Think Like A Scientist

Exploring Matter in Space!

NSTA eBooks+ Kids

TEACHER'S GUIDE

Overview

This teacher's guide supports teachers using the *Exploring Matter in Space!* e-book in their classrooms. It lays out learning goals for each chapter, shares student misconceptions and how to address them, and highlights where students explicitly practice science and use crosscutting concepts to support their learning. It also provides end-of-chapter investigations that connect readings and interactives in the e-book with students' world.

The goals of this teacher's guide are as follows:

- engage students in grade-level appropriate, three-dimensional learning;
- use the e-book as a tool in class-wide, small group, or independent explorations of its content;
- provide additional ideas and activities that utilize the e-book content but are not included in the e-book;
- explore how STEM content can be effectively integrated into literacy (English language arts);
- facilitate investigations that utilize the e-book content and connect it with students' own classroom and community; and
- assess students on the second-grade content standards to which this e-book is aligned and additional *Common Core State Standards*, in English language arts and mathematics suggested throughout the e-book.

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The Phenomenon and the Driving Question

A phenomenon is an observable event in which science can be used to explain or predict the event. In engineering, a solution is designed in order to solve a problem related to the phenomenon.

The phenomenon for this e-book is: Matter is made of particles that are too small to see, but these particles are still detectable.

A driving question is one that drives the teaching and learning for a given unit, or even an entire school year. It provides context for the purpose of student exploration and understanding of a phenomenon.

The driving questions for this book are:

1. ***What is matter made of?***
2. ***How does the small-scale structure of matter explain the everyday properties of everyday objects?***

Page 8

This page is again about asking questions, making observations, and constructing explanations. Peter models the process of asking questions then describes some observations (observations that your students can make themselves in the end-of-chapter investigation). Students should observe patterns in the salt structure. The final question—What does this tell me about what salt is made of?—asks students to construct an explanation for their observations.

Discourse

There are some subtle issues here so it can be helpful to scaffold the explanation construction process with some leading questions.

Begin by asking your students to recall the purpose of this experiment. The broad goal was to help understand what salt is made of, but this experiment won't be able to give a full answer to such a big question. Instead, the experiment is designed to answer a small question that is nestled inside that big question: Is salt made of a combination of different kinds of things, or is it a combination of all the same kinds of things?

This sets up a dichotomy with two competing hypotheses. Ask your students to identify the two hypotheses:

- Salt is made of a combination of different kinds of things.
- Salt is made of a combination of all the same kinds of things.

End-of-Chapter Investigation: Structure and Function

Before Lesson

The following investigation into wall-building may help students to understand how small-scale structure can affect large-scale function. This investigation can be done in groups or individually.

Materials:

- 50 blocks per group (in two piles of 25)

Larger blocks tend to feel nicer than smaller blocks and be easier to work with, but any size will do. Note that for this activity to be useful, the blocks must have smooth sides. If they don't (as with Legos), students won't be able to explore the full range of construction possibilities and discover the value of density, order, and interconnectedness.

During Lesson

Challenge each group (or individual) to construct two, flat, 5 × 5 walls (five blocks wide and five blocks tall). One wall should be as sturdy as possible. The other wall should be as weak as possible.

Give students 5 to 10 minutes to build their walls, then ask students to share their walls and what they have discovered about wall construction: what features contribute to a strong wall and what features contribute to a weak wall.

Students should notice three features that help produce strong walls:

1. Density: All other things being equal, a dense wall will be stronger than a loose wall.
2. Order: All other things being equal, an orderly wall will be stronger than a disorderly wall.
3. Interconnectedness: All other things being equal, a 6-to-1 type structure tends to be stronger than a 4-to-1 structure.

Ask students to compare their walls to the structure of salt. They should notice that salt has a dense and orderly structure. If a dense and orderly block structure yields a strong and sturdy wall, then it is only natural that a dense and orderly particle structure makes salt a strong and sturdy material.

Chapter 2

The Pot Is Mightier Than the Hammer

This chapter expands and elaborates on ideas from the previous chapter. Using ismofs, students will make observations of the structure of salt, water, and saltwater. They will also make observations of a simple stovetop experiment. These observations will help them to better understand what it means for matter to be made of particles. Among other things, they will discover that small-scale structure helps to explain everyday-scale phenomena and construct a small-scale particle-based explanation for how and why salt (and other materials) dissolve in water.

In this chapter, students will:

- make observations of water and salt water at multiple scales;
- develop a mental model of the structure of liquid water and salt water, understanding that both are made of tiny particles that are constantly moving in random directions;
- practice the art of interpreting data by making sense of their observations;
- use the particle theory of matter to help explain why salt seems to disappear in hot water (it dissolves);
- learn about the principle of parsimony—also known as Occam's Razor—a critically important tool in the practice of constructing scientific explanations;
- practice asking questions;
- use their observations to construct an explanation that uses the concepts of particles and structure and function to describe how the small-scale structure of water explains and determines the everyday-scale properties of liquid water; and
- take notice of a few of the many wonderful opportunities for science-based puns.

Features worthy of notice:

- At the everyday scale, water has a smooth texture and appears motionless in the cooking pot.
- At the smallest scale (the atomic scale), water has a lumpy texture. There are water particles and then empty spaces between the particles. Curiously, the water particles seem to be made of even smaller particles, with three sub-particles per water particle. The water particles move quickly and randomly.

Finally, ask students to compare their observations of salt to their observations of water. Again, consider colors, shapes, textures, patterns, and movement (or lack of movement).

- At the everyday scale, what is the same, and what is different?
- At the very smallest scale, what is the same, and what is different?
- Features worthy of notice:
- At the everyday scale, both salt and water appear motionless.
- At the everyday scale, salt is hard while water is soft. (This isn't evident from the illustration, but it's an important thing to notice nonetheless).
- At the very smallest scale, both salt and water have a lumpy texture, as if they are made of particles.
- At the very smallest scale, the salt particles are orderly, while the water particles are moving and disorderly.

Preconceptions

Several of these discussion questions address a very common preconception about liquids. Many students believe that when a liquid is still and unmoving, the particles in that liquid must also be still and unmoving (Johnson, 1998). In fact, this is not true.

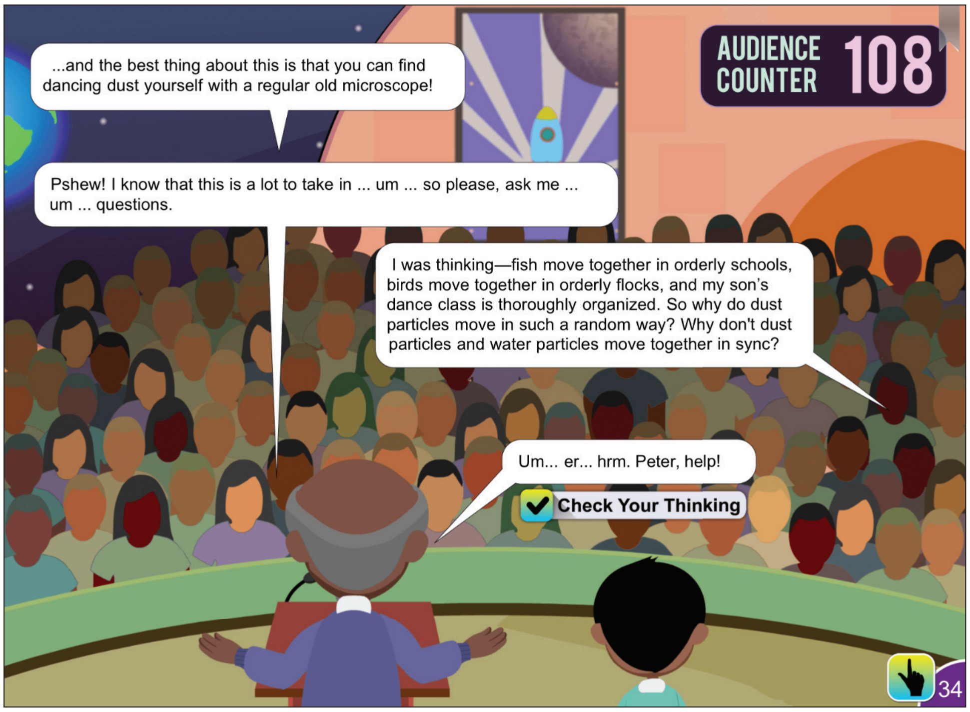
As an example, consider the pot of water on this page. To the eye, the water appears still. The pot isn't moving, the water isn't sloshing, and there are no ripples on the surface. For all this apparent stillness, the pot is full of motion. The zillions of particles that make up the water are constantly zipping back and forth, bouncing off the sides of the pot, and crashing into each other. Because the individual water particles are invisible, their individual motion is invisible, and the water appears still, even though it is nothing close to still.

Thinking Beyond

Many people consider detailed observation to be a painful and thankless task. Yet detailed observation has let to countless scientific breakthroughs.

Exoplanets are a great example. One way of detecting planets around other stars (a.k.a. exoplanets) has to do with the tiny flickering that happens when an exoplanet passes in front of that other star. To detect these flickers in brightness, you need years of careful observations, but the payoff is enormous! You get proof that other worlds exist and a general feel for the size and location of the world. Is it big in size and far from the star, like our Jupiter? Is it small and close, like our Mercury? Is it small and middling, like Earth?

Page 34



This page elaborates on the earlier Brownian motion investigation, challenging students to explain one of the more subtle features that they may have observed, namely the seemingly random nature of the movement of the dust particles. The answer to this question also helps to build a foundation for a deeper understanding of the central experiment of Chapter 4.

Differentiated Instruction

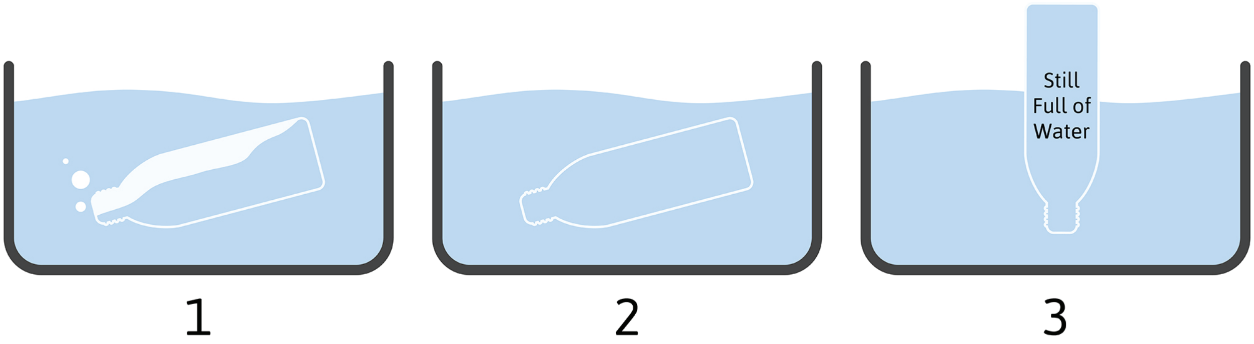
Most places and most times, the zillion particles that make up a liquid are moving in all different directions at many different speeds. One of the major reasons for this is that at the scale of particles, most surfaces are really rough and lumpy. When a bunch of particles all moving at the same speed in the same direction run into a wall, the microscopic peaks and valleys in that wall cause the particles to bounce away in different directions. It is cause and effect at the atomic-scale.

This is easy to explain in words, but it can be hard to turn this abstract verbal explanation into a useful mental model. The following activity may help students to create that mental picture by building and participating in a life-size model of this phenomenon.

Materials:

- 5 to 20 desks or tables that you can lay sideways on a floor
- A medium to large space with a smooth floor
    - Good options would be a school gym, a tennis court, or an empty parking lot

- A bucket or plastic tub: Dishwashing bins work great. The key thing is that your container must be wide enough and deep enough that you can turn your water bottle sideways, dunk the bottle in the tub, and have the entire bottle be underwater.
- Water
- Food coloring (optional)



Hold bottle under water ...

... until all the air is gone.

Keep mouth of water bottle fully under water, and turn upside down.

Procedure:

- Fill your bucket or tub mostly full of water.
- (Optional) Put several drops of food coloring into the water so that the water is lightly tinted.
- Dunk the bottle in the tub.
- Hold the bottle underwater until it is entirely full of water—no air bubbles.
- Keeping the mouth of the bottle underwater, turn the container upside down.
- The bottle will try to float. If it pops up to the surface, the water will drain out. You will need to hold it in place by hand or put something weighty on top to hold it in place and keep the water in the bottle.

Observe and discuss:

- Why isn't the water draining out of the bottle?
- The level of water in the bin is clearly much lower than the level of water in the bottle. Why is the level of water in the bottle so much higher than the level of water in the bin?
- The water fills the bottle all the way up. If the bottle were taller, would the water still fill the bottle all the way up?

Key concepts:

- The surface of the Earth is covered in a layer of air that is about 60 miles deep (or 100 km). The top edge of this layer is hard to define because the air just slowly thins to nothing, but 60 miles is a good number. This is the maximum possible height at which an airplane

Lastly, students should build a cause-and-effect explanation to connect these two ideas. This is a multi-step explanation that may be best communicated with a concept map, as shown below.

Higher temperature inside balloon.	Air particles inside of balloon move.	Air particles hit inside of balloon harder.	Balloon walls are pushed outwards, and balloon gets bigger.

Preconceptions

Many students may be familiar with the connection between temperature and volume, simply from everyday life. They may have noticed that a bag of chips left in the sun will expand, puffing up as it warms up. They may have heard of the Challenger accident, where cold weather caused a piece of a rocket to shrink, creating a weakness in the rocket that ultimately caused the rocket to explode. While they may be superficially familiar with this cause-and-effect connection, many students misunderstand the root cause.

Research has shown that some students believe that heat makes particles grow larger and heavier. These students believe that it is the change in the size of particles that causes the change in size in an object (AAAS Project 2061). In fact, temperature has relatively little effect on the size of individual particles. Instead, temperature affects the spacing between particles. As temperatures increase, particles move faster, spreading out farther, and this is what makes objects expand.

A good analogy is that of cars on a freeway. In a traffic jam, cars slow down and move closer together. In an open freeway (with no traffic jam), cars speed up and spread out. Particles do the same. When cooled, they slow down and huddle together. When heated, they speed up and spread out.

Differentiated Instruction

If students are having trouble gaining an intuitive grasp of these ideas from a freeform exploration of the simulated experiment, ask them to carry out a pair of careful experiments following the example of the water and temperature experiment from the End-of-Chapter Investigation at the end of the previous chapter.

Experiment #1: Temperature and Air Particle Speed

Begin by clearly stating the first driving question: How does temperature affect air particle speed?

Note that in this experiment, students won't be able to collect numerical data on air particle speed, but they can still make qualitative observations about speed (slow, medium, fast, very fast, etc.)

Suggested Scenarios

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<tr>
<td>What: “Little Things Matter”
Where: Annual Meeting of Mega & Macho

Once a year, the members of M&M meet up to show and enjoy the biggest of the big: the world’s biggest ball of string, the world’s largest hot dog, etc. They believe that big things matter and little things don’t.

You must:
Warm up the audience with a pair of jokes.
Present a two-minute argument in favor of the idea that little things (like particles) really do matter.
Answer any questions that the audience may have.</td>
<td>What: “Pandas Aren’t Made of Pudding”
Where: The Pudding Matters Society

The PMS believes that matter is like pudding. They believe that if you were to have a ridiculously good microscope and look really closely at any object, you would find that it was made of smooth stuff, like pudding. It might be hard pudding or soft pudding or something in between. Whatever the details, it would totally and for sure be pudding-like.

You must:
Warm up the audience with a pair of jokes.
Present a two-minute argument in favor of the idea that pandas are made of particles (rather than pudding).
Answer any questions that the audience may have.</td>
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<td>What: “We’re in Hot Water Now”
Where: Curious and Caring Kids

CACK is a kid-based, action-oriented, environmental justice group created by kids and run by kids. CACKers care about the environment. They hold regular meetings both in person and on the web and invite speakers to help them understand important issues, like climate change. Their motto is: “Learning then action!”

You must:
Warm up the audience with a pair of jokes.
Present a two-minute explanation of why heat makes things expand and how adding heat to oceans might change the size of oceans.
Answer any questions that the audience may have.</td>
<td>What: “A Particle’s Life”
Where: Animists Anonymous

Having grown up on a steady diet of animated movies, the members of AA have a slightly odd view of life. Among other things, they believe that everything is alive—dishes, toys, cars, planes—and that they don’t talk to us because they think we won’t understand. Therefore, they are on a quest to understand what it feels like to be an object.

You must:
Warm up the audience with a pair of jokes.
Deliver a two-minute biography of a particle of your choice (based on real life events).
Answer any questions that the audience may have.</td>
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