Session 2

The Particle Nature of Matter: Solids, Liquids, and Gases

What explanation might account for the differences between the states of matter, as well as explain its different properties? Session 2 introduces the particle model of matter, the principles that underlie a wide range of phenomena. By contrasting this model with what is variously called the continuous, continuum, or plenum model, this session shows how the particle model is useful for making accurate predictions about a variety of behaviors of matter on a macroscopic scale.

The Video

The video begins by defining what scientists mean by the term "model," establishing what makes a *good* model, and describing the process by which models are continually revised. Then, children in the Science Studio divide a piece of aluminum foil into the smallest pieces possible and are asked: Is it possible to go on dividing forever? Is there ever a point at which the pieces no longer have the properties of the aluminum foil? Science historian Dr. Al Martinez recounts the history of the continuous model originally proposed by the Greeks, explains its appeal, and later tries to use this model to explain the expandability and compressibility of gases.

Back in the Science Studio, children continue to reveal *their* models of matter, which support what science education research says about the difficulty children sometimes have connecting their ideas about macroscopic matter with the particles that make it up. By "taking a trip into a drop of water," we then explore the size and scale that make this connection so challenging. This raises the question, "What's in between the particles of matter?"

For an answer, we first explore fifth graders' ideas on the subject, and then visit vacuum engineer Bob Childs, whose work in nuclear fusion relies on an important principle of the particle model. We return to the Science Studio one last time, where we find children further developing their models to explain the compressibility of gases and proposing a model to explain an everyday change of state—boiling.

In Session 2's Featured Classroom segments, Linsey Newton's third graders in Hudson, Massachusetts, observe two more changes of state—evaporation and condensation—and Russell Springer's fifth graders in Newtonville, Massachusetts, try to explain the seemingly random movement of oil droplets suspended in water. In both classrooms, the students express a variety of macroscopic rationales for what is happening.

Learning Goals

During this session, you will have an opportunity to build understandings to help you:

- Recognize characteristics of a good scientific model
- Understand the macroscopic evidence for each of the four basic principles of the particle model of matter:
  1. Matter is made of tiny particles.
  2. There is empty space between the particles.
  3. The particles are in constant motion.
  4. There are forces that act between the particles.

On-Site Activities

Getting Ready (60 minutes)

Activity One—Problem Set and Reading Discussion (20 minutes)

Work in small groups.

1. To prepare for this session, you were asked to think about the smallest piece of a pencil imaginable. With a partner, draw and share what you think this piece would look like.
2. With the whole group, discuss the Nussbaum article. What does the research that the author cites suggest about waiting until children are in middle school to teach them the particle model?

Activity Two: Continuous versus Particulate (20 minutes)

Facilitators: Distribute the Session 2 materials.

1. With a partner, cut a piece of aluminum foil in half, take one of the pieces, cut it in half again and continue this process. When you can no longer hold the piece in your fingers, use tweezers and a magnifying glass if necessary. Predict what would happen if you had the tools to keep on going. Could you keep going forever? What would be the final result? Would it still be aluminum? Try to convince your partner of your answer.
2. As a whole group, discuss your answers and consider how the example of cutting aluminum foil in half is similar to and different from Zeno's Paradox:

   > Peter Rabbit is 10 feet from a fence. Each time he hops forward, he advances half of the distance remaining to the fence. How many hops will it take for him to reach the fence?

Activity Three: Drawing Particles (20 minutes)

1. With a partner, draw pictures of what you would see if you examined both the tiniest piece of aluminum foil and a drop of water under the world's most powerful microscope.
   - What are the differences between your two drawings?
   - What are the similarities between the two drawings?
   - What aspects of your drawings could explain some of the macroscopic properties of the material?
2. Repeat the above activity for a syringe of air.
3. Place a drop of food coloring in a glass of room temperature water and watch it spread out. What do you think is happening on the microscopic level that accounts for this phenomenon?

Watch the Video (60 minutes)

As you view the video, think about the following focus questions:

1. What is the fundamental difference between the continuous and the particle models of matter? Make note of the characteristics of the particle model that are presented throughout the video.
2. In the Science Studio, children don't always agree on what they think matter looks like up close. How are these ideas different from those reflected in your drawings from Activity Three in Getting Ready?
3. As you watch the Featured Classrooms, think about how an understanding of the particle model would enhance the students' understanding of the macroscopic phenomena that they are observing.

On-Site Activities, cont'd.

Going Further (60 minutes)

1. A metal spoon is easier to bend than a plastic spoon. As a whole group, try to explain this using first the continuous model of matter and then the particle model of matter.
2. As a whole group, re-examine the drawings that you did in Activity Three in Getting Ready. How do they either represent or fail to represent the four characteristics of the particle model presented in the video (and listed below)?
   a. Matter is made of tiny particles.
   b. There is empty space between the particles.
   c. There are forces that act between the particles.
   d. The particles are in constant motion.
3. In a small group, select one of the characteristics of the particle model (listed above). Discuss the macroscopic evidence for that characteristic as presented in the video. Then reconvene as a whole group and report your conclusions. Is the support for each principle convincing?
4. One of the overarching goals of this course is to help you understand the microscopic reasons for macroscopic phenomena. The rest of the course will continue to refine the particle model. To assess how well you understand it now, with your partner, explain each of the following phenomena in terms of the particle model. Record your answers and save them for future sessions.
   - Nails left on the ground outside rust.
   - Honey "disappears" when stirred into hot tea.
   - Beach balls held under water and then released "pop" to the surface.
   - Bathroom mirrors get fogged up when the shower is on.
   - Dogs pant to cool off.

Between Sessions

Homework (* = required)

* Reading Assignment

Novak, J. "The Theory Underlying Concept Maps and How To Construct Them" located at http://cmap.coginst.uwf.edu/info.

As you read, begin thinking about how what you have learned about matter up to now might fit into the concept map that you will be asked to develop in the "Ongoing Concept Mapping" activity below.

* Physical Science Problem Set

(Suggested answers are listed in the Appendix.)

1. Session 2 introduces the four basic principles of the particle model of matter. Explain how each of these contributes to a microscopic explanation of what happens when you compress a closed syringe filled with air.
2. What are the characteristics of a good scientific model and how does the particle model show these characteristics?
3. Why does water "beading" on a windshield help support the idea that there are forces between particles?
4. In the video, Russell Springer's students, with the help of another teacher "Mr. O," acted out a life-sized model to help them understand the microscopic phenomenon of Brownian motion. Explain how Brownian motion works using this model.

About Concept Maps

Concept maps are graphic ways of organizing and representing knowledge. They are built around concepts to which labels can be applied. Each concept is linked by words to one or several other concepts to form propositions: meaningful statements about some object, process, or event.

Concept maps are hierarchically organized around a domain of knowledge. The domain of knowledge is the most general concept around which the map is built, e.g., the particle model of matter. Once the domain has been selected, key concepts that apply to this domain are identified. These concepts can range from more general concepts (principles of the model) to more specific concepts (phenomena explained by the principles). This "ranking" of concepts is used primarily to assist in building the hierarchy of the concept map.

It is good practice to first build a preliminary concept map (sticky notes can be useful) to allow for changes in thinking that occur as you learn more about the concepts and their relationships to other concepts. Your ongoing drafts can reflect these changes. In general, the main concept (the domain) is placed at the top of the map, with the most general key concepts placed in one or more levels under it, depending on the number of concepts and their relationship to the domain and the other concepts. The most specific concepts are placed toward the bottom of the map, under the more general concepts to which they apply.

Once the concepts are laid out, one or more connecting words are chosen to link the concepts in such a way that a meaningful, although abbreviated, statement results. Connecting words should be chosen carefully, as they reflect how you understand the linked concepts are to be related. The finished proposition represents a unit of meaning. This unit of meaning can be built upon or revised.

Another key feature of concept maps is cross-links. Cross-links are connections between concepts that are made by searching for relationships between different map segments. Cross-links help reveal the extent to which concepts are understood to be connected to each other. You can use cross-links to connect different, but related, concept maps.

Between Sessions, cont'd.

* Ongoing Concept Mapping

After you have read the Novak article, develop a concept map around the idea of how the particle model explains the behavior of solids, liquids, and gases. Be sure to include the following concepts:

- States of matter
- Particles
- Empty space
- Constant motion
- Forces
- Model
- Compressibility
- Vacuum
- Predictions
- Particle model
- Continuous model
- Volume
- Solid
- Liquid
- Gas
- Plasma
- Evaporation
- Condensation
- Boiling

Guided Journal Entry

During Session 2, you moved from classifying matter based on its properties to trying to understand the reasons for similarities in its behavior (i.e., all matter can change state). In your opinion, which approach is more useful for understanding the world around you? Would you rather have the principles of the particle model or a "materials handbook" that lists the properties of many different substances?

Weigh the advantages of having a single model to explain everything against the inevitable limitations of any model. (Even at the end of this course, you won't be able to explain all properties of any material. Modern-day researchers are still trying to do this.)

Guided Channel-TalkPhysicalSci Posting

In the last two sessions, you've seen several children discuss their ideas about particles. Even though the particle model of matter is sometimes not introduced in the earlier elementary grades, how could you incorporate ideas about the particle nature of matter into one of your current lessons? What would be the most important idea that you could realistically get across to your students? How could you lay the groundwork for them to think about the particle model as opposed to a continuous model of matter?

Textbook Reading Suggestions

The following are suggestions for several reading topics that may provide additional background and enrichment information. These topics are likely to be addressed in any college-level physics textbook, and can usually be located in some form in the table of contents and/or index.

- Kinetic molecular theory of matter
- Condensation
- Evaporation
- Brownian motion

Between Sessions, cont'd.

* Preparing for the Next Session

For "Getting Ready"

A statement you may have heard or used is: "Matter cannot be created or destroyed." Between now and next time, think about everyday examples in which matter seems to disappear. Make a list of these instances and bring it to the next session.

Materials Needed for Next Time

- 250 ml beakers, glasses, or clear plastic cups
- Sand
- Sugar
- Stirrers
- Funnels
- Magnifying glasses
- Tablespoon
- Salt
- Plastic cups
- Gram scales
- Filter paper

Notes