that it is volume that determines how much water is displaced, ask students for an explanation of the displacement phenomenon.

*Does it make sense that it's volume and not the weight of an object that determines how high the water will rise? How do you explain this?*

*What happens to the water when an object sinks in it? Where does it go?*

- Water will go in whatever direction the shape of the container allows. In a straight-sided container it will move straight up. In a bowl with sloping sides, it will move up and sideways. If the container is full, the water will overflow.

*Have you seen water displacement happen anyplace else?*

- In the bath tub, in a cooking pot, in a puddle when you step in it.

### Summarize the discussion and recap the investigation

*Here is what I think I heard you say:*

Use the same language that students have used to summarize the discussion. Include student comments that address claims and evidence, but be sure to highlight students' reasoning and explanations of displacement.

Describe the initial observations using rocks, and the dilemma of not being able to determine whether it was weight or volume that was causing the water level to rise. The rock with the greater volume also weighed more.

The tests students did using the three cubes allowed us to separate weight from volume; in both tests, it became clear that volume was the property that determined how much the water rose, and weight did not make a difference.

A key concept is that two objects cannot occupy the same 3-D space at the same time.

## 4. Mineral Materials: Investigation 4.2

# *How can we measure the volumes of rocks?*

## Plan Investigation 4.2

The students are getting good at measuring different kinds of earth materials. They can weigh rocks and minerals and cubes with ease using the digital scale. They can measure the volume of liquid samples using their own "measuring cups." But how can they measure the volume of an irregularly shaped solid, like a key or a rock or a handful of sand?

A clue can be found in the last investigation. Students discovered that when a rock is submerged in water, it displaces a "rock's worth" of volume. In this investigation, students find a way to measure that volume in cubic centimeters. By the end of the investigation students will understand that the volume of solid objects can be found by measuring the amount of water they displace.

**Formative Assessment**

*Do students understand that a collection of centimeter cubes equal to the volume of a rock will displace an equal amount of water?*

Available online at inquiryproject.terc.edu

### Learning Goals

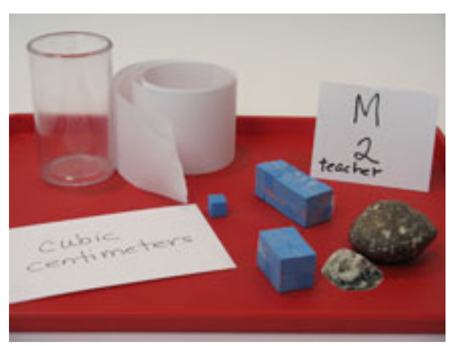
- Recall that volume is measured in cubic centimeters
- Understand that the volume of a solid object can be found by water displacement

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 15 Mins |
| 2. Estimate and measure the volume of rocks | Small Groups | 15 Mins |
| 3. Share the volume data | Small Groups | 5 Mins |
| 4. Discuss the results | Discussion | 10 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- 1 classroom volume measure line (see kit for instructions)
- 1 12cc rectangular block made by joining 12 centimeter cubes in a 2x2x3 shape (use clear tape).
- 1 20cc rectangular block made by joining 20 centimeter cubes in a 2x2x5 shape (use clear tape).
- 1 centimeter cube
- 1 empty 150cc container
- 2 rocks or minerals of different sizes



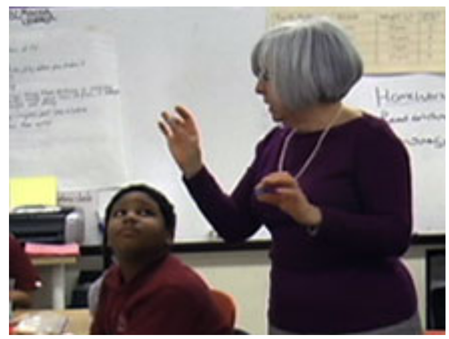
For each tray:

- 2 rocks or minerals
- 1 cup holding approximately 75 centimeter cubes
- 4 150cc containers each with a vertical strip of masking tape applied to the outside, approximately half full of water
- 1 3oz cup of water
- 2 pipettes
- 1 fine tip permanent marker
- 2 paper towels
- 1 plastic fork


## 1. Ask the question

All Class 15 Mins

Meet in a circle and show students the two rocks or minerals.



*Which rock has the greater volume? How **much** greater?*

Listen to the students' comparisons. Do they distinguish weight from volume? Can they express relative volume ("This one is twice as big"; "That one has less stuff in it"?) Do they remember the correct unit of measure — cubic centimeters? Do they suggest submerging the rocks in water to find out? (If yes, tell them to "Hold that thought!") As you field the comments, encourage students to think about a quantitative comparison:

> **Weight vs. volume:** Fourth graders sometimes have difficulty distinguishing weight and volume. If you hear this confusion entering the discussion, stop and ask, "Are you talking about weight or volume? If this rock were made of Styrofoam or feathers instead of minerals, would its volume be any different? No, volume is the amount of space the rock takes up, not how much it weighs."

*What if we want to know **exactly** how much greater, how could we figure that out?*

> **Estimating volume:** Thinking about how much space objects take up can sometimes be easier when we see those objects enclosed in defined spaces — like a plastic container. If students are having difficulty imagining solid volumes, take a moment to practice estimation skills.
>
> Place each of the three demonstration blocks inside an empty 150cc container, one at a time, starting with the largest. Ask, "How many more of these 20cc [12 cc, 1cc] blocks do you think can fit into this container?" Four to six 20cc blocks will fit comfortably in the container, and it will hold more than six 12cc blocks.
>
> You might also measure the volumes of some small, common classroom objects before class, and make them available for reference during the demonstration.

Draw attention to the investigation question:

*How can we measure the volumes of rocks?*

Let students brainstorm some ideas. Entertain all ideas for now.

Bring out the three blocks — the 1cc cube, the 12cc block, and the 20cc block — and pass them around. Ask students to inspect each one carefully, looking from all sides and counting the number of centimeter cubes, then ask for the volume of each object (1cc, 12cc, 20cc).

Bring out the volume line and ask a volunteer to place the three blocks on the line. Point out that the volume line is just like a weight line, e.g. it starts at zero and has even intervals of measure, but it is marked in *cubic centimeters* and is used to compare the volumes of objects. Ask volunteers to place the two rocks on the volume line where they estimate they should go.

**Volume vs. surface area:** Fourth graders will sometimes confuse volume with surface area, counting the two-dimensional "faces" of the cubes on the outside of the block instead of the three-dimensional cubes that make up its volume. Model the three-dimensional space with your hands or take one of the blocks apart, count the individual cubes with the class, then tape the cubes back together again.

> *Does the volume line help us to see any more information about how the volumes of the objects compare?*

Sum up the work so far. Students have estimated the volume of the two rocks using their eyes and three reference blocks. But they still don't have a measured volume.

> *Can we get any closer to the actual volumes of the two rocks? Is there any way we can use our centimeter cubes to help us?*

Demonstrate how to estimate the volume of a rock by replicating its size and shape with a pile of centimeter cubes. Then, place two 150cc containers, approximately half full of water, side by side with the cubes in front of one container and the rock in front of the other.

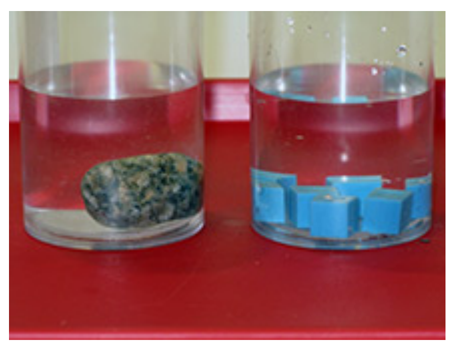
> *If we want to find out if this replica has the same volume as the rock, what could we do?*

Listen for ideas about water displacement and settle on a procedure like this one:

1. Equalize the amount of water in the two containers, using the pipette
2. Place the rock in one container and add the cubes to the second container, counting as you go, until the water levels are the same.

## 2. Estimate and measure the volume of roc Small Groups 15 Mins Notebook

Distribute a tray of materials to each group. Explain that each pair of students will estimate and then measure the volume of one of the rocks on the tray; they will then combine their data with the data for the second rock collected by the other pair.



Students estimate the volume of their rock. They first build a rock replica using centimeter cubes. Students record their estimates in their notebooks specifying the unit of measurement (cubic centimeters) each time *[Which rock has more volume?]*.

Students then check their estimates using the water displacement procedure devised by the class, recording the procedure and results in their notebooks.

**Steps for Measuring the Volumes of the Rocks:**

1. Equalize the starting water levels and mark them on the containers.
2. Place the rock in one container and mark the new water level after the water has been displaced.
3. Add centimeter cubes to the second container, one at a time, counting as you go, until the water level matches the water level in the first container. The number of cubes is the measured volume.

## 3. Share the volume data

Small Groups | 10 Mins | Notebook

After the pairs finish their measurements, the students fill out the group's data table in their notebooks. They then place their rocks on the class volume line, labeling each rock with the measured volume. Finally, they record the position of their rocks on the volume line in their notebooks *[Measured volumes]*.

## 4. Discuss the results

Discussion | 10 Mins | Notebook

### Purpose of the discussion

The purpose of the discussion is for students to be able to explain how to measure the volume of rocks and other solid objects, and understand the advantages of using displacement to determine volume. Again, focus the discussion on the investigation question.


Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage students in the focus question

To engage students in the discussion, first allow time for them to complete the Reflection Questions in their notebooks *[Volume reflection]*, and then return to the investigation question:

*How can we measure the volumes of rocks?*

> *If you wanted to find the volume of your hand, would you use cubic centimeters to build a replica or use displacement of water? Why?*

If there is time, ask students to consider the following question:

> *Do you think the displacement method for measuring solid volumes would work if we used mineral oil instead of water? Why? (Yes, any liquid will work.)*

Let students know that it is often difficult to estimate volume, just as it can be difficult to estimate weight. Practice helps, but measurement is better. Unfortunately, there is no "volume scale" like a "weight scale." For irregularly shaped objects, we can measure volume only indirectly, by measuring water displacement, as the students did today.

### Summarize the discussion and recap the investigation

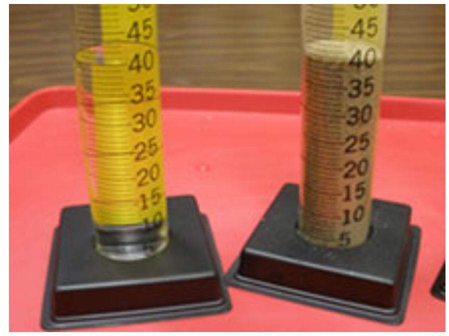
Use students' own words to summarize how can we measure the volume of rocks and other objects using displacement.

As you review the investigation, make sure students understand the following main points:

- Volume is often measured in cubic centimeters.
- With practice, we can estimate volumes by comparing new objects with objects whose volumes are already known.
- The volume of any solid objects can be measured by the displacement of water.

# What happens when we add earth materials to water?

## Plan Investigation 4.3



Cheerios … jellybeans … sand … gravel. What do these things have in common? They are all *granular materials*, assemblages of individual pieces or *grains* with "empty" spaces between them. Unlike solids and liquids, granular materials have *three* volumes: the volume of the solid material, the volume of the space between the grains, and the combined *bulk volume*.

In this investigation, students continue their investigation of volume and water displacement by adding solid, liquid, and granular materials to water and recording the volumes that result. By the end of the lesson, students will understand that the volumes of solids and liquids can be added directly. However, when a granular material is added to a liquid, the combined volume is equal to the sum of the separate volumes *minus the volume of the air between the grains in the sample*.

### Learning Goals

- Become familiar with a graduated cylinder
- Understand that the volumes of solids and liquids can be added together
- Understand that granular materials displace water differently than solids and liquids

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 10 Mins |
| 2. Explore volumes in water | Small Groups | 20 Mins |
| 3. Make meaning | Discussion | 15 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- 1 strainer (for clean-up)
- 1 50cc graduated cylinder filled with 40cc of water
- 1 100cc graduated cylinder filled with 40cc of sand
- 10 centimeter cubes

For each tray:

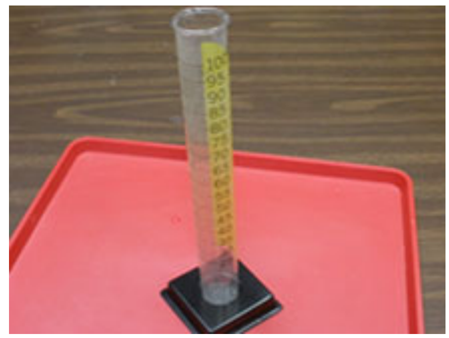
- 1 cup holding at least 40 centimeter cubes
- 1 20oz cup for use as a "waste bucket"
- 2 plastic forks
- 2 pipettes
- 2 3oz cups approximately two-thirds full of bulk gravel
- 2 20oz cups approximately half full of water
- 2 50cc graduated cylinders
- 2 140cc graduated cylinders - student-made measuring cups, from Investigation 3.2
- 2 rocks or minerals that will fit in the cylinders; sandstone or granite works well
- 4 paper towels

### Concept Cartoon

The Volume Concept Cartoon is typically used as a formative assessment at the end of this investigation.

## 1. Ask the question

All Class 10 Mins



Let students know they have come a long way measuring their earth materials.

- They know how to find the weight of materials using a digital scale.
- They know how to find the volume of liquids using their measuring cups.
- They know how to find the volume of objects by observing how much water they displace.

Today they will get more practice finding volumes using the water displacement method, and they will find the volume of some new earth materials: gravel and sand. They will also learn how to use a new instrument — a *graduated cylinder*.

Show the class the 50cc graduated cylinder with 40cc of water in it. Explain that scientists use graduated cylinders to measure liquids and solids, much as the students did when they used their "measuring cups" to measure water samples — and when they used the containers to measure the volume of rocks in the last session. Explain that graduated cylinders come with measuring lines already marked on them. Pass around the cylinder.

> *What is the unit of measurement?*
>
> *How much water is there in the cylinder right now?*

Check students' understanding of the relationship between volume and water displacement.

> *What do you think will happen to the water level if we put 10 centimeter cubes into this graduated cylinder?*
>
> *How **much** will it rise? What marking will the water reach on the graduated cylinder?*

Check students' predictions by dropping 10 cubes into the cylinder.

> *What if we dropped in 15 centimeter cubes? 20? What about a rock with a volume of 30 cubic centimeters? How would that affect the water level?*

Students will likely propose that the water level will rise to a level that equals the sum of the water volume and the material volume. If not, review the principles in the boxed note.

**Four key understandings:**

1. Two objects cannot occupy the same space at the same time.
2. Objects that are submerged in water will displace water (push it out of the way and take its place) and this raises the water level.
3. The more space the submerged object takes up, the higher the water level rises.
4. The amount of water displaced by a submerged object is equal to the volume of the object.

Call attention to the investigation question:

*What happens when we add earth materials to water?*

## 2. Explore volumes in water

Small Groups | 20 Mins | Notebook

Distribute a tray of materials to each group. Point out that the graduated cylinders are the same "measuring cups" that the students made to measure water volumes in an earlier investigation.

Ask students to open their notebooks *[What happens when we add earth materials to water?]* and review the list of materials they will add to water in their graduated cylinders: centimeter cubes, water, rocks, and gravel. Explain that they will investigate one material at a time, and that they will start with a fresh measure of water (40cc) each time they change materials. They can work in pairs.

Before students get to work, remind them to predict how much the water level will rise with the addition of each material. Students can make their predictions in their notebooks, or they can make predictions with their partners. In either case, they should explain their reasoning. Model this kind of conversation with a volunteer:

*What do you predict will happen when we put 10 centimeters cubes in 40 cubic centimeters of water?*

- I predict that when I put 10 centimeter cubes in the water the water level will rise to 50 cubic centimeters.

*Why do you think so?*

- Because the water and the cubes can't be in the same place at the same time, and the cubes will push the water up.

The investigation is straightforward. Students add measured volumes of material to 40cc of water and observe the change in volume in the graduated cylinder. The results for the first three tests are straightforward, too. The combined volume is equal to the sum of the separate volumes.

But the gravel is a different story. When students add 40cc of gravel to 40cc of water, the combined volume is considerably less than the sum of the two.

40cc water + 40cc bulk gravel = approx. 65cc combined volume in the cylinder

As you circulate among the groups, see how students are grappling with this result.

**What's going on with the gravel?** When 40cc of bulk gravel are added to 40cc of water, the resulting volume in the graduated cylinder is considerably less than 80cc. A portion of the volume of granular materials is air in the "empty spaces" between the grains. That air escapes the container when the material is added to water.

## 3. Make meaning

Discussion 15 Mins Notebook

### Purpose of the discussion

The purpose of the discussion is for students to explain displacement in the case of a granular material (e.g., gravel or sand) being added to water in a graduated cylinder. Return to the investigation question:

*What happens when we add earth materials to water?*

Talk Moves

Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage students in the focus question

Ask students about their predictions and results.

> *What did you observe when you added materials to the water in the cylinder?*
>
> *Did any of your observations surprise you?*

Students are typically surprised by what happened when they added the gravel. The combined volume seems to have come up short.

> *Did you all get the same result?*
>
> *What do you think happened? Why doesn't the combined volume equal 80 cubic centimeters?*

Let students brainstorm some ideas. Maybe they measured wrong. Maybe some of the water soaked into the gravel or splashed out of the cylinder. Or maybe the empty spaces between the pieces of gravel have something to do with it.

Remind students what they learned early on about granular materials like sand and soil. They are made up of grains of earth materials surrounded by empty spaces that can fill with air or water. Explain that when a granular material is put in water, the air escapes from the container and the water takes its place. This means that the rise in water level we see in the cylinder represents only the volume of the solid, rocky material not the original volume, which was the gravel plus the spaces.

**40cc sample:**

- Approximately 24cc of the bulk volume of gravel, pebbles, sand is rock and 16 cc are air.
- 16cc of the water settle into the air spaces (displaces the air) leaving the other 24cc above the rock grains.

To consolidate the understanding, and for a formative assessment, ask students to answer the Reflection Questions in their notebooks *[Does 40cc plus 40cc equal 80cc?]*. When they are done, conduct the experiment detailed there and discuss the results. As time permits, discuss the observation that the amount of air in 40cc of sand seems to be equal to the amount of air in gravel.

> *How can that be? Shouldn't there be more air in the gravel? Aren't the spaces between the pieces of gravel much bigger?*

### Summarize the discussion and recap the investigation

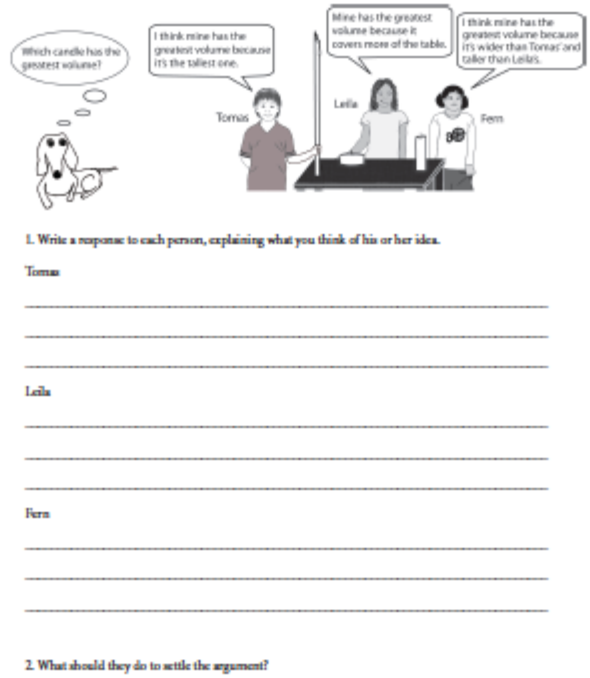
Use the language that the students used to explain what happens to the volume when solid, liquid, and granular materials are added to a liquid material.

Make the following points as you wrap up the investigation.

- When a solid is added to a liquid, the combined volume is the sum of the separate volumes.
- When a liquid is added to a liquid, the combined volume is the sum of the separate volumes.
- When a granular material is added to a liquid, the combined volume is equal to the sum of the separate volumes minus the volume of the air between the grains in the sample.

# Volume Concept Cartoon

This cartoon was developed to probe students' understanding of volume as a 3-dimensional measure of the amount of space an object occupies. At issue is whether students differentiate volume from length (height) or area. Length is very salient to children, so they sometimes focus on that. In everyday language, children often use the same words "takes up space" to describe area (the piece of paper covers most of the space on my desk) and to describe volume (the basketball takes up more space than the golf ball). Unless these two meanings for the same word (space) have been explicitly addressed, students may continue to confuse area and volume.




A second issue is whether they can use their experience measuring the volumes of liquids and irregularly shaped solids (building replicas with centimeter cubes or displacement of water) to come up with a method for comparing the volumes of the three candles in this concept cartoon.

This cartoon is typically used after Investigation 4.3, *What happens when we add earth materials to water?*

## Things to look for in student responses

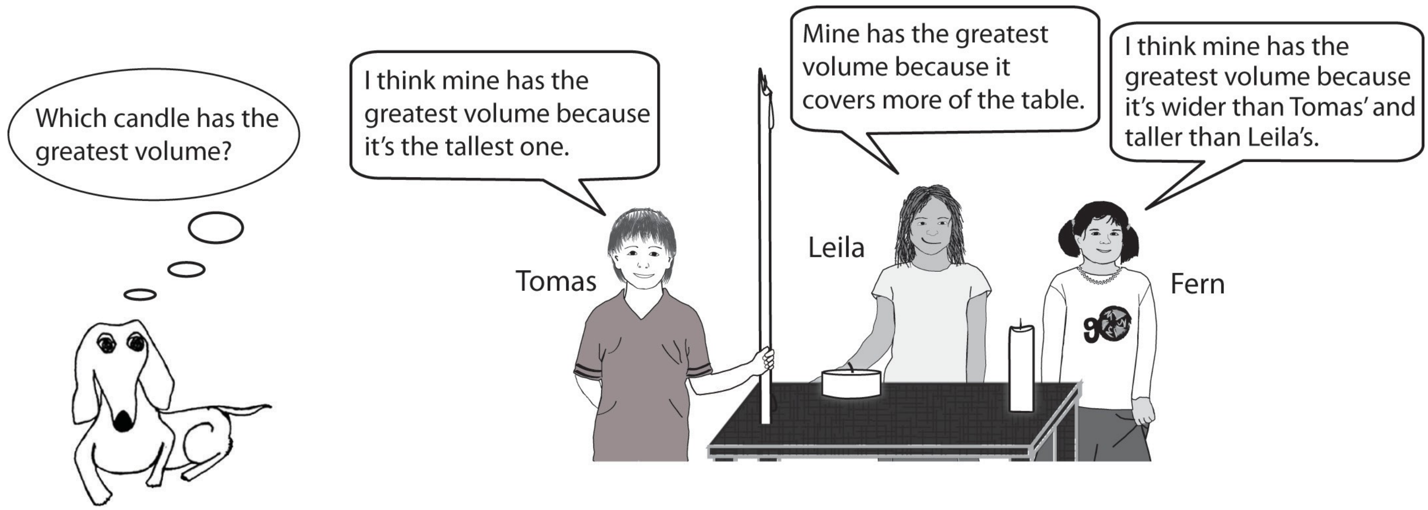
1. How do students use the information in the drawings to think about comparing the volumes of the three candles?

Neither Tomas, Leila, or Fern is reasoning accurately about how to compare the three volumes.

- Some students may confuse volume with length or height and agree with Tomas.
- Others may confuse volume with area and agree with Leila.
- Still others may agree with Fern because she mentions area and height but fails to recognize that Fern would also need to know the areas and heights of all three candles to compare their volumes.

2. From the drawing alone, it is hard to tell which candle occupies the most space so students have to think of what they might do to settle the argument.

- Some students may reason that the candles are all made of the same material (wax) and if you could melt them down and pour the wax from each one into identical containers you could compare the amount of space each one occupies.
- Other students may suggest that they use centimeter cubes to build replicas of each candle, count the number of cubes, and compare them.
- Still others will suggest using a container of water that will accommodate any of the candles, marking the water level, and seeing which candle displaces the most water (makes the water level rise higher).
- Some students imagine each candle as a thin-walled container and imagine comparing the amount of water or number of objects such as centimeter cubes that could be held by each.




1. Write a response to each person explaining what you think of their idea and why you think that.

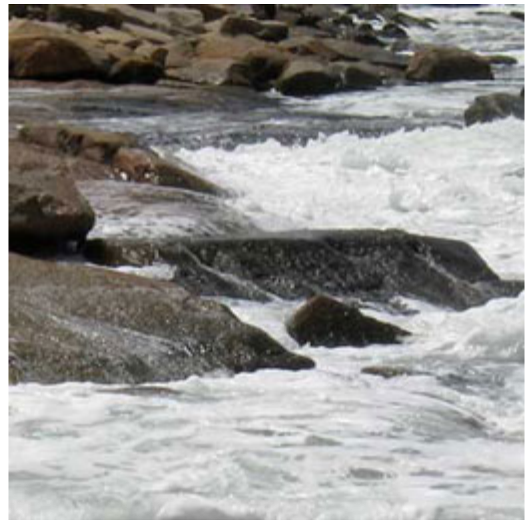
Tomas

Leila

Fern

2. What should they do to settle the argument?

# 5. Transformations



What happens to a pile of shells if we crush them into hundreds of tiny pieces? Does the weight change? What about a ball of clay? If we mold it into the shape of a dragon, does the volume change?

These are not idle questions. In fact, earth materials are changing all the time, subject to such forces as wind, water, gravity, tectonic movements, chemical reactions, and human activity. As they undergo transformations, some things change and others remain the same. In this final set of investigations, students consider the effects of certain physical transformations on weight, volume, color, shape, size, and other properties of earth materials.

As they make their way through the investigations, students continue to distinguish properties of *objects* from properties of *materials*. They also strengthen their developing understanding of conditions under which mass, weight, volume, and other properties are conserved or changed. In the concluding investigation, students return to the question they began with — "What's underfoot?" — to create a new story of a place on Earth's surface.

### Investigations:

- 5.1 What happens to shells when we crush them?
- 5.2 What happens to weight and volume when we reshape a ball of plastic modeling clay?
- 5.3 What's under my feet?

### The Child and the Scientist

**The Child:**
The Challenges of Learning about Transformations

**The Scientist:**
What's important about transformations?

### Concept Cartoon

The Additive Property Concept Cartoon is typically used after Investigation 5.1 *What happens to shells when we crush them?*.

# The Challenges of Learning about Transformations

> *in science, some of the most important things about these transformations are what doesn't change*

Our perceptual systems are designed to attend to change in our environment. Even infants grow bored when they repeatedly encounter the same thing—the same toy, the same tone, the same smell, the same color, the same food—and often turn away or "tune out" seeing, hearing, or smelling the familiar thing entirely. They also show renewed interest and attention when they encounter something new. Attending to what changes *is* important. It signals something new has come into our perceptual field that needs to be checked out to understand what it is and whether it is a potential boon or threat,Äîa new person, a new food, a new animal, an unexpected car or other moving object in our path of movement.

Thus, it is not surprising that children find the topic of investigating transformations of materials particularly engrossing and interesting. Children enjoy *doing* things, and find permission to pound, mold, break, rip, burn or otherwise "take apart" and play with materials both novel and liberating. Further, the changes that occur as they watch what happens when they crush or grind up things, carve, mold or reshape things, heat or cool things, and combine or mix things can be dramatic and surprising, especially when reactions occur, things change color or texture, or disappear entirely from view.

Children will naturally first pay attention to the changes they observe in those transformations. For example, grinding up a piece of hard wood produces something that has a totally different appearance—soft, light, and powdery. But in science, some of the most important things about these transformations are *what doesn't change*. For example, when materials are crushed into little pieces, the total volume and weight of all those pieces remains the same, as does the kind of material of which each piece is made. These constancies provide clues to some of the most fundamental physical principles (e.g., conservation of mass and matter) that will ultimately be useful in tracing matter across transformations until it appears to "disappear" entirely.

Challenges in teaching children about transformations include not only getting them to attend to what doesn't change, but also helping them understand why attending to these constancies is particularly important for science. Children will find these constancies more interesting and attention-worthy if they are asked to make predictions ahead of time about whether the volume or weight will change and then are asked to figure out ways to test or evaluate their predictions. Most children expect that the volume changes with reshaping or that things get lighter when they are ground up into little pieces, and are surprised to learn that they don't. But because these underlying constancies are not obvious based on casual inspection, it also take careful measurements and discussion of measurement error for children to notice them at all, along with discussion about how these constancies can be explained for children to be convinced that they really occur.

—Carol L. Smith

The Scientist's Essay for *5. Transformations*

# What's important about transformations?

> *Change is so ubiquitious, in fact, that when we find something that doesn't change, there's a strong suspicion that it's telling us something important.*

The clich√© that change is the only constant is as true in the physical world as it is in human affairs. Change is so ubiquitious, in fact, that when we find something that *doesn't* change, there's a strong suspicion that it's telling us something important. Biologists look for aspects of life that are the same across species or that persist over millions of years of evolution. Anthropologists look for aspects of human society that are the same across disparate cultures and over hundreds or thousands of years. And physicists pay particular attention to quantities that remain constant even as a system undergoes (sometimes radical) transformations. These "invariants" or "conserved quantities" often carry deep implications for understanding, even if we're not always clever enough to figure them out right away. They also serve as valuable tools for predicting some aspects of a system's behavior even when the details are too complicated to figure out.

One of the reasons for looking at what happens when materials are cut, crushed, ground, or molded into different shapes is to focus attention on what *doesn't* change. Among the things that don't change under these sorts of transformations are the total weight and total volume of the material. But other things remain the same, too — is it still "the same stuff"? How can you tell?

Another goal of these transformations, though, is to provoke the imagination. Any real experiment eventually runs into practical limits — you just can't go any smaller, or any hotter, or any thinner, or whatever. But it's often instructive to ask: What if you could keep going? Would there eventually be a "smallest piece" that you couldn't divide any more? If so, would it still be "the same stuff"? How would you know? If not — if there's no limit to how small you can go — what would that imply about the nature of matter?

—Roger Tobin

# *What happens to shells when we crush them?*

## Plan Investigation 5.1

Broken rocks … weathered cliffs … eroded riverbanks … dynamited roadbeds. Earth materials can change — that's obvious; indeed, children can observe such changes with their own eyes. What is less obvious is that despite all these physical changes there remains a finite and constant amount of matter on Earth — and in the Universe.

In this investigation students are introduced to the idea of conservation of matter through a classroom activity that mimics the long-term effects of weathering. After recording information about a handful of shells, including their weight and volume, students crush the shells underfoot. As they examine the crushed pieces, students record what has changed and what has remained the same.

By the end of the investigation students will see that while the size and shape of the shell pieces have changed, the weight and volume remain the same. They consider whether this is likely to be true for transformations of other earth materials.

**Formative Assessment**

*Can students use data to support a claim about what changes and what stays the same when you crush some shells and provide a possible explanation?*

Available online at inquiryproject.terc.edu

### Learning Goals

- Understand that when earth materials are transformed, some properties remain the same while other properties change
- Consider whether weathering causes earth materials to disappear

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 5 Mins |
| 2. Predict what will happen | Small Groups | 15 Mins |
| 3. Collect data and check predictions | Pairs | 15 Mins |
| 4. Make Meaning | Discussion | 10 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.

For each tray:

- 2 sandwich bags, each filled with approximately 50 grams of shells
- 4 additional sandwich bags
- 2 20oz cups approximately half full of water
- 1 3oz cup of water
- 1 fine-tip permanent marker
- 1 digital scale
- 1 pipette
- 4 paper towels

### Concept Cartoon

The Additive Property Concept Cartoon is typically used as a formative assessment at the end of this investigation.

## 1. Ask the question

All Class 5 Mins

Let students know they are nearing the end of their work with earth materials. In this last part of their study, they will investigate what happens when natural forces change earth materials.

Have students close their eyes for a moment and then call up a couple of different scenarios.

> *Imagine you are standing on top of a mountain, and you can stand there for millions of years. The wind blows, the rain comes down, water freezes and thaws. Gradually the mountain wears away. Where does it go? How much is left? Does it actually disappear?*
>
> *Imagine you are the ocean, pounding against the cliffs in some faraway place. You are a wild ocean, and you pound away for thousands of years. What happens to the rocks? To the sand? To the soil? Where does it go? How much is left? Does it actually disappear?*

Listen to the answers, and remind students that they learned a word for this kind of "wearing away" of earth materials earlier in the unit. The process is called *weathering* and it takes a very, very long time. As earth materials weather, they break into smaller and smaller pieces — like the tiny bits of mica and quartz students saw in their rocks a couple of weeks back. Now pose a new scenario.

> *Imagine you have a bag full of shells and you smash them all to bits, like a giant wave or a big wind, but working much faster. What happens to the shells? What changes? What remains the same?*
>
> *Does the weight change? Does the volume? What about the material itself?*

Point out the investigation question:

*What happens to shells when we crush them?*

Let students know they are about to find out for themselves.

## 2. Predict what will happen

Small Groups 15 Mins Notebook


Distribute a tray of materials to each group, and then hold up a bag of shells.

> *Think about this bag of shells as they are right now, before they are crushed. If we keep them in this bag and crush them by stepping on them, what do you predict will change and what will stay the same?*

Give students a few minutes to record their predictions in their science notebooks *[What changes and what stays the same when we crush shells?]*. Make sure students explain the reasoning behind each prediction: *Why* do they think what they think?

After the students have finished recording their predictions, ask them to share their ideas in their small groups. What properties of the shells are they thinking about? Many students will think of color, size, and shape. Others may mention weight and volume. Some may think of smell, texture, or luster.

As you circulate among the groups, take note of what students predict will change and what they predict will stay the same.

> *How can you check your predictions? What kind of data would you need to collect?*

Bring the ideas together in a list of the students' predictions. Make sure weight and volume are on the list, and that each prediction has a corresponding idea for how to test it, as in the chart below.

| Some likely student predictions | How to check predictions |
|---|---|
| The weight will [or will not] change. | Weigh shells before and after crushing. |
| The sizes of the pieces will change. | Trace one shell before crushing the bag of shells. |
| The volume of the shells themselves will [or will not] change. | Measure shell volume before and after crushing. |
| The color will [or will not] change. | Save a sample of uncrushed shell for comparison. |

Tell students you'd like each team of students to check the weight and volume of the shells, along with two additional properties, then set them to work.

## 3. Collect data and check predictions

Pairs 15 Mins Notebook

Students engage in a three-step investigation. First they collect data on the unbroken shells, then they crush them, then they collect data on the crushed shells to check their predictions. They record data in their notebooks as they go along *[Crushing shells claims]*.

All students will collect data on weight and volume, using the digital scale and the water displacement technique they learned earlier in the unit. Let them know they should collect this weight and volume data first. As time allows, students can collect data to check their predictions about other properties they have chosen to investigate, such as color, size, shape, or smell.

There may not be enough time for every group to gather data to check every prediction. Let students know they should work carefully and not hurry; the class will share their results at the end.

As you circulate among the groups, make sure students collect all the data they need before they crush the shells. Students will need to triple-bag the shells before crushing them, and while they should weigh the shells in the bags, they will need to take them out to collect the volume data (see accompanying note).

**A Likely Sequence of Investigation:**

1. Weigh the shells, along with the three sandwich bags, and record the initial weight.
2. Check characteristics such as initial size, color, shape, etc., and record the results.
3. Check volume using the water displacement method and record the results.
4. Dry the shells with the paper towels.
5. Triple-bag and crush the shells by stepping carefully but forcefully on the bag several times. Some shells may not crush easily. These may remain uncrushed in the bag.
6. Weigh the crushed shells in their triple bags and record the results.
7. Check characteristics such as size of pieces, color, shape, etc. and record the results.

### Share class data

Ask students to share their predictions and findings with the class, beginning with the weight and volume findings. As you record the results in a class list, make sure students specify the evidence that verifies or refutes their predictions.

**What happened to weight and volume when we crushed some shells?**

| Group | Weight | Volume |
|---|---|---|
| 1 | Stayed the same | Stayed the same |
| | | |
| | | |
| | | |

## 4. Make meaning

Discussion 10 Mins Notebook

### Purpose of the discussion

The purpose of this discussion is to construct an explanation of what happens to the volume and weight of shells when they are transformed through crushing. The students' explanation should be consistent with their observations and evidence . They also connect their shell crushing experience with the phenomena of weathering. Return to the investigation question for discussion.

Talk Moves

Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

### Engage students in the focus questions

Students go out on a limb when they make a prediction and they are usually interested in the outcome of their data collection. When their predictions are not supported by data, some are willing to rethink their ideas based on these findings while others are reluctant to let go of their original ideas. Ask students to compare their predictions and the class data (refer to the group data table).

*What happened to the shells when you crushed them?*

> *When you look back at your predictions, do any of these findings surprise you? Why?*

Help students find relevance in today's investigation.

> *How would you connect today's findings to weathering in the natural world?*

Listen for ideas about how shells are weathered by tides pushing them along on the shore, rolling them against each other, breaking off pieces here and there, and distributing the smaller pieces on the beach or in the waves. *The shell weathers but it doesn't go away*; the smaller pieces just become more spread out across the beach and ocean floor.

Point out that the plastic bags represent Earth. As shells and rocks and soils weather, the pieces get smaller and smaller but they are still on Earth — just as the shells remained in the bag after the students crushed them. The Earth does not lose any material when a shell is turned into dust; the material is transformed into something different, but no material is lost from Earth. The earth materials you see today will be here forever in some form or another.

Provide time for students to make claims in their notebooks *[Crushing shells claims]*.

> **Weight and volume stay the same:** Unless some pieces of shell are lost in handling, crushing the shells will not result in a change of weight or shell volume. The bulk volume of the shells, on the other hand, is likely to become smaller. Although students will not measure bulk volume, you may wish to remind them of the concept and ask what they think has happened to bulk volume.

### Summarize the discussion and recap the investigation

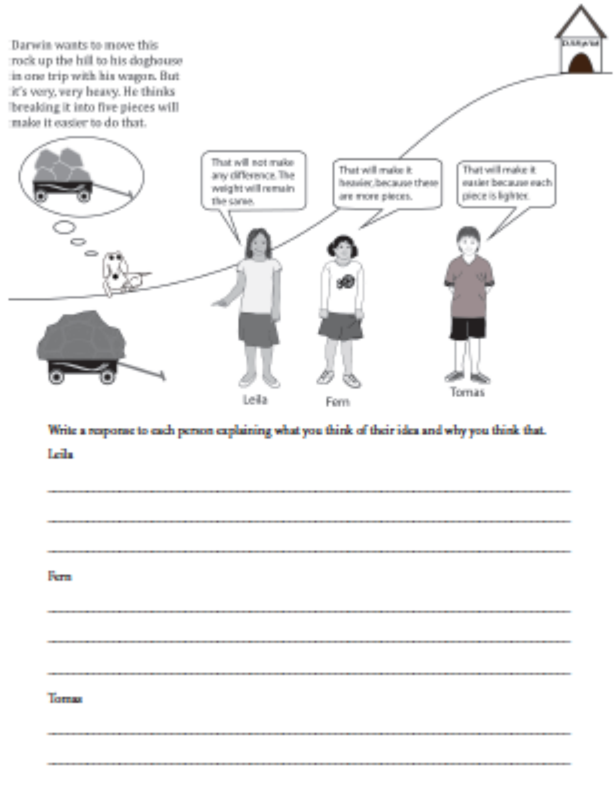
Summarize the discussion by having several students share (from their notebook) their claims, evidence, and explanations for what happens to shells when we crush them.

As you wrap up today's investigation, check for a beginning understanding of the following points:

- When an object is transformed, some things stay the same and other things change.
- When earth materials become weathered, they do not disappear; they keep their weight and volume but get spread out over a greater area.
- Earth is made up of a finite and constant amount of material.

# Additive Property Concept Cartoon

This cartoon was developed to assess students' ability to:




- Reason about the weight of different sized pieces of the same material (rock)
- Understand the additive property — that the weights of all the pieces of an object are equal to the weight of an object

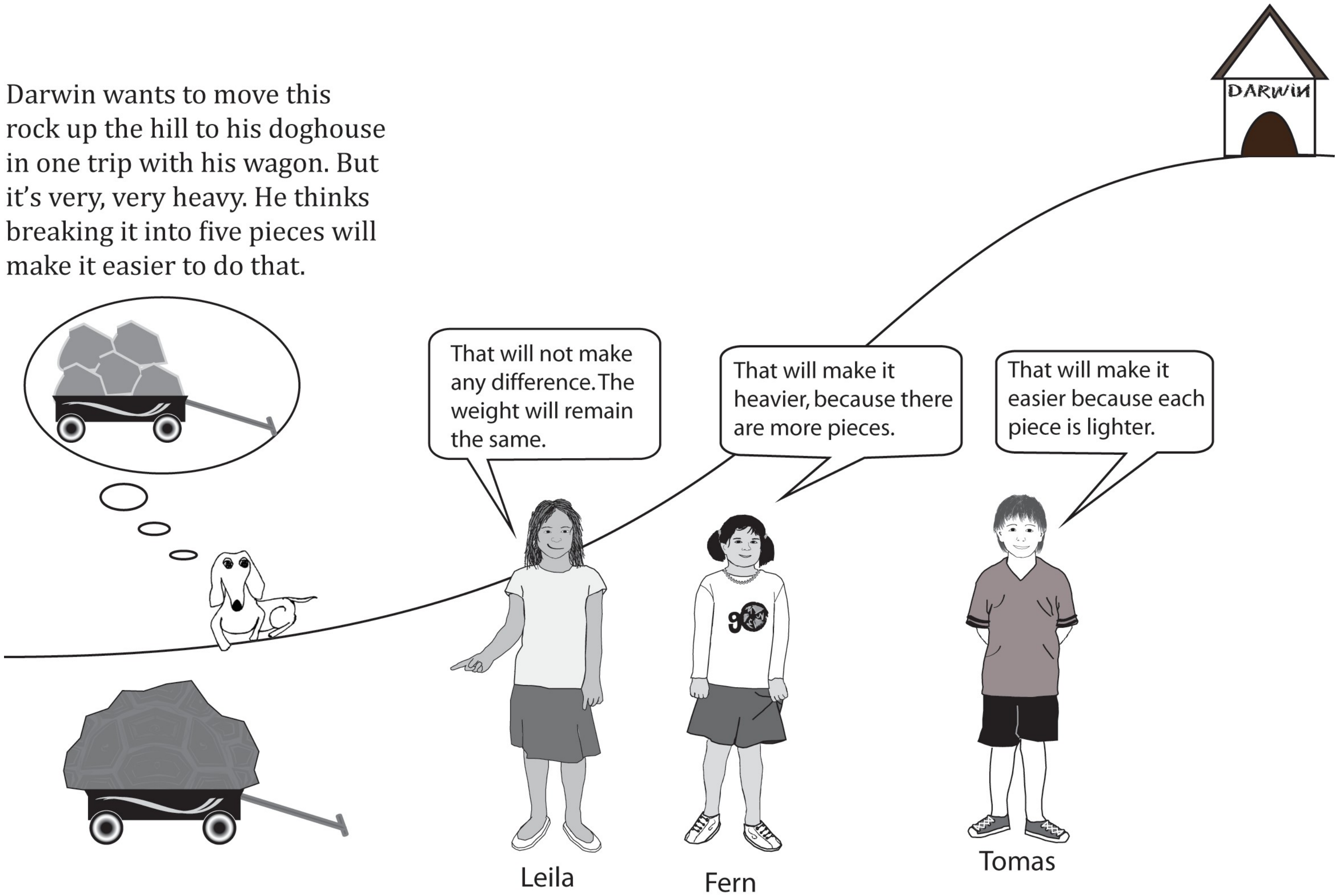
This cartoon is typically used after Investigation 5.1, *What happens to shells when we crush them?*

## Things to look for in student responses

Do students realize that the weight of all the broken pieces together equals the weight of the unbroken rock that needs to be moved up the hill?

- Some students may agree with Leila that the weight will stay the same. For these students, look to see if they can also supply a deeper reason: for example, "because no more rock material has been added and none has been taken away." or "the weight of the five parts equals the weight of the whole", showing they can think of both the whole and the parts at the same time.
- Others may agree with Fern failing to recognize that although there are more pieces, the amount of matter hasn't changed. These students may simply reason "more pieces is more" (a kind of undifferentiated more is more response.)
- Still others, may agree with Tomas thinking erroneously that because each piece is lighter, the load will be less heavy, when, in fact, there is the same amount of matter to be moved as there was before. These children reveal that in focusing on the parts, they have lost track of the whole.

Darwin wants to move this rock up the hill to his doghouse in one trip with his wagon. But it's very, very heavy. He thinks breaking it into five pieces will make it easier to do that.




Write a response to each person explaining what you think of their idea and why you think that.

Leila

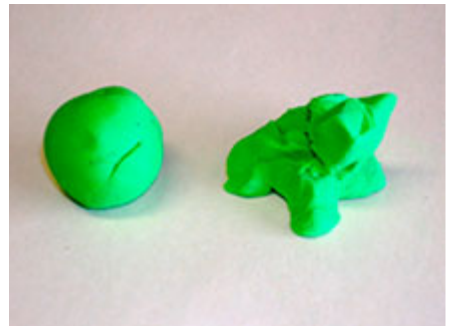
Fern

Tomas

***What happens to weight and volume when we reshape a ball of clay?***

## Plan Investigation 5.2

What if we take a ball of plastic modeling clay and mold it into the shape of an elephant? Does the weight stay the same? Does the volume?



In this investigation, a companion piece for the previous one, students continue to explore what happens when earth materials are transformed. Instead of crushing shells, students this time manipulate a ball of plastic modeling clay, which serves as a stand-in for clay, a malleable earth material. Students record the weight and volume of a ball of plastic modeling clay, form it into a new shape of their own choosing, and then measure weight and volume again.

By the end of this investigation students will understand that plastic modeling clay or clay retains its weight and volume no matter what shape it assumes.

**Formative Assessment**

*Do students understand that a ball of plastic modeling clay will weigh the same and displace the same volume of water no matter how it is reshaped?*

Available online at inquiryproject.terc.edu

### Learning Goals

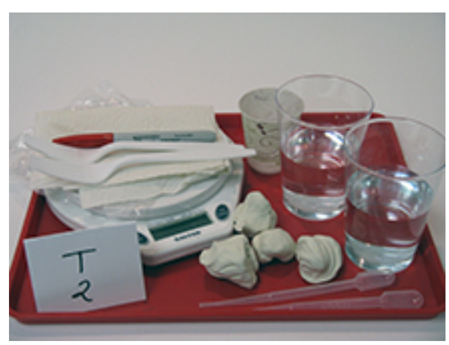
- Discover what happens to weight and volume when clay changes shape

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 5 Mins |
| 2. Explore weight and volume | Pairs | 25 Mins |
| 3. Make meaning | Discussion | 15 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- 1 tray of materials, as below, for class discussion




For each tray:

- 1 fine-tip permanent marker
- 1 digital scale
- 1 3oz cup of water
- 2 20oz cups approximately half full of water
- 2 forks
- 2 pipettes
- 4 balls of plastic modeling clay, approximately 30g each
- 4 paper towels

## 1. Ask the question

All Class 5 Mins

Recall the last investigation, when students crushed a handful of shells in a bag.

*What did we discover about the weight of the crushed shells?*

- It was the same as the weight of the whole shells.

*What about the volume?*

- It was also the same.

Now pass around the four balls of plastic modeling clay.

*What do you know about this material? What are some of its properties? How is it different from shell?*

- soft vs. hard, squishy vs. breakable, man-made vs. natural, different colors, etc.

Plastic modeling clay is a lot like clay, a natural earth material. Unlike shell, which is brittle, plastic modeling clay and clay are malleable; they can be reshaped without snapping into tiny pieces.

> **Brittle vs. malleable:** The terms *brittle* and *malleable* may be new to some students. While they may be familiar with materials that are brittle (glass, pottery, chalk) or malleable (clay, plastic modeling clay), they may not be aware that these are *properties* of the material.

*But what happens when we change the shape of the plastic modeling clay? If we squish the ball really tight, does it get heavier? If we roll it out really thin, does it have more volume — or less?*

*If one of you makes a dog out of the plastic modeling clay and another makes a snake, which will weigh more? Which will have more volume?*

*What if you break the ball into 25 little pieces? Will there be more volume or less? What about the weight?*

Listen to all the suggestions, and let students argue if they have different ideas, but make no judgments. Instead, introduce the investigation question:

*What happens to weight and volume when we reshape of a ball of clay?*

Explain that this investigation is much like the last one. Students will each take a ball of plastic modeling clay, measure its weight and volume, change its shape, and measure again. But instead of crushing the material, as they did with the shells, they can change it into any shape they please.

## 2. Explore weight and volume

Pairs 25 Mins Notebook

Distribute a tray of materials to each group. Ask volunteers to outline the steps to answer the investigation question. What data will they need to collect before and after changing the shape? What methods will they use? Write the steps on the board as students offer them, and then refine the sequence as necessary. In particular, explain the following two rules:

1. Students must use all of the original material in the transformed shape; otherwise it is not a fair test.
2. In order to check volume, students must be able to fit their new shape into the big cup and submerge it completely in the water; if they need to curl their shape to do this, that's OK.

Give students a few minutes to record their predictions in their science notebooks *[What happens to weight and volume when we reshape a ball of clay?]*, and then have them each transform a ball of plastic modeling clay into a shape — or a collection of shapes — of their own choosing.

Have students work through the procedure in pairs, everyone recording their own data in their notebooks as they go along. Students may try as many shapes as time allows.

As you circulate among the groups, ask students what they are thinking about how shape affects volume. If they are already certain that their new shape will not change the weight and volume of the plastic modeling clay, challenge them to try to find a shape that will.

**A Likely Sequence of Investigation:**

1. Weigh the plastic modeling clay and record the weight in the notebook.
2. Mark the starting water level in the big cup.
3. Carefully lower the plastic modeling clay into the cup to determine how much water is displaced.
4. Mark the new water level and record the information in your notebook.
5. Remove the plastic modeling clay, dry it with a paper towel, and change its shape.
6. Repeat the process with the new shape.

After students finish collecting and recording their data, have them record their claims in their notebooks and then share them within their small groups.

## 3. Make meaning

Discussion 15 Mins

### Purpose of the discussion

The purpose of the discussion is to construct an evidence-based explanation of what happens to weight and volume when a ball of clay is reshaped. Focus the discussion on the investigation question.

Talk Moves

Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

**What about conflicting claims?** Students should find that the weight and volume remain constant no matter what shape they make with the plastic modeling clay. If a conflicting claim arises in class, i.e., if someone claims that the weight or volume of their plastic modeling clay has indeed changed, lead a discussion of what might account for the finding. Could some of the plastic modeling clay have been lost in the transformation? Could there be a measurement error? Could the counterclaim in fact be correct? The student may wish to repeat the experiment with a new ball of plastic modeling clay to resolve the dispute. In any case, let students know that scientists sometimes do get different results from the same investigation. It's by sharing data that they resolve these differences.

### Engage students in the focus question

To engage students, have the investigation materials available and recalling the investigation question. Provide a minute for students to discuss the claim they would make and the evidence that supports it.

*What happens to weight and volume when we reshape a ball of plastic modeling clay?*

> *What claims can you make? What is your evidence?*
>
> *Does this make sense to you? Why do you think the weight and volume stay the same when you change the shape?*

Listen for the argument that weight and volume do not change because no material has been added or removed; the material has just been rearranged. If someone says that the new shape "looks" bigger or smaller, acknowledge that this may be so, ask the student to describe what the data say, and revisit the idea that we can't always rely on our senses for measuring weight or volume.

Make a connection to the students' everyday life.

> *Can you think of an example of crushing something and having the volume change? How would you explain this?*
>
> - The volume of the space inside an empty soda can will change when the can is crushed, but the volume and weight of the aluminum will remain the same.
> - The bulk volume of a box of cornflakes will change if the contents settle. As with the soda can, it's the volume of air that is reduced; the weight and volume of the cornflakes themselves remains the same.

**Sometimes Volume Seems to Change:** Solids and liquids are virtually incompressible. Squeezing them will not change their volumes or weights. Gases are a different story. Gases are compressible because their molecules are much more spread apart than those of solids or liquids, but this is not a topic you need to raise with students at this point.

### Summarize the discussion

Use the same language that the students used to explain that weight and volume do not change because no material has been added or removed, only rearranged.

As you recap the investigation, check for understanding that when the shape of a malleable object changes, its weight and volume stay the same.

# *What's under my feet?*

## Plan Investigation 5.3

The students have spent several weeks looking closely at small samples of earth materials and carefully measuring weights and volumes. It's time for them step back out into the natural world — at least in their imaginations.

Students imagine standing in a place somewhere on Earth's surface. They identify two earth materials that might be under their feet and use their experiences in this curriculum to think about their properties including "heavy for size" and imagine possible transformations that might have occurred.

By the end of the investigation students will have made connections between their classroom work with earth materials and what's actually underfoot when they stand in different places on Earth's surface.

### Learning Goals

- Think about earth materials in the real world

| Sequence of experiences | | |
|---|---|---|
| 1. Ask the question | All Class | 5 Mins |
| 2. Prepare to discuss | All Class | 20 Mins |
| 3. Where are we now??? | Discussion | 20 Mins |

### Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Post the class chart of earth materials that was created in the first class.
- 1 set of earth materials: pebbles, gravel, sand, clay, organic soil, shells, water, mineral oil, rocks, and minerals (for the demonstration)

## 1. Ask the question

All Class | 5 Mins

Start by reminding the class where they began the unit. Remember how, in the first class, we closed our eyes and imagined standing barefoot someplace on Earth's surface? Someplace that wasn't covered by a carpet or a floor or a parking lot or a sidewalk?

- We're going to do that again today only we'll be discussing a new set of questions.

Draw attention to the investigation question:

*What's under my feet?*

## 2. Prepare to discuss

All Class | 20 Mins | Notebook

Ask students to think of a place where they could stand in their bare feet on Earth's natural surface and to name two earth materials that might be under their feet.

Provide time for them to think of a place and the earth materials.

Direct them to the last notebook page where they will find a few questions that will be the focus of their wrap-up discussion. *[What's under my feet?]*.

Provide time for them to draw their place and to jot down responses to the questions. After they have had time for notebook writing, ask students to turn and talk to a neighbor about their place and their ideas.

> **Location, Location, Location:** Just as Earth's surface has a great variety of conditions, the earth materials under our feet will vary with location. In fact, no two shovelfuls of soil will ever be identical — even if both are sand from adjacent locations. While it's possible that a soil sample would include the full variety of mineral sizes (pebbles, gravel, sand, silt, and clay), as well as some organic matter, these materials would not occur in exactly the same proportions.

## 3. What are our ideas now?

Discussion | 20 Mins

### Purpose of the discussion

The purpose of the discussion is to consolidate learning from across the unit and for students to connect their learning to a self-selected location. This is also an opportunity to elicit students' ideas about the concepts central to this study (e.g., properties of earth materials, heavy for size, volume, weight, transformations.) Focus the discussion on the following questions:

*What are two earth materials under your feet? How might they have been transformed?*


Use this checklist to plan and reflect.

Available online at inquiryproject.terc.edu

## Engage students in discussion

Students will have started the conversation with a partner already. Now they will broaden the conversation with all of their classmates.

In order to make this a real discussion rather than a "report out," encourage students to build on each others' comments by, for example, adding on, comparing and contrasting, asking questions, challenging respectfully.

**1) Begin with a discussion of properties of earth materials.**

*What place did you select? What are two earth materials that might be under your feet?*

Supporting questions:

> *Did anyone else select a (beach, playground, field, etc.)?*
>
> *People who chose a beach, did you pick the same earth materials or different ones?*
>
> *What about a different place? How do you think the weights of two same-sized samples would compare? Are there other ideas about volumes and weights?*

**2) Consider possible transformations that might have taken place.**

*How do you think the materials under your feet might have been transformed?*

Supporting question:

> *What are your ideas about weight and volume in this transformation process?*

## Summarize the discussion

Summarize some of the ideas you heard, pointing out evidence that students' ideas about earth materials have broadened and matured over the course of this science unit.

Learning always ends with new questions. End with an opportunity to raise questions.

> *What other things would you like to know about earth materials? How could you find out about them?*

# Science Background

## What is a mineral?

You've met seven minerals that we frequently find in rocks, including feldspar, mica, and quartz, the most common mineral on Earth. There are thousands of other minerals on Earth, including gems like diamonds and emeralds, and metals like gold and copper. People have found thousands of different ways to make use of Earth's minerals. We use talc in baby powder. We season our food with halite (salt). The clay mineral kaolinite is used in pottery, but you might also find kaolinite in the ingredients list for ice cream — it's used to keep ice cream from melting quickly.

**What makes a mineral a mineral?**
All of the substances that we call minerals occur in nature. You can see feldspar, mica and quartz in granite rocks. If a substance is manmade, like plastic or steel, it's not a mineral. To be classified as a mineral, a substance must be a solid. That rules out water (a liquid) but ice (the same stuff in solid form) is a mineral. When a mineral crystallizes, its particles come together in a 3-dimensional pattern that's repeated in all directions, known as a crystal structure. The shape of the crystals may be intricate, like a snowflake, or may be as simple as a cube.


**Mineral crystals**
Mineral crystals form in several different ways. Water crystallizes when it freezes. Hot liquid magma crystallizes when it cools. Minerals crystallize in granite when magma cools slowly, deep underground. Salt minerals, on the other hand, form when salty water evaporates, leaving behind deposits of rock salt. Sometimes, when rock particles are heated they rearrange themselves to form a new crystal structure and become new minerals, with new properties.

**Properties of minerals**
The properties of minerals, such as hardness, color and heaviness for size, give us clues about their composition and their crystal structure and help us identify them. Diamonds are the hardest minerals by far and you cannot scratch them with other minerals. When you break off a piece of halite you may find squared-off corners, reflecting the repeating cubes of its crystal structure. Mica crystals, on the other hand, form in sheets, and you'll find that it breaks along flat surfaces. You can tell hematite apart from other dark colored minerals because it is heavy for its size and magnetic.

## Weathering

When you look at sand, you may see tiny pieces of quartz in the sand that match large pieces of quartz rocks nearby, and you may see tiny pieces of shiny mica that match larger piece of mica. Small pieces of rocks and minerals are always wearing off and breaking off larger pieces, and those small pieces themselves wear down and break into smaller pieces.

photo link on US Geologic Survey

What causes this to happen? Rivers and oceans roll rocks and minerals across one another thousands or millions of times, and wind and storms and other natural forces on earth keep moving and grinding earth materials into smaller and smaller pieces.

When rainwater gets into rocks and then freezes, it expands and can cause pieces of rock to break off. Plant roots may also expand in cracks and cause pieces of rock to break off. When acid rain falls on limestone or chalk, over a long period of time, the material breaks down. The name used to describe this wearing down of Earth materials on the Earth's surface is weathering, although weather is just one of the forces that makes things break down into smaller pieces.

Earth materials that have been loosened by weathering may move, carried by air, water or ice, or carried downhill by gravity. The name used to describe this movement is erosion.

# Rock Reference

**Sandstone**

**Basalt**

**Conglomerate**

**Granite**

# Mineral Reference

**Biotite**

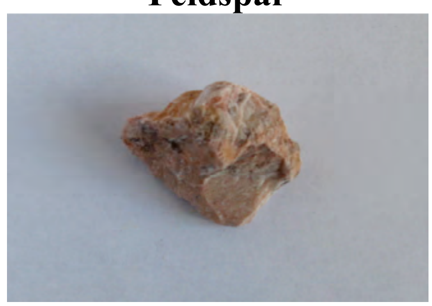
**Quartz**

**Mica**

**Hematite**

**Talc**

**Feldspar**



**Graphite**

**Halite**

# Curriculum Kit

## How to Obtain a Kit

Information on how to obtain a materials kit is available on the Inquiry Project website (inquiryproject.terc.edu) in the Grade 4 Curriculum.

## Curriculum Kit Materials

Materials are listed for a classoom of 24 students split into 6 groups of 4. Your classroom may require modifications of this list.

### Earth Materials

**Rocks**

- 6 sandstone
- 6 conglomerate
- 6 basalt
- 6 granite

**Minerals**

- 6 quartz
- 6 graphite
- 6 mica
- 6 biotite
- 6 feldspar
- 6 halite
- 6 hematite
- 6 talc

**Other Earth Materials**

- 1 liter pebbles
- 1 liter gravel
- 1 liter sand
- 1 liter top soil/organic material
- .5 liter clay
- .5 liter mineral oil
- 600g shells

**Density Cubes**

- 6 aluminum cubes (1” x 1” x 1”)
- 6 copper cubes (1” x 1” x 1”)

### Containers

- 125 clear plastic cylindrical containers with cover (capacity = 150ml)
- 6 clear plastic rectangular containers (12cm x 12cm x 5cm)
- 6 280ml clear plastic rectangular containers (7.5 cm x 11cm x 5.5cm)
- 24 clear plastic boxes (fits 20 plastic cc cubes)
- 14 50cc graduated cylinder
- 1 100cc graduated cylinder

### Other

- 1 TERC measure line
- 1 roll paper adding machine tape
- 1 blue food coloring
- 1 plastic eraser
- 1 pitcher (2-3qt)
- 1 strainer
- 1 roll heavy duty aluminum foil (25')
- 6 digital scales
- 8 trays
- 2lbs plastic modeling clay
- 12 plastic pipettes
- 12 Rock/Mineral Reference Sheets
- 25 plastic magnifiers
- 30 heavy duty plastic forks
- 30 heavy duty plastic spoons
- 30 20oz or larger, clear plastic cups
- 60 3oz cups
- 60 heavy duty white dinner plates - plastic
- 50 fold-top plastic sandwich bags
- 500 cubes (1cm x 1cm x 1cm)

### Classroom Supplies:

- paper towels
- clear plastic tape
- masking tape
- 6-8 black fine tip permanent markers
- index cards

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## Refill/Replacement Kit

### Earth Materials

- 1 liter pebbles
- 1 liter gravel
- 1 liter sand
- 1 liter top soil/organic material
- .5 liter clay
- .5 liter mineral oil
- 600g shells

### Other Materials

- 2lbs plastic modeling clay
- 50 fold-top plastic sandwich bags
- 24 heavy duty white dinner plates - plastic
- 1 roll paper adding machine tape