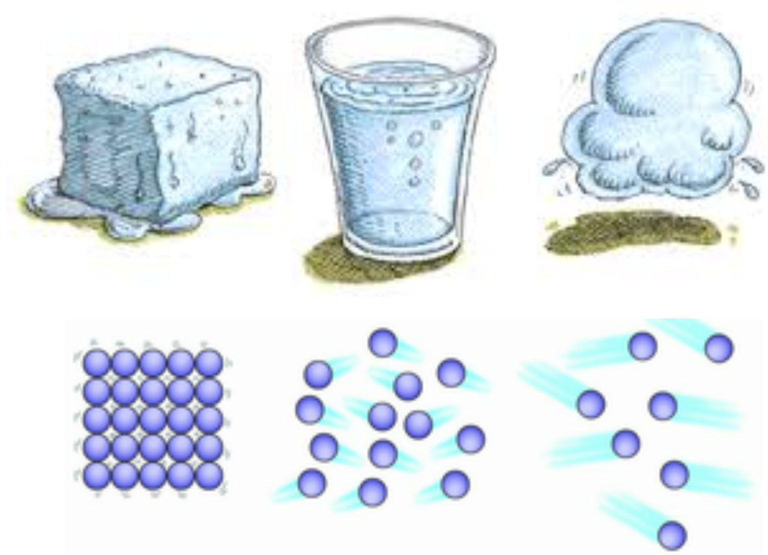
Sensing Science through Modeling Matter

S2M2

2020 Teacher Guide



S2M2 TEACHER GUIDE

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S2M2 LESSONS IN THE CLASSROOM

Overview

<u>The S2M2 Approach</u>

The lesson guides developed by the *Sensing Science through Modeling Matter* (S2M2) project are provided as examples of how an inquiry-based science curriculum might be implemented in your classroom. Sample activities and comments are meant as guides that teachers can modify, adapt, and extend to suit their needs and those of their students. S2M2 takes the approach that learning science is a process of constructing, evaluating, and reconstructing models of the world. Just like scientists, children will use reading, writing, oral communication, measuring, drawing, and building as tools to articulate and share their models.

<u>The Role of the Teacher</u>

In the S2M2 framework, the teacher acts as a facilitator to support children's learning throughout the inquiry units. The teacher scaffolds the children's learning by asking questions as well as providing hints, scaffolds and reminders to children through the process of investigation, and modeling skills for children as needed. The teacher also helps children communicate by encouraging small-group and whole-class discussion and by developing a system for children to share what they have learned in each investigation cycle.

<u>Structure of MPG lessons:</u>

Each S2M2 Lesson is comprised of 4 phases:

Exploratory Phase: Typically, this is the opening of the lesson, which consists of a whole-class or small-group activity that serves to activate prior knowledge, introduce the purpose of the lesson, and provide children with the task framework for their investigations.

Concept Development Phase: During this part of the lesson, children engage in activities and investigations that help them develop an initial understanding of the target concepts.

Making Sense Phase: Children engage in activities that help them make sense of the data collected in the concept development phase, construct explanations with evidence from their data, and extend/deepen their conceptual understanding.

Application phase: Children synthesize what they have learned during the lesson and apply it to a new context.

LESSON 1: MODELS AND MODELING

Pre-Lesson Preparation

Guiding Questions

1. What are scientific models?
2. How do we use models in science?

Major Concepts

1. Often scientists use models to answer questions about the world or to make guesses (hypotheses) about how things work.
2. A model represents something in the natural world.
3. A model is similar to the thing it represents in some ways and different in other ways.
4. We use models to understand and explain:
    a. Structure – what things are made of and how the different parts that make up something relate to each other.
    b. Function or behavior – how something works, what it can be used for, or how it behaves.
    c. Mechanism – how things happen and to predict what will happen in the future.
5. We can test our models by using them to form hypotheses or predict what will happen and by gathering evidence about what actually happens.
6. We use models to share what we know with each other.

Learning Goals

Children will be able to:

1. list several ways that a model (e.g., a globe, a map, a toy car, digital simulation) is not an exact or literal copy of things in the world as well as ways that it is similar to the thing(s) that the model represents.
2. identify models that are of different forms (e.g., paper and pencil drawings or diagrams, photographs, computer graphics or simulations, and 3D objects).
3. identify models that represent things that are very large and models that represent things that are very small in scale. They will explain that we need models for very large and very small things so that we can study them and share what we know about them.
4. identify a model that can be used to show how things work, how things change over time, what things are made of, or how their parts are related.
5. use words and drawings to create and share a model of something.

Students' Naïve Ideas

1. Models are literal copies of things. A good model must show every aspect or feature of the object represented.
2. Models show only structural features (shape, size, color, parts) not behavior or processes (e.g., how things change over time)

Materials for Pre-Lesson

For class:

- ☐ Globes
- ☐ World maps
- ☐ Various models (e.g., toy car, doll, drawings, poster of how to wash hands, etc.)
- ☐ Chart paper or white board for the Globe, Map, Earth chart
- ☐ Chart paper to record important ideas about models
- ☐ Markers

For each group:

- ☐ Thermoscope set for each group (iPad and sensor kit)
- ☐ Plastic cup or container (ca. 100 ml) of very warm water (not hot enough to burn!)
- ☐ Plastic cup or container (ca. 100 ml) of cold (ice) water
- ☐ "The Land of Bump"

For each child:

- ☐ Science notebook
- ☐ Pencil

Lesson 1: MODELS AND MODELING

What are Models and Why Do Scientists Use Them?

❖ This first section of Lesson 1 highlights models that show structure–*what things are made of and how the different parts that make up something relate to each other*, as well as function or behavior–*how something works, what it can be used for, or how it behaves*.

1. Introduce a model that is familiar to children. Show children a globe and ask:
   - *What is this?* [Children might say *earth* or *globe*]
   - *What is this globe supposed to show us?* [Children might say *Earth* or *world* or *our planet*]
   - *Why do we use globes?* [Children might say *to find places*, *to see the world*, to see the land and the oceans on the Earth.]

2. After children provide their ideas for why we use globes, acknowledge their ideas (e.g., write on board) and tell them:
   - *A globe is a **model.** A **model** represents something in the natural world. Scientists use **models** to study the natural world.*
   - Pointing to the globe, say: *This is a **model** that shows the earth/world/our planet.*

> **Teacher Note**
>
> **Models/modeling** is an essential, core idea of this unit. It is important for teachers and students to build an understanding of what models are and begin to *use language of models and modelling* appropriately in their science "talk" throughout this unit.

3. Ask children what other types of **models** of the Earth they have seen. This is important to ask so that children begin to develop the idea that different models can exist for the same thing. If they do not come up with a map, hold up a map of the Earth and ask:
   - *What is this?* [*a map*].
   - *If a model represents something in the natural world, do you think a map is a model?* [yes] *What is it a model of?* [It is also a model of the Earth.]
   - Tell children that they are going to look more closely at the globe and map, and how these models *represent* the Earth. Using the globe and map, they are going to learn about **models**—what are examples of models, what are characteristics of models, and why do we use models.

4. For younger children, we suggest conducting the following activity as a large group but have children sit with a partner so that they may discuss your questions with each other first, before answering in the large group discussion. Tell the children they are going to discuss and describe the (real) Earth, a globe and a map. Introduce a chart that the class will fill out together. On the board, the teacher will show the children a simple chart such as:

WHAT ARE SOME WORDS TO DESCRIBE:

Globe	Map	Earth

5. Children will help fill out the chart. Ask children to talk with their partner to come up with at least one word to describe the globe. Once each small group has a word, allow each group to share a word that describes the globe as the teacher writes that word in the first column of the chart.
    - If children have difficulty coming up with several different words to describe a globe, the teacher may want to use these prompts:
        - *What shape is the globe?*
        - *What are some of the features on the globe? (The globe may have ridges for mountains; different colors for different countries; words or names of countries, oceans, etc.; lines for latitude and longitude)*
        - *Is the globe straight up and down or tilted?*

Teacher Note

The main idea behind using this chart is to help the children notice—using models that are likely familiar to them—the similarities and differences between models and the thing(s) that the models represent (Learning Goals 1 and 2).

6. Next, ask children to talk with their partner to come up with at least one word to describe the map. Once each small group has a word, allow each group to share a word that describes the map as the teacher writes that word in the second column of the chart.
    - If children have difficulty coming up with several different words to describe a map, the teacher may want to use these prompts:
        - *What shape is the map?*
        - *What are some of the features on the map? (The map may have different colors for different countries; words or names of countries, oceans, etc.; lines for latitude and longitude)*
        - *Is the map round or flat?*
        - *Is it tilted like the globe?*

7. Finally, ask children to talk with their partner or small group to come up with at least one word to describe the Earth. Once each small group has a word, allow each group to share a word that describes the Earth as the teacher writes that word in the third column of the chart.
    - If children have difficulty coming up with several different words to describe the Earth, the teacher may want to use these prompts:
        - *What shape is the Earth?*
        - *What are some of the features of the Earth? (Does the Earth have different colors for different countries? words or names of countries, oceans, etc.? lines for latitude and longitude?)*
        - *Is the Earth straight up and down or tilted?*

8. As a large group, discuss some ways in which the globe, the map, and the Earth are the **similar**. Were there any words that were used to describe two? all three? Possible responses include:
    - Maps, globes, and Earth have countries, oceans, etc.
    - Maps and globes are similar because they have lines that go up and down (longitude) and left to right (latitude).
    - Maps and globes have names of continents, countries and bodies of water.
    - Globes and the Earth are round (sphere).
    - Globes and the Earth are tilted and spin on an axis.

9. Discuss some ways that the map and globe are different from each other and different from the Earth.
    - Maps are flat, but globes and the Earth are round.
    - Globes and maps are smaller than the Earth.
    - The globe can show one way in which the earth moves (it spins on its axis), but it cannot show how the Earth revolves around the sun. The map cannot show movement.

10. Emphasize that we often have multiple ways—*multiple models*—to represent the same thing. Each model has some useful features, but not all of the features may be on each model. Ask the children, can you think of something that can be modeled in different ways? Is there anything you can think of that has multiple models? [examples: *Children may say they have different models of a house or a car or an animal.*]

11. Ask the children, "Why do you think scientists use models to study the Earth? [*Scientists use models to study the Earth because the whole Earth is too big to be able to study in its actual size*.]

12. Write down the important ideas about models so far; post in room for children to see during S2M2 lessons:
    - Models represent the natural world.
    - Models are similar in many ways to the thing they represent, but they are also different in many ways.
    - There can be more than one type of model for something (e.g., globe and map are both models for the Earth, but they are different types of models).

Teacher Note

Posting a summary on chart paper of the main ideas about models is a useful tool to which teachers can refer when discussing models throughout the unit. The chart can also serve as a reminder to use **modeling language** throughout the unit.

IMPORTANT IDEAS ABOUT MODELS
• Models represent the natural world. • Models are similar in many ways to the thing that they represent, but models are also different from the thing that they represent in many ways. • There can be more than one type of model for something.

❖ The second section of Lesson 1 highlights models that show structure–*what things are made of and how the different parts that make up something relate to each other*, as well as function or behavior–*how something works, what it can be used for, or how it behaves.*

13. Set up the next investigation in which children will be introduced to models of things we cannot see. Each group should have a cup (with lid if needed) that is 1/3 of the way filled with ice water and a cup (with lid if needed) that is 1/3 of the way filled with very warm water.

14. To introduce the activity, make an explicit link between the first modeling activity (Earth, globe and map) and the new activity:
    - *Remember in our first activity, we used **models** to see things that are too big for us to work with, like the earth? Scientists also use **models** to study things that are too small to see with our eyes. They use models to study what things are made of and how the different parts that make up something relate to each other.*
    - *Today we are going to use **models** to examine things that are too small for us to see. We are going to look at models to find out what makes up cold water and warm water.*
    - *What do you think water is made of? What do you think we will see when we view a model of cold water? Of warm water?*

THERMOSCOPE INSTRUCTIONS

Before Class:

- Connect each iPad to Wi-Fi.
- On the opening screen, open the Thermoscope app.
- Turn each Thermoscope on (small black button above the little icon).
- On iPad screen, touch Connect in upper left corner.
- On the iPad screen in the upper right corner, tap the three short horizontal lines to see "Options." Make sure that the View/Hide button is activated (green). Click the "x" to close the menu.
- Choose the orange block that says "Water."
- "Hide" the two circles by tapping the small box with the eye/line through the eye. Children should not see any particles moving yet.

In Class, After Predictions:

- Children insert yellow probe in the cold water and tap the small box with the eye on the left.
- Children insert blue probe in the hot water and tap the small box with the eye on the right.

15. Have children break into their small groups. In front of each group will be an iPad with the Thermoscope app open to a screen with two empty magnifying lenses. Before using/viewing the Thermoscope, tell the children:
    - *In a few minutes, you will put the probes in the cups of water, and the tool on the iPad will show you what makes up the water.*
    - *This tool is called a **Thermoscope.** We will use the Thermoscope during our science investigations over the next few weeks. The Thermoscope will show us **models.***
    - *Before we use the Thermoscope, though, I want you to predict—make your best guess—about what you will see.*
16. Allow children time to imagine and draw in their science notebooks on page 2 ***what they think*** they may see when they use the Thermoscope to see what makes up cold water and warm water. Tell

children:

- *One page 2 of your science notebooks, draw in the green circle* ***what you think you will see*** *in the Thermoscope circle when the probe is in cold water.*
- *Next, draw in the purple circle* ***what you think you will see*** *in the Thermoscope circle when the probe is in warm water.*

17. While children are drawing, the teacher should walk around to each of the small groups to:
    - listen to children's ideas,
    - encourage them to discuss their ideas with each other, and
    - ask them questions to elaborate when appropriate.

Teacher Note

Teachers may walk around to groups and write in children's ideas below their pictures. Simply ask them: *Tell me about your picture* or *tell me about what you drew.* Write down word-for-word what the child says. Do not paraphrase, add or delete from their ideas.

18. When everyone has had a chance to draw their ideas, let children share in the large group what they think they will see on the Thermoscope when they insert the probes in cold and warm water:
    - *Who would like to share one of their ideas about what they think they will see?* [At this point in the lesson, what is important is that children express their ideas and respect each other's ideas. Whether the drawing is "right or "wrong" is not important.] Some questions you may ask children to elaborate:
        - *Tell me about [name a feature in the drawing; for example, tell me about the lines in your drawing or tell me about the big square in your drawing—what is the big square?]*
        - *How is your drawing of cold water different from your drawing of hot water? Why did you draw [repeat the difference they stated]?*
        - *Where did your ideas come from? [Some children may have seen a TV program or a picture in a book that inspired their drawing]*

Teacher Note

Allowing children to share their ideas with others is an important part of the lesson. When students articulate their ideas, they "make sense" of the models they have drawn—e.g., they may become more aware of the purpose of various features in their drawings, or realize that they are not sure why they included a certain feature. They also may consider new ideas from their peers or from the teacher's questioning.

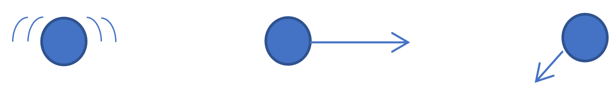
19. Introduce the Thermoscope. Tell children that the tool they will use to examine the water is called a ***Thermoscope***. They should follow instructions carefully and observe what happens in the big circles (magnifying lens) on the screen.

20. During the cold-water observation, the teacher may want to cover the circle on the right side of each Thermoscope with a piece of paper or a sticky note, so that the right side is not a distraction.

21. Have each small group of children insert the <u>Thermoscope Yellow Probe</u> into the cold water and observe the screen. Ask children to discuss with their small group or partner:
    1. *What do you see on the screen? What words would you use to describe the model that you see?*
    2. ***How does the Thermoscope model differ from what you predicted?***
        - *When children compare their predictions to the Thermoscope model, it offers the teacher a chance to emphasize features of the model. For example, a child might notice that his drawing is only one big "piece" while the model has many smaller*

"pieces". Or a child might say that her prediction did not have something that moves, but the circles in the Thermoscope model move.

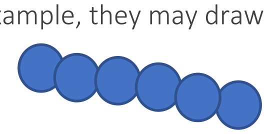
22. Have the children draw and write about their observations of the Thermoscope model of particles that make up cold water in their science notebooks on page 3, in the green circle. Give them time to carefully observe the motion and draw. As the children work on their drawings, walk around to groups and encourage them to look carefully:
    - *Describe what you observe (what you see) about the spheres (or balls or circles) in your science notebook. What are some things that you see?* [Children may say: There are many circles or balls. They are close together. They are moving or bouncing around. They are gray.]
    - Students may want to know how to draw the motion of the spheres. Solicit their ideas or suggest that they use arrows (the length of the arrows could indicate speed; longer arrow, faster speed) or curved lines around the spheres.



23. After children have had a chance to draw their models, convene the large group and ask the children: *What do you think these spheres (or balls or circles) are?* If they do not have any ideas, tell them:
    - *The spheres (or balls or circles) are* ***<u>models</u> of the tiniest pieces that make up water****. We call these tiny, tiny pieces "****<u>particles</u>****". We cannot see these tiny, tiny pieces—particles—with our eyes, so we need a tool to see them. The Thermoscope is a tool that shows us a* ***<u>model</u>*** *of the particles. What kinds of things do the* ***models*** *of the particles that make up cold water show us?* [*Children may answer something about how the pieces move (bump into each other), that the particles move slow*.]

> **Teacher Note**
>
> This is an important question in this lesson that will have implications later in the unit. It may be difficult for children to comprehend at this moment that water is made up of tiny, tiny pieces we call "particles". In fact, they may call the spheres "bubbles". While the spheres may look like bubbles, they are not bubbles. They are **models** of particles that make up water.
>
> Also, be careful to say: "**The particles that make up** water (or whatever substance they are investigating)" and <u>not</u> "water particles. "

24. Allow the children to share their models that they have drawn. This is a time in which you can provide some feedback for children that will help them think about what they have drawn. Many children at this stage in the lesson may draw something that looks completely different than what is on the screen. Allowing children to explain their drawing will help the teacher understand what their drawing represents. For example, they may draw something like this:

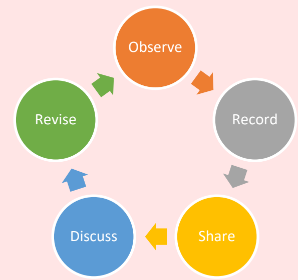


While this image does not appear on the Thermoscope screen, the drawing makes sense to the child because she is showing the path of motion that one of the particles takes after bumping into another particle. By allowing the child to articulate what her drawing represents, we are able to understand that she recognizes important features of the Thermoscope model: she is representing a particle and showing that a particle moves after bumping into another particle.

- During the large group discussion, point out/confirm the important features of children's models (as best as one can expect children can draw them):
    - particles
    - particles are same size
    - close together but not packed
    - moving around and bumping into each other
- If children do not identify these characteristics, it is okay to prompt them with questions. Rather than pointing out what may be wrong with their drawings, prompt children to go back and compare their drawing to the Thermoscope model. Example questions:
    - *What do you notice about the arrangement (or spacing) of the particles? Are the particles far apart or close together in the Thermoscope model? How does your model compare to the Thermoscope model?*
    - *What do you notice about the movement of the particles? Are the particles in the Thermoscope model moving? What are some words we can use to describe their motion? How are the particles moving in your model?*
    - *What do you notice about the size of the particles? Are the particles in the Thermoscope model different sizes or the same size? How does that compare with your model?*

Teacher Note for 22-25

Steps 22-25 are a cycle that will be a recurring part of the lessons:



25. *Allow children the opportunity to revise/refine their observation drawing based on the discussion.*

Teacher Note

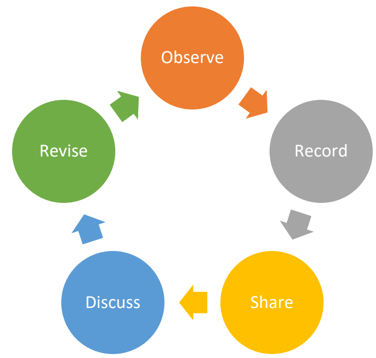
If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

26. Tell children they will now look at what makes up the warm water. Using the Thermoscope, have each small group of children insert the Thermoscope Blue Probe into the warm water and observe the screen. Ask children to discuss with their small group or partner:
    3. *What do you see on the screen?*
    4. *What words would you use to describe what you see?*
    5. ***How does the Thermoscope model differ from what you predicted?***
        - *When children compare their predictions to the Thermoscope model, it offers the teacher a chance to emphasize features of the model.*
    6. *How are the particles that make up warm water* ***the same as*** *the particles that make up cold water?* [The particles in both warm and cold water move and bump into each other.]
    7. *How do the particles that make up warm water* ***differ from*** *the particles that make up cold water?* [Particles that make up cold water move slower than the particles that make up warm water.]

27. Have the children draw and write about their observations of the Thermoscope model of particles that make up warm water in their science notebooks on page 3, in the purple circle. Give them time to carefully observe the motion and draw. As the children work on their drawings, walk around to groups and encourage them to look carefully:

- *Describe what you observe (what you see) about the spheres (or balls or circles) in your science notebook. What are some things that you see?* [Children may say: There are many circles or balls. They are close together. They are moving or bouncing around faster than the ones that make up cold water.]

28. After children have drawn their observations, allow them to share their models that they have drawn. During the large group discussion, point out/confirm the important features of children's models (as best as one can expect children can draw them):
    - particles
    - particles are same size
    - close together but not packed
    - moving around and bumping into each other
        - particles that make up warm water are moving faster than particles that make up cold water
    - If children do not identify these characteristics, it is okay to prompt them with questions. Rather than pointing out what may be wrong with their drawings, prompt children to go back and compare their drawing to the Thermoscope model. Example questions:
        - *What do you notice about the arrangement (or spacing) of the particles? Are the particles far apart or close together in the Thermoscope model? How does your model compare to the Thermoscope model?*
        - *What do you notice about the movement of the particles? Are the particles in the Thermoscope model moving? What are some words we can use to describe their motion? How are the particles moving in your model?*
        - *What do you notice about the size of the particles? Are the particles in the Thermoscope model different sizes or the same size? How does that compare with your model?*



29. ***Allow children the opportunity to revise/refine their observation drawing based on the discussion.***

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

30. Review and summarize with the children as a large group what they observed:
    - *What did you see on the Thermoscope when you put the probe in cold water?*
    - *What are those spheres (balls, or circles)?* [A ***model*** of the particles that make up cold water.]
    - *What did you see on the Thermoscope when you put the probe in warm water?*
    - *What is similar between the behavior of particles that make up cold water and particles that make up warm? [They both move around and bump into each other.]*
    - *What is the difference between the how the particles that make up cold water behave and the particles that make up warm water behave? [The particles that make up cold water move slower than the particles that make up warm water.]*

Teacher Note

Emphasize that the Thermoscope shows a ***model*** of the particles, their arrangement, and their behavior/movement.

31. ***Introduce the Particle Modeler***. Tell children:
    - *You just used a tool to show a model of the particles that make up water. It is called a **Thermoscope**.*
    - *Now you will use a tool that allows you to **make a model** of what you observed on the screen. This tool is called a **Particle Modeler**. Instead of drawing our model by hand, you can use the Particle Modeler to make your model with an iPad app.*
    - *Remember earlier in the lesson when we had more than one model of the Earth? What did we notice about different models of the Earth?*
        - *You can have more than one model for the same thing.*
        - *The models of Earth had some similarities to the Earth and to each other.*
        - *That's what we'll be doing in our lessons—using several different ways to model particles.*
        - *Our models of particles will have some similarities to the actual particles and each other.*

PARTICLE MODELER INSTRUCTIONS

Before using:
- Make sure that each iPad is connected to Wi-Fi.
- On the opening screen, open the Particle Modeler app.

During lesson:
- To build their model, the children put their finger on the sphere in the "New" box.
- Drag the sphere into the container, then release finger from the sphere.
- To drop another sphere in the container, the child will put finger on the sphere in the "New" box, drag a new sphere into the container, and then release finger from the sphere.
- The child should continue dragging particles into the container until s/he has enough for the model.
- Once the particles are in the container, the child may view the motion of the particles by pressing the "Play" button (circle with arrow head inside).
- NOTE: The particles will drop to the bottom of the container once the child presses "Play." They will not stay in the arrangement that the child made before pressing play.
    - To pause the motion, press the "Play" button again.
    - Children may speed up the motion of the particles by pressing the sun or slow down the particles by pressing the snowflake.
    - They may put a lid on the container by choosing the icon of a container with lid on the far right. If they wish to start over, they may choose the circular arrow icon (reload) on the far left.

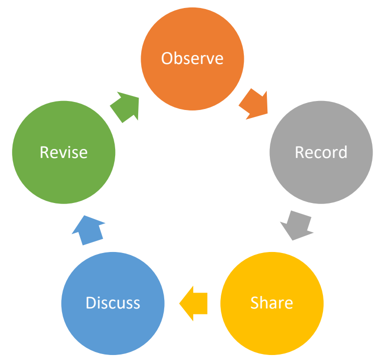
32. Allow children some time to explore with the Particle Modeler without instructions. Allow them time to see, for example, what happens when they place particles too close to each other; what happens to the particles after they place them in the container and then press play; what happens when they tap the sun multiple times or the snowflake multiple times; what happens when they take the lid off.

33. After they have had time to explore the Particle Modeler, prompt students to think about using the

tool to build models of what they observe. Ask children:

- *How will you use the Particle Modeler to build a model that looks like your observations on the Thermoscope? What will you need to do*? [Add particles to the inside of the container; when they drop to the bottom, use the sun or the snowflake to make them move like the particles in the Thermoscope model.]

34. Ask the children to use the Particle Modeler to create a model that looks like their observation of the Thermoscope model of particles that make up warm water (in their science notebooks on page 3, in the purple circle).
35. After the children have had time to make their model with the Particle Modeler, have a large group discussion in which you allow some of the children to share their Particle Modeler model. As children show their models, allow the class to discuss the models— for example,
    - *How does [children's names] Particle Modeler model look like their drawings or the Thermoscope model?* (e.g., Are the particles in the same arrangement? Are they moving similarly?
    - [If the Thermoscope model or their drawing looks different from the Particle Modeler model] *What suggestions do you have for [children's names] to revise their Particle Modeler model?*



Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

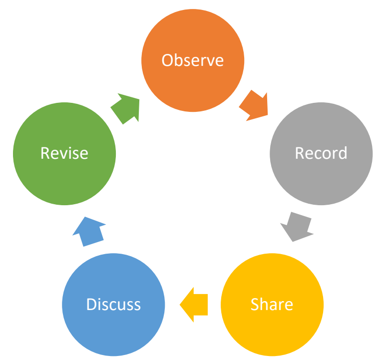
36. *Allow children the opportunity to revise/refine their Particle Modeler models, if they want to.*
37. Ask questions that prompt them to recognize/think about the different features of each of their models, such as:
    - *How are your two models **similar**—the <u>one you drew</u> and the <u>one you created with the Particle Modeler</u>? [They both have circles/spheres to represent the particles; they both look similar to the Thermoscope particles]*
    - *How are your two models **different**—the one you drew and the one you created with the Particle Modeler? [We can't make the particles that we draw move around (we can make symbols to show motion), but the particle modeler can show the particles moving around like the Thermoscope shows.]*
    - *Remember how we learned earlier in our lesson that things can be modeled in different ways? Just like the Earth can be modeled with a map or a globe? The particles that make up water can be modeled using the*
        - *Thermoscope,*
        - *the drawings you created, or*
        - *the Particle Modeler*
38. Ask the children to make another prediction:
    - *What do you think will happen to the particles that make up the water when you mix cold and warm water together?*
    - *Use your **Particle Modeler** to show what you think will happen when the cold and warm water have mixed.*

- *What do you think will happen to the particles that make up water when you mix the cold water and the warm water?* Allow an opportunity for a few children who may want to share their predictions to share and explain why they predicted the model they made.
- *Why do you think that will happen?*

> **Teacher Note**
>
> It is important to emphasize to children that ***scientists make predictions all the time***, and their predictions are not always the same as what we will observe—and that's OK! Children might not want to make a prediction because they think they will be wrong. A prediction is simply what you think will happen. After making a prediction, you can modify your prediction based on what you observe and think about how your observation is different from your prediction and why. It's part of learning. ☺

39. Let's see what happens. With the probe in the warm water, very slowly pour some of the cold water into the warm water.

40. Ask the children for their observations.
    - *What happened to the particles that make up warm water when you mixed in the cold water?* [The particles that make up warm water slow down and the particles that make up cold water speed up. They all end up at the same speed. The particles still stay the same size; they are still close together but not tightly packed.]



41. Allow children to **modify** their model using the Particle Modeler.
    - *How did your prediction compare to your observations?*
    - *If your prediction was different than what you observed, it's completely OK. Now that you have observed what happens, you can use your particle modeler to change your model.*
        - *What kinds of changes would you like to make?*

42. Segue into the short animation, "Land of Bump":
    - *Another way that models can be used is in stories—in pictures of a book or characters in a movie.*

43. Watch "The Land of Bump" as a whole class.

> **Teacher Note**
>
> Emphasize that the Land of Bump shows a ***<u>model</u>*** of the particles, their arrangement and behavior.

44. Lead a brief discussion about the "The Land of Bump" and models:
    - *How were the tiny hot and cold particles modeled in "The Land of Bump"?* ["red hots" and "cool blues"]
    - *What did you learn about the <u>motion</u> of the "red hots" and the "cool blues"?*
    - *Were the "red hots" moving like any of the particles that you saw modeled with the Thermoscope?* [Yes, the warm water.] *Were the "cool blues" moving like any of the tiniest pieces that you saw modeled with the Thermoscope?* [Yes, the cold water.]
    - *What happened when the "red hots" mixed with the "cool blues"?* [Children should notice that the "cool blues" sped up (and became warmer) and the "red hots" slowed down (and became

cooler) until they all were at the same speed—i.e., temperature]

  - The teacher should point out that the animation modeled a *process*, showing what happens when the particles of water at two different temperatures mix.

45. Let the children know that throughout the coming weeks, they will be using the Thermoscope to see models of the particles that make up different materials and the Particle Modeler to make models of those particles.

❖ Children articulate and share what they have learned about models.

46. Student scavenger hunt: Ask small groups or pairs of children to find at least one model in the classroom. Let them know that they will share their models with the class, so they should discuss with their partner:
    - What does the model represent?
    - How is the model similar to what it represents?
    - How is the model different from what it represents?

47. Allow each group to briefly share their models. After every small group has shared a model, ask children to identify something that is:
    - So small that it is hard to see with the naked eye (e.g., a speck of dust, a germ).
    - So large that that it is too big to work with in its natural form (e.g., solar system, a city)
    - Ask them how they might learn more about it and make a model of it (using words and drawing) to share what they know.

48. Share with children that in the coming weeks, *models will be very important to their scientific investigations*. They will be: viewing models, using models, drawing models and describing models.

Encourage children to use the language of models in science learning!

LESSON 2: STATES OF MATTER

Pre-Lesson Preparation

Guiding Questions

1. What are the states (phases) of matter?
2. What characteristics/properties define the states (phases) of matter?
    a. What are the macroscopic properties of each state of matter?
    b. What are the microscopic behaviors and interactions that give rise to the macroscopic properties of each state of matter?

Major Concepts

1. There are three common states of matter that are all around us. They are solids, liquids, and gases.
2. Matter is described and identified by characteristics and properties.
3. Different types of matter can have the same characteristic or property. For example, soil can be brown just like Coke can be brown. Glass can be clear just like water can be clear.
4. Matter can be divided into pieces too small to see. [We will call these pieces "particles". This project uses the term "particle" to refer to the invisible particles that make up matter (molecules/atoms). Smallest particles of matter we cannot see, but they combine to produce the properties that we can see.
5. The defining properties of the three states of matter that we will study include:
    - Liquids:
        i. Macroscopic characteristics:
            - Have no shape of their own;
            - Take the shape of their container and fill to a level. The surface of a liquid in a container is flat, and parallel to the plane of the surface of the Earth;
        ii. Microscopic characteristics:
            - Particles are somewhat close together, but not as close as a solid and not as far apart as a gas;
                1. Particles move around slowly near the bottom the jar; they are not locked into place like particles that make up solids, but they do not move around as quickly as particles that make up gases.

    b. Solids:
        iii. Macroscopic characteristics:
            - Have definite shape;
            - Do not change shape when the solid object moves from one container to another;
        iv. Microscopic characteristics:
            - The particles in a solid are tightly packed (not much space between them);
            - The particles in a solid are in a regular pattern;
            - The particles in a solid jiggle ("vibrate"), but they generally do not move from place to place like the particles in liquids or gases;

    c. Gases:
        v. Macroscopic characteristics:

- Have no shape of their own;
- Have no constant volume; they expand to fill all the space in a container

vi. Microscopic characteristics:

- Particles are well separated and have no regular arrangement;
    i. Particles making up a gas move freely at high speeds. They are not locked into place like particles that make up solids, and they move more quickly than particles that make up liquids;
    ii. There is lots of free space between particles.

6. The properties that we can observe with our eyes (without a microscope) can be explained by the properties of the particles that make up that material (that we can observe with a microscope).
    - The particles in a liquid move around slowly, so they will **move and spread out** to take up the shape of the bottom of container.
    - The particles in a solid are packed tightly together and do not move around in a container (they jiggle or vibrate in place), so they will not change their shape. They keep their shape (i.e., they have a "definite" shape).
    - The particles in a gas move around quickly and are spread apart, so they will move around and spread out to fill all the space in a container.

Learning Goals

Children will be able to

1. state the three phases of matter on Earth, give examples of each state of matter, and verbally explain why the example is the state of matter they claim it is.
2. describe and identify macroscopic level and microscopic (particle) level characteristics and properties of the three states of matter.
3. identify and write about at least one macroscopic and one microscopic characteristic/property that define each of the three states of matter.
4. verbally explain how the microscopic characteristics/properties of particles—the particle behaviors and interactions—relate to macroscopic properties for each state of matter.

Students' Naïve Ideas

1. Gases are not matter because they are invisible.
2. Air is weightless.
3. Some matter (e.g., salt, water) is made up of tiny particles, while some matter (e.g., wood, paper) is continuous.
4. The macroscopic properties of materials (shape, color, texture) are their intrinsic or defining properties.

Materials

For class:

- Flip chart and markers
- Bottle of vegetable oil (big enough for the demonstration)
- Bottle of dish soap (big enough for the demonstration)

- 2 droppers (one for each liquid)
- Wooden blocks (or tree branches) in the following sizes
    - 1 for demonstration ca. 6” long so that children in a large group can easily see
    - 1 for demonstration that is ca. 3” long (half of long block)
    - 1 for demonstration that is ca. 1.5” long
    - Smaller bits and chunks of wooden block that are various sizes but smaller than 1.5” long
    - bags of sawdust
    - a small block for each group
- Stones
    - 1 for demonstration
    - a small stone for each group
- 7 clear containers (preferably identical) for demonstration in which liquids will be divided into consecutively smaller amounts:
    - 4 for the oil: one will hold half of the oil; the other containers will be used to divide the oil in consecutively smaller amounts
    - 1 for the dish soap
    - 1 for the wood
    - 1 for the stone
- Different sizes/shapes of clear containers to show that liquids take the shape of a container of any size/shape
- Gallon size Ziploc© bag filled with air
- Roll of painter’s tape or masking tape

For each group:

- Thermoscope (Only iPads will be used in Lesson 2; probes will not be used.)
- Paper towels for clean up

For each child:

- Science notebook
- Pencil

LESSON 2: STATES OF MATTER

What are the states (phases) of matter?
What characteristics/properties define the states (phases) of matter?

Part A: Liquids

1. Convene children in a large group circle and let them know that today they are going to investigate some materials from everyday life, make observations about the materials, and figure out some patterns about the materials. A sample script is provided below:
   - *Today we are going to observe some materials that you see in your everyday life. You are going to make many careful observations about these materials. Let's start with these materials.*
   - *Here I have a cup (or bottle or beaker) of oil, a piece of wood, a stone, and a bottle dish soap.*
   - *We are going to make observations about these materials and record our observations. Observing means looking closely at something.*
     - *What do you observe about these materials—How are these materials different? How are they alike*?

2. The teacher may wish to keep track of children's responses on the board, with the goal of helping children begin to see that the oil and dish soap are similar to each other and the wood and stone are similar to each other.
   - If children do not spontaneously group the materials into solid and liquid groups, it is fine to prompt the children after giving them some time to discuss the items:
     - *Which materials are similar to each other? Why?*
     - *How could we group items that are similar to each other?*

❖ Defining Matter and Its Characteristics

3. Children may come up with the idea that all of the materials take up space, but if the children do not offer this idea, then at the end of the discussion and after allowing them sufficient time to come up with observations, prompt the children to observe one important similarity among all of the materials:
   - *Do all of these materials take up space?* [yes]

4. Make sure to write on both charts "takes up space" and explain:
   - *Anything that takes up space is called <u>matter</u>.*
     Since all of these materials take up space, they are all matter. Oil is matter; dish soap is matter; wood is matter; and a stone is matter.

> **Teacher Note**
> After eliciting children's descriptions of the materials, it is important to ask children a series of questions to help them recognize the defining characteristics of the materials. They likely will not spontaneously come up with these characteristics, so it is important to engage them in questions and observations:
> *a. Does [material] take up space?*
> *b. What happens when we pour [material] into a container?*

5. Next, if a child has stated that the oil and the dish soap can pour, then use their observation as a natural segue to pouring the oil and the dish soap in a different container to begin a discussion about "shape". If the children have not said anything about pouring the liquids, the teacher may prompt the children:
   - *What do you think will happen when I pour each of these materials (the oil and the dish soap) into another container?* [Allow time for children to predict what they think will happen.] *Let's see what happens.*

6. Pour the oil from its current container into a different clear container. Then, pour the dish soap from its current container into a different clear container (for children to see that the materials take the shape of their new container). Ask,
   - *What did you observe?* [Children should observe that the oil and the dish soap took the shape of the containers, although they will most likely not express it in those terms. They may say that the oil/dish soap "spreads out" or "goes to the bottom of the container."]
   - If the children do not say something like the oil/dish soap "spreads out" or "goes to the bottom of the container", ask them if they saw the oil and the dish soap "spread out" and the oil and dish soap "go to the bottom of the container."
   - *You may want them to predict what will happen to the oil and dish soap when you pour each into yet* ***another container of a different shape than the first containers****—e.g., a tall glass or graduated cylinder and a small square container. They should predict the oil and dish soap will take the shape of whatever container it is poured in. If they still do not see the patterns, you can try yet another container.*

Teacher Note

An important feature in the design of science instruction with young children is the use of ***patterns***. Scientists look for patterns in order to classify and organize things into systems. Patterns help children learn to sequence, compare and contrast, and make predictions.

7. Then, focus on the wood and the stone by asking:
   - *What do you think will happen when I move each of these materials (the wood and the stone) into a container?* [Allow time for children to predict what they think will happen.]
   - *Let's see what happens.*

8. Move the wood into a container that is similar to containers used for the liquids. Then, move the stone into a different container for children to see that these materials do not change their shape to take the shape of their new container. They are different than the oil and the dish soap because the wood and the stone stay the same shape no matter what container we put them in.
   - *What did you observe?* [Children should observe that the wood and the stone stayed the same shape; they did not take the shape of the container, although they will most likely not express it in those terms.]
   - If the children say that the wood and the stone also "go to the bottom of the container", acknowledge their ideas and ask: *Yes, they both go to the bottom of their containers. How are the wood and stone different than the oil and the dish soap?* [Children should say that the wood and stone do not spread out at the bottom—i.e., do not change shape. If they do not offer a response similar to this, it is a good strategy to ask them if the wood and stone spread out or changed shape.]

9. Add these observations to your charts:
   - ❖ The oil and dish soap do not have a definite shape, but they changed their shape to take the shape of the container.
   - ❖ The wood and the stone have a definite shape and did not change shape when they were put in different containers.

Teacher Note

This part of the lesson is important because children are learning about the *macroscopic* characteristics of matter. Later, they will learn how the macroscopic characteristics result from the microscopic particle arrangement and behavior.

10. Have the children summarize the characteristics of the materials they have observed so far by asking:
    - *So, what have we learned so far about these materials? What are the characteristics that we can* ***see****?* Allow children to share their ideas. You may wish to make a chart, so that you can refer to the characteristics later in the lesson (see examples to the right). In the end, they should come up with:
      - All of the materials take up space.
      - The oil and dish soap do not have a definite shape, but they changed their shape to take the shape of the container.
        - If children have not been using the term "liquids", this would be a good time to let them know:
        - *We call materials that do not have a definite shape but change their shape to take the shape of the container, "liquids."*
      - The wood and the stone have a definite shape and did not change shape when they were put in different containers.
        - If children have not been using the term "solids", this would be a good time to let them know:
        - *We call materials that have a definite shape, and do not change their shape, "solids."*

Liquids
(examples: oil and dish soap)

- Change shape; do not have a definite shape
- Take the shape of their container
- Take up space

Solids
(examples: wood and stones)

- Do not change shape; have a definite shape
- Do not take the shape of their container
- Take up space

❖ Investigating Liquids: Oil

11. Introduce the investigation:
    - *We just looked at characteristics of oil and dish soap that we were able to see with our eyes. What do you think oil and dish soap are made of? Imagine the tiniest pieces of oil or dish soap—what do you think those pieces look like?* [Children may relate their experience with the Thermoscope in the models and modeling lesson—i.e. because the water was made up of the tiny particles, oil must be made out of tiny particles. If so, acknowledge the connection (e.g., "That's a really good reason for your prediction")
    - Let children know that they are going to do a little activity to observe "what we can see with our eyes" to "what we cannot see with our eyes"—a ***model*** of the particles that make up the materials.

12. Perform a demonstration in which you show children consecutively smaller and smaller portions of oil and prompt them to think about the smallest possible "pieces" or particles that make up oil:
    - *Take our bottle of **oil** (show the oil). If I divide this amount of oil in half, it looks like this (show half). If I divide that **oil** in half, it looks like this (show 1/4). If I divide it in half again, it looks like this (show 1/8). If I keep dividing in half and dividing in half, we will eventually have tiny **oil** drops (show a drop of oil).*
    - *What do you think will happen if I keep dividing this tiny droplet of **oil** in half, and then in half again, and then in half again, and so on?* [Allow time for children to express their ideas.]
    - ***Do you think the particles that make up oil still exist even if we cannot see them?***
    - *The Thermoscope can help us see a **model** of the particles (tiniest pieces) of oil, just like it helped us see the particles that made up water.*
    - *Remember how we talked about scientists using **models** to represent things that are too big or too small to see? They use models to examine things that are too big for a room (like the solar system or a building or a storm) or too tiny to see (like the particles that make up oil).*
    - *Would you like to see the particles that make up **oil**?*

Teacher Note

This brief demonstration is a "thought experiment" for the children. The goal is to try to get them to imagine a progression to the teeniest, tiniest pieces that we cannot see with our eyes, but they still take up space.

Teacher Note

Be careful to say: "**The particles that make up** oil (or whatever substance they are investigating)" and not "oil particles. "

13. Have children break into their small groups. ***Before using the Thermoscope*** app on the iPad, allow children time to imagine and draw in their science notebooks *what they think* they may see when they use the Thermoscope to see what **oil** is made up of:
    - *In your student notebook on page 4, draw in the green circle what you think you will see on the Thermoscope screen—what will the Thermoscope model look like?*

14. The teacher should walk around to each of the small groups to listen to children's ideas, encourage them to discuss their ideas with each other, and ask them questions to elaborate when appropriate. Allow some children to share their ideas with the class. This is a good opportunity to ask children:
    - *What should we look for in the Thermoscope model? What kinds of features did we see with the model of particles that make up water?*
    - *If children need some prompting, feel free to add: How do the particles move? How are they arranged?*

Teacher Note

Teachers may walk around to groups and write in children's ideas below their pictures. Simply ask them: *Tell me about your **model*** or *tell me about what you drew.* Write down word-for-word what the child says. Do not paraphrase, add or delete from their ideas.

THERMOSCOPE INSTRUCTIONS

<u>Before Class</u>:

- Connect each iPad to Wi-Fi.
- Open the Thermoscope app if not already open on the iPad.
- Make sure the home screen is visible.
- Choose the icon that shows a bottle of oil and a bottle of dish soap.
- Hide the models by tapping the small icons showing an eye with a line through it.
- The temperature should remain around 24C or 76F.

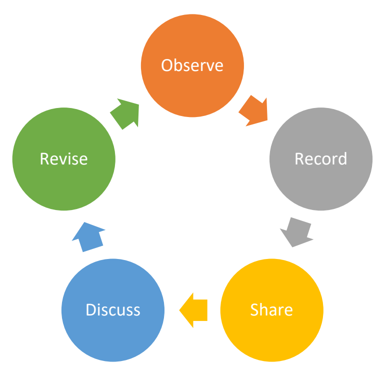
<u>In class:</u>

- When ready to view the oil model, children should tap on the eye icon to the left of the hand lens for oil.

15. Using the Thermoscope app on their iPad, have each small group of children tap the eye to the left of the hand lens for oil and observe on the screen the model of particles that make up oil. ***Note that children do not need the probe for this activity.*** Ask children to discuss with their small group or partner:
    - *What do you see on the screen? What words would you use to describe what you see?*

16. Have the children draw and write about their observations of the Thermoscope **model** of the particles that make up oil in their science notebooks. Give them time to carefully observe the motion and draw.
    - *In your student notebook on page 5, draw what you see in the green circle.*

17. *Describe in your science notebook what you observe (what you see) about the particles. What are some things that you see?* [Children may say: There are many particles. They are close together. They are moving or bouncing around. They are all the same size.]
    - Prompt children to compare: *How does the Thermoscope model compare to your prediction? What are some similarities? What are some things that you see in the Thermoscope model that you did not have in your prediction?*



18. Back in the circle, in a large group discussion, have children share their pictures and descriptions of the **model** of particles that they saw on the Thermoscope.
    - *Who would like to share their **model**?*
        - *Tell us about your **model.*** [Children may say: There are many particles. They are close together. They are moving or bouncing around.]
        - *What are the circles/spheres*

Teacher Note

Children may not understand that the circles/spheres are modeling particles that make up <u>**oil**</u>. Therefore, it is crucial to ask these questions. Having children share their models is an opportunity for you and the other children to provide feedback.

***modeling**? [Particles (that make up oil)]*
    - *If they do not refer to oil, ask: What do the particles make up? The particles make up the oil.*

19. Some characteristics that the children may identify include:
    - Particles are close together.
    - Particles move or bounce around.
    - The particles are the same size as each other.
    - If children do not identify these characteristics, it is okay to prompt them with questions. Rather than pointing out what may be wrong with their drawings, prompt children to go back and compare their drawing to the Thermoscope model. Example questions:
        - *What do you notice about the arrangement (or spacing) of the particles? Are the particles far apart or close together in the Thermoscope model? How does your model compare to the Thermoscope model?*
        - *What do you notice about the movement of the particles? Are the particles in the Thermoscope model moving? What are some words we can use to describe their motion? How are the particles moving in your model?*
        - *What do you notice about the size of the particles? Are the particles in the Thermoscope model different sizes or the same size? How does that compare with your model?*

20. Ask the children if they have not spontaneously offered "take up space" as a characteristic:
    - *Do the particles that make up oil take up space?* [Yes]
    - *How do you know?* [The model shows us that they take up space. Even though they are teeny, tiny, and too small to see, each particle still takes up a teeny tiny bit of space.]

21. *Allow children the opportunity to revise/refine their observation drawing based on the discussion.*

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

❖ Investigating Liquids: Dish Soap

22. Continue the investigation with the **dish soap**.
    - *We said earlier that the oil and the dish soap have similar characteristics. For example, they both take up the space of the container in which we pour them. Do you think the particles that make up the dish soap will be similar or different from the particles that make up oil? Let's find out!*
        - *Would you like to explore the **dish soap** with the Thermoscope?*
        - *What do you think you will see when we look at the **dish soap** with the Thermoscope?*

23. **Before using the Thermoscope**, allow children time to imagine and draw in their science notebooks *what they think* they may see when they use the Thermoscope app on the iPad to see what **dish soap** is made up of:
    - *In your student notebook on page 6 in the green circle, draw your prediction—what you think you will see—in the Thermoscope model of dish soap.*

24. The teacher should walk around to each of the small groups to listen to children's ideas, encourage them to discuss their ideas with each other, and ask them questions to elaborate when appropriate.

Teacher Note

Teachers may walk around to groups and write in children's ideas below their pictures. Simply ask them: *Tell me about your **model*** or *tell me about what you drew.* Write down word-for-word what the child says. Do not paraphrase, add or delete from their ideas.

25. If time permits, have a large group discussion in which children describe their predictions. Use this discussion as a springboard to help children focus on their upcoming observation:
   - *You have expressed several good ideas [name a few]. Next we will make our observation on the Thermoscope. Let's make sure we look for [name some features that students mentioned in their predictions, questions that need to be resolved. For example, if a child predicts that the particles that make up dish soap will move much slower or faster than the particles that make up oil, the speed of particles would be something that the children could make sure to examine.]*

THERMOSCOPE INSTRUCTIONS

<u>Before Class</u>:
- Connect each iPad to Wi-Fi.
- Open the Thermoscope app if not already open on the iPad.
- Make sure the home screen is visible.
- Choose the icon that shows a bottle of oil and a bottle of dish soap.
- Hide the models by tapping the small icons showing an eye with a line through it.
- The temperature should remain around 24C or 76F.

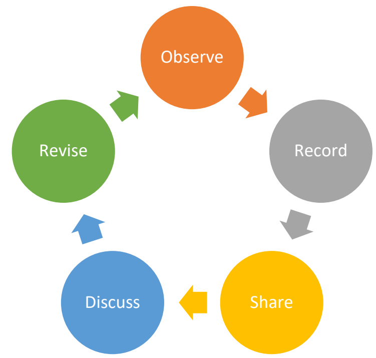
<u>In class:</u>
- When ready to view the dish soap model, Children should tap on the eye icon to the right of the hand lens for dish soap.

26. Using the Thermoscope app on their iPad, have each small group of children tap the eye to the right of the hand lens for dish soap and observe on the screen the model of particles that make up dish soap. Ask children to discuss with their small group or partner:
   - *What do you see on the screen?*
   - *What words would you use to describe what you see?*
   - ***How does the Thermoscope model differ from what you predicted?***
      - When children compare their predictions to the Thermoscope model, it offers the teacher a chance to emphasize features of the model.
   - *How are the particles that make up dish soap **the same as** the particles that make up oil?* [They are close together and bump into each other. They are the same size.]

27. Have the children draw and write about their observations of the Thermoscope model of particles that make up dish soap in their science notebooks on page 7. Give them time to carefully observe the motion and draw.
   - *In your student notebook on page 7, draw in the green circle what you see/observe.*

- *Describe what you observe (what you see) about the particles in your science notebook. What are some things that you see?* [Children may say: There are many particles. They are close together. They are moving or bouncing around. They are the same size as each other.]

28. In a large group discussion, have children share their pictures and descriptions of the particles that make up dish soap that they saw from the Thermoscope. They should be able to articulate that the particles that make up dish soap look just the like the particles that make up oil.
    - o *How are the particles that make up dish soap **similar** to the particles that make up oil?* The children should note that like the particles that make up oil, the particles that make up dish soap:
        - o are close together.
        - o move or bounce around (slowly).
        - o take up space.



- If children do not identify these characteristics, it is okay to prompt them with questions. Rather than pointing out what may be wrong with their drawings, prompt children to go back and compare their drawing to the Thermoscope model. Example questions:
    - o *What do you notice about the arrangement (or spacing) of the particles? Are the particles far apart or close together in the Thermoscope model? How does your model compare to the Thermoscope model?*
    - o *What do you notice about the movement of the particles? Are the particles in the Thermoscope model moving? What are some words we can use to describe their motion? How are the particles moving in your model?*
    - o *What do you notice about the size of the particles? Are the particles in the Thermoscope model different sizes or the same size? How does that compare with your model?*
- *How do the particles that make up dish soap **differ from** the particles that make up oil?*
    - o There are no substantive differences.

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

29. ***Allow children the opportunity to revise/refine their observation drawing based on the discussion.***

30. Ask the children,
- *Do the particles that make up dish soap take up space?* [Yes] *How do you know?* [The model shows us that they take up space; even though they are teeny, tiny, each particle still takes up a teeny tiny bit of space.]

31. Lead a discussion in which the children *summarize* what they have been examining in this investigation. Allow them to help you make a list of the characteristics of the particles that make up liquids. Continuing in the large group, let children know:

Teacher Note

This is a critical step in the lesson. Here, the teacher helps the children (1) connect the particle models they made of liquids to the behavior of liquids that children observed at the beginning of the lesson, thereby (2) begin to learn a particle-based definition of liquids.

- ★ *Materials that are made of particles that are close together but move (or bounce) around slowly are a type of matter called* ***liquids****.*
- ★ *Earlier in the lesson, we observed that the oil and dish soap were on the bottom of the container and changed their shape to that of the container—the liquids spread out to take the shape of the container. Now that you have seen/observed models of the particles that make up liquids using the Thermoscope, why do you think liquids spread out in their container?*

Teacher Note

This is a ***KEY IDEA!*** **Help children connect a macroscopic property** (i.e., liquids take the shape of their container) **to the microscopic particle behavior** (i.e., the particles move around and bump into each other; they will bump into each other and take up the space that they have at the bottom of the container.

32. Elaborate your chart. You may wish to (1) add more examples (that the children provided); (2) add the particle structure and behavior; and (3) show both the macroscopic properties we can see without models and the microscopic particle structure and behavior we see with models. An example is below:

Teacher Note
Do not use the words "macroscopic" and "microscopic" with children. Instead, use "see with our eyes" or "see without models" and "see with models".

	Liquids (oil, dish soap, water, juice)
Observations without using models	○ Change shape; do not have a definite shape. ○ Take the shape of their container. ○ Take up space.
Observations about particles using models	○ Particles are close together. ○ Particles move and bump into each other.

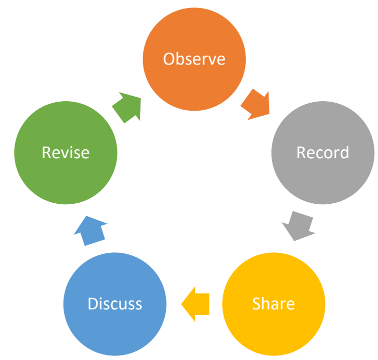
33. *Oil and dish soap are liquids. Can you think of something else that is a liquid?* Allow children to share their ideas about what else is a liquid.

34. Next, ask the children to work with their partner to create a model using the **Particle Modeler** that looks like their observations of the Thermoscope models of particles that make up liquids—oil, dish soap, water (in their science notebooks on pages 3, 5 and 7).

35. After the children have had time to make their model of a liquid with the Particle Modeler, have a large group discussion in which you allow some of the children to share their Particle Modeler model. As children show their models, allow the class to discuss the models— for example,
    - *How does [children's names] Particle Modeler model look like their drawings or the Thermoscope model?* (e.g., Are the particles in the same arrangement? Are they moving

similarly? Are they bumping?

- *How does [children's names] Particle Modeler model look like their drawings or the Thermoscope model?* (e.g., Are the particles in the same arrangement? Are they moving similarly? Are they bumping?)
- [If the Thermoscope model or their drawing looks different from the Particle Modeler model] *What suggestions do you have for [children's names] to revise their Particle Modeler model?*



36. ***Allow children the opportunity to revise/refine their Particle Modeler models of liquids, based on the discussion.***

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

❖ Making a Human Model: Liquids

37. The last model is a human model. Have the children (8-12 children at a time) make a human model of liquids. Ask children:
    - *How do you think you could make a <u>model</u> of liquids if <u>you</u> are the particles that make up a liquid? What would you be doing?* Explain that you have the shape of a container taped off in the room. Ask children to think about how they would model what they saw on the Thermoscope if they were the particles.

38. Mark off a large container shape (rectangle) on the ground with masking tape, leaving an opening on one side, like a jar would have. The marked area represents an open jar. Children will pretend they are matter in the jar. Individuals will be particles of a liquid.

39. Instead of directing the children to make the model, allow the children to develop an initial human model based on the model that they saw on the Thermoscope screen. Begin by prompting them to think about how they will "be" the particles that make up a liquid:
    - *How can you make yourselves behave like the particles you saw on the Thermoscope for oil and dish soap? What were the particles doing?*

40. Then, **allow children who are watching** to offer suggestions to refine the model. The children (and the teacher if needed) may ask probing questions:
    - *What did you notice in the Thermoscope model about the arrangement (or spacing) of the particles that make up the oil or dish soap?* [They are close together but moving (or bouncing) around slowly.] *How are you moving in your human model? How are you arranged? Are you bumping into other particles like the particles in the Thermoscope models?*
    - *When we observed the liquids poured into a container, where did the liquids go?* [Liquids sit at the bottom of a container.] *Even though we could not see the container on the Thermoscope, where do you think the particles in your human model should be*? [Around the bottom of their container.]
    - *When we observed the liquids poured into a container, did the liquids take the shape of the*

container? How can you show that in your human model? [Spread out to take the shape of the jar.]

41. This process may be continued until the class (including the teacher) is satisfied with their human model. If children are having problems generating ideas the activity can be transitioned from student-directed to teacher-directed.

42. After children have made an acceptable model, engage children in a discussion in which they generate a summary of the characteristics of liquid that they modeled.

Part B: Solids

1. If Part B begins on a new day, then ask children to recap Part A of the lesson in a large group. Allow children the opportunity to provide a summary, encouraging them to build on each other's' contributions to the discussion.
   - *Who would like to help us remember what we learned yesterday about the materials we are investigating?*

❖ Investigating Solids: Wood

2. Introduce today's investigation:
   - *Yesterday we looked at characteristics of particles that make up **liquids**, like oil and dish soap. But, we haven't looked at the wood and stone yet. Would you like to investigate the wood and stone?*
   - *How are the wood and stone similar to the oil and dish soap?* [e.g., They take up space. They have weight.]
   - *How are the wood and stone different from oil and dish soap?* [e.g., They do not fill a container; they do not change shape; they have a definite shape]
   - *Do you think the wood and stone are made up of particles like the oil and dish soap? Why do you think so (or why do you think they are not?)*
   - *Remember how we divided the oil in half, and then in half again, and then in half again, and kept dividing it until we had to think about the very tiniest pieces? We can do the same with wood.*

3. Perform a demonstration in which you show children consecutively smaller and smaller portions of wood and prompt them to think about the smallest possible "pieces" or particles that make up wood:
   - *Take out a block of wood (show them the block). If I cut this block in half, it looks like this (show half). If I cut that **block of wood** in half, it looks like this (show 1/4). If I cut it in half again, it looks like this (show 1/8). If I keep cutting the wood pieces in half and cutting in half, we will eventually have small shavings of wood like the shavings in this bag (show them the bag).*
   - *What do you think will happen if I keep cutting a tiny wood shaving in half, and then in half again, and then in half again, and so on?* [Allow time for children to express their ideas.] *Do you think*

Teacher Note

This is another "thought experiment" for the children. Like the one with oil, this activity helps children to begin to think about **scale**—from large, visible pieces to the tiniest, invisible-to-the-naked-eye, single "pieces" or particles that that make up the material.

the particles that make up wood still exist even if we cannot see them?

4. Ask children:
   - *How can we find out?* [Children likely will suggest the Thermoscope.]
   - *The Thermoscope can help us see a **model** of the particles (tiniest pieces) that make up wood, just like it helped us see the particles that make up water, oil, and dish soap.*
   - *Would you like to see the particles that make up **wood**?*

Teacher Note

Be careful to say: "**The particles that make up** wood (or whatever substance they are investigating)" and not "wood particles. "

5. Have children break into their small groups. ***Before using the Thermoscope***, allow children time to imagine and draw in their science notebooks *what they think* they may see when they use the Thermoscope app on the iPad to see what **wood** is made up of.
   - *In your student notebook on page 8 in the green circle, draw your prediction— what you think you will see— in the Thermoscope model of wood.*

6. The teacher should walk around to each of the small groups to listen to children's ideas, encourage them to discuss their ideas with each other, and ask them questions to elaborate when appropriate.

7. If time permits, have a large group discussion in which children describe their predictions. Use this discussion as a springboard to help children focus on their upcoming observation:
   - *You have expressed several good ideas [name a few]. Next we will make our observation on the Thermoscope. Let's make sure we look for [name some features that students mentioned in their predictions, questions that need to be resolved. For example, if a child predicts that the particles that make up wood will move much slower or faster than the particles that make up oil or dish soap, the speed of particles would be something that the children could make sure to examine.]*

THERMOSCOPE INSTRUCTIONS

Before Class:

- Connect each iPad to Wi-Fi.
- Open the Thermoscope app if not already open on the iPad.
- Make sure the home screen is visible.
- Choose the icon that shows a piece of wood and a piece of stone.
- Hide the models by tapping the small icons showing an eye with a line through it.
- The temperature should remain around 24C or 76F.

In class:

- When ready to view the wood model, children should tap on the eye icon to the left of the hand lens for wood.

8. Using the Thermoscope app on their iPad, have each small group of children tap the eye to the left of

the hand lens for wood and observe on the screen the model of particles that make up wood. Ask children to discuss with their small group or partner:

- *What do you see on the screen? What words would you use to describe what you see?*

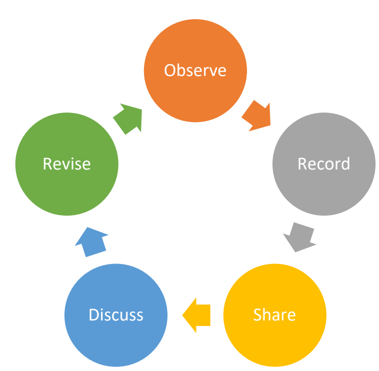
9. Have the children draw and write about their observations of the Thermoscope model of the particles that make up wood in their science notebooks. Give them time to carefully observe the motion and draw.
   8. *In your student notebook on page 9, draw in the green circle what you see in the Thermoscope model.*
   9. *What are some things that you see?* [Children may say: There are many particles. They are packed very close together. They are jiggling, wiggling or vibrating. They do not move around like the particles that make up the oil and dish soap. They stay in place. They are the same size as each other.]
   10. Ask the children,
       - *Do the particles that make up wood take up space?* [Yes] *How do you know?* [The model shows us that they take up space. Even though they are teeny, tiny, and too small to see, each particle still takes up a teeny tiny bit of space.]

10. In a large group discussion, have children share their pictures and descriptions of the particles that make up wood that they saw from the Thermoscope. Children should note that the particles that make up wood:
    - are packed close together.
    - arranged more orderly than particles that make up a liquid.
    - stay in place and jiggle, wiggle, or vibrate.
    - take up space.

Teacher Note

Children may not understand that the circles/spheres are modeling particles of wood. Therefore, it is crucial to ask these questions. Having children share their models is an opportunity for you and others to provide feedback.

i. If children do not identify these characteristics, it is okay to prompt them with questions. Rather than pointing out what may be wrong with their drawings, prompt children to go back and compare their drawing to the Thermoscope model. Example questions:
   - *What do you notice about the arrangement (or spacing) of the particles? Are the particles far apart or close together in the Thermoscope model? How does your model compare to the Thermoscope model?*
   - *What do you notice about the movement of the particles? Are the particles in the Thermoscope model moving? What are some words we can use to describe their motion? How are the particles moving in your model?*
   - *What do you notice about the size of the particles? Are the particles in the Thermoscope model different sizes or the same size? How does that compare with your model?*



- *How do the particles that make up wood **differ from** the particles that make up oil or dish soap?* [The particles that make up wood are very close together and they are arranged neatly, not moving around like the particles that make up liquids; the particles that make up wood wiggle/jiggle/vibrate but stay in place unlike the particles that make up liquids.]

11. *Allow children the opportunity to revise/refine their observation drawing based on the discussion.*

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

❖ Investigating Solids: Stone

12. Continue the investigation with the **stone**.
    - *We said earlier that the wood and the stone have similar characteristics. For example, they both take up the space of the container in which we pour them. Do you think the particles that make up the stone will be similar or different from the particles that make up wood? Let's find out!*
        - *Would you like to explore the stone with the Thermoscope?*
        - *What do you think you will see when we look at the stone with the Thermoscope?*

13. ***Before using the Thermoscope***, allow children time to imagine and draw in their science notebooks *what they think* they may see when they use the Thermoscope app on the iPad to see what the stone is made up of.
    - *In your student notebook on page 10, in the green circle, draw your prediction—what you think you will see—in the model on the Thermoscope.*

14. The teacher should walk around to each of the small groups to listen to children's ideas, encourage them to discuss their ideas with each other, and ask them questions to elaborate when appropriate.

15. If time permits, have a large group discussion in which children describe their predictions. Use this discussion as a springboard to help children focus on their upcoming observation:
    - *You have expressed several good ideas [name a few]. Next we will make our observation on the Thermoscope. Let's make sure we look for [name some features that students mentioned in their predictions, questions that need to be resolved. For example, if a child predicts that the particles that make up the stone will move or be arranged much differently than the particles that make up wood, the speed and arrangement of particles would be something that the children could make sure to examine.]*

THERMOSCOPE INSTRUCTIONS

<u>Before Class</u>:
- Connect each iPad to Wi-Fi.
- Open the Thermoscope app if not already open on the iPad.
- Make sure the home screen is visible.
- Choose the icon that shows a bottle of oil and a bottle of dish soap.
- Hide the models by tapping the small icons showing an eye with a line through it.
- The temperature should remain around 24C or 76F.

<u>In class:</u>
- When ready to view the stone model, children should tap on the eye icon to the right of the hand lens for stone.

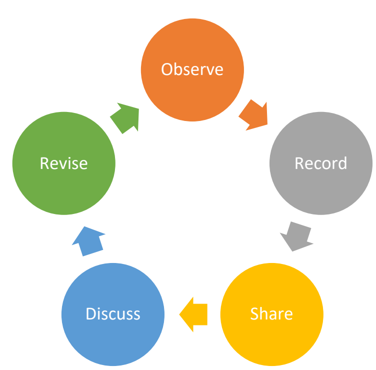
16. Using the Thermoscope app on their iPad, have each small group of children tap the eye to the right of the hand lens for stone and observe on the screen the model of particles that make up stone. Ask children to discuss with their small group or partner:
    - *What do you see on the screen? What words would you use to describe what you see?*

17. Have the children draw and write about their observations of the Thermoscope model of the particles that make up stone in their science notebooks. Give them time to carefully observe the motion and draw.
    - *In your student notebook on page 11, draw in the green circle what you see in the Thermoscope model.*
    - *What are some things that you see?* [Children may say: There are many particles. They are packed very close together. They are jiggling, wiggling or vibrating. They do not move around like the particles that make up the oil and dish soap. They stay in place like the particles that make up wood. They are the same size as each other.]
    - Ask the children,
        - *Do the particles that make up stone take up space?* [Yes] *How do you know?* [The model shows us that they take up space. Even though they are teeny, tiny, and too small to see, each particle still takes up a teeny tiny bit of space.]

18. In a large group discussion, have children share their pictures and descriptions of the particles that make up stone that they saw from the Thermoscope. Children should note that the particles that make up stone:
    - are packed close together.
    - arranged more orderly than particles that make up a liquid.
    - stay in place and jiggle, wiggle, or vibrate.
    - take up space.

Teacher Note
Children may not understand that the circles/spheres are modeling particles of stone. Therefore, it is crucial to ask these questions.

- If children do not identify these characteristics, it is okay to prompt them with questions. Rather than pointing out what may be wrong with their drawings, prompt children to go back and compare their drawing to the Thermoscope model. Example questions:
    - *What do you notice about the arrangement (or spacing) of the particles? Are the particles far apart or close together in the Thermoscope model? How does your model compare to the Thermoscope model?*
    - *What do you notice about the movement of the particles? Are the particles in the Thermoscope model moving? What are some words we can use to describe their motion? How are the particles moving in your model?*
    - *What do you notice about the size of the particles? Are the particles in the Thermoscope model different sizes or the same size? How does that compare*



with your model?

- *How are the particles that make up stone **similar to** the particles that make up wood?* [The particles that make up stone are also very close together and they are arranged neatly, not moving around like the particles that make up liquids; the particles that make up stone wiggle/jiggle/vibrate and stay in place like the particles that make up wood.]

- *How do the particles that make up stone **differ from** the particles that make up oil or dish soap?* [The particles that make up stone are very close together and they are arranged neatly, not moving around like the particles that make up liquids; the particles that make up stone wiggle/jiggle/vibrate but stay in place unlike the particles that make up liquids.]

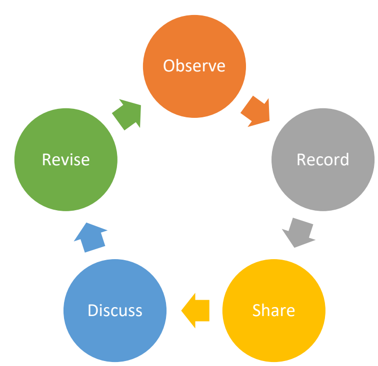
19. *Allow children the opportunity to revise/refine their observation drawing based on the discussion.*

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

20. Next, ask the children to use the Particle Modeler to create a model that looks like their observation of the Thermoscope model of particles that make up stone (in their science notebooks on page 11, in the green circle).

21. After the children have had time to make their model with the Particle Modeler, have a large group discussion in which you allow some of the children to share their Particle Modeler model. As children show their models, allow the class to discuss the models—for example,
    - *How does [children's names] Particle Modeler model look like their drawings or the Thermoscope model?* (e.g., Are the particles in the same arrangement? Are they moving similarly?
    - [If the Thermoscope model or their drawing looks different from the Particle Modeler model] *What suggestions do you have for [children's names] to revise their Particle Modeler model?*



Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

22. *Allow children the opportunity to revise/refine their Particle Modeler models based on the discussion.*

23. Lead a discussion to let children summarize what they have been examining in this investigation. Continuing in the large group, ask students to help you make a list of the characteristics of particles that make up a solid. Then share with them:
    ★ ***Materials that are made of particles that are very close together, arranged in a pattern, and do not move (or bounce) around the container but vibrate in place are a type of matter called solids.***

- ★ *Earlier in the lesson, we observed that the wood and the stone were on the bottom of the container and did not change their shape—the solids stayed the same shape and did not change shape when we put them in a container like the liquids changed shape.*
- ★ *Now that you have seen (using the Thermoscope) models of the particles that make up solids, why do you think solids do not spread out in their container like liquids do? Why do you think solids keep their shape?* [The idea here is to help children connect a macroscopic property (i.e., solids keep their shape in the container) to the microscopic particle behavior (i.e., the particles stay in place and jiggle or vibrate; they do not move around to take up the space that they have at the bottom of the container.]
- *Wood and stones are solids. Can you think of something else that is a solid?*

> **Teacher Note**
>
> *<u>This is a critical step in the lesson.</u>* Here, the teacher helps the children (1) connect the particle models they made of solids to the behavior of solids that children observed at the beginning of the lesson, thereby (2) begin to learn a particle-based definition of solids.

> **Teacher Note**
>
> This is a *KEY IDEA!* **Help children connect a macroscopic property** (i.e., solids do not change to take the shape of their container) **to the microscopic particle behavior** (i.e., the particles stay in place and wiggle/jiggle/vibrate; they stay at the bottom of the container.

❖ Making a Human Model: Solids

24. The last model is a human model. Have the children (8-12 children at a time) make a human model of solids. Ask children:
    - *How do you think you could make a <u>model</u> of solids if you are the particles that make up a solid? What would you be doing?* Explain that you have the shape of a container taped off in the room. Ask children to think about how they would model what they saw on the Thermoscope if they were the particles.

25. Mark off a large container shape (rectangle) on the ground with masking tape, leaving an opening on one side, like a jar would have. The marked area represents an open jar. Children will pretend they are matter in the jar. Individuals will be the particles that make up a solid.

    <u>Student-Directed Model</u>

    Instead of directing children to make the model, allow children to develop an initial human model based on the model that they saw on the Thermoscope screen. Begin by prompting them to think about how they will "be" the particles that make up a solid:
    - o *How can you make yourselves behave like the particles you saw on the Thermoscope for wood and stone? What were the particles doing?*

    Then, **allow children who are watching** to offer suggestions to refine the model. The children (and the teacher if needed) may ask probing questions:
    - o *What did you notice in the Thermoscope models about the arrangement (or spacing) of the particles that make up wood or a stone?* [They are close together but not moving (or bouncing)

around; they stay in place and vibrate.] *How are you moving in your human model? How are you arranged? Are you staying in place and vibrating like the particles in the Thermoscope models?*

- *When we observed the solids as they were placed in a container, what did the solids do?* [Solids sit at the bottom of a container; they did not spread out to take the shape of the container.] *Even though we could not see the container on the Thermoscope, where do you think the particles in your human model should be*? [At the bottom of their container.]

This process may be continued until the class (including the teacher) is satisfied with their human model. If children are having problems generating ideas the activity can be transitioned from student-directed to teacher-directed.

7. After children have made a model with which they are happy, review one more time the characteristics of particles of solids that they modeled and help them make the connection to the characteristics of solids they observed.
   - ***We observed, and you modeled, that the wood and rock were on the bottom of the container and did not change their shape to that of the container—the solids kept their shape. Who would like to explain why you think solids keep their shape?*** [This brief discussion reiterates the connection between a macroscopic property (i.e., solids keep their shape; do not take the shape of their container) to the microscopic particle behavior (i.e., the particles stay in place and vibrate/wiggle/jiggle but do not move around like the particles of liquid).

8. Elaborate your chart for solids. You may wish to (1) add more examples (that the children provided); (2) add the particle structure and behavior; and (3) show both the macroscopic properties we can see without models and the microscopic particle structure and behavior we see with models. An example is below:

	Solids (wood, rock, ice, a coin)
Observations without using models	○ Have a definite shape. ○ Do not take the shape of their container. ○ Take up space.
Observations about particles using models	○ Particles are packed close together. ○ Particles stay in place and do not move around each other. ○ Particles vibrate/wiggle/jiggle.

❖ Review and Summarize Both Liquids and Solids

26. Have children sit in a large group circle. Also, have them bring their science notebooks to use during this large group activity. First, recap what student have learned so far:
    - *From our investigations with the Thermoscope, what did we find out about liquids?*
        - Ideally, their summary will include the following ideas:
            - Liquids are made up of particles that:
                - Are close together
                - Move (or bounce) and bump into each other around slowly
                - Take up space
            - Liquids:
                - Stay at the bottom of their container
                - Spread out to take the shape of their container
                - Are matter
            - Examples of liquids:
                - The oil and dish soap are liquids.
        - *Matter that is made of particles that are close together, and move around and bump into each other are called <u>liquids</u>.*

> **Teacher Note**
>
> These are ***KEY IDEAS!*** As children share characteristics of liquids (and then solids), we recommend writing them on the board. In one column, record the characteristics of the microscopic *particles* of liquids or solids that children articulate, and in the second column, record the characteristics of macroscopic "liquid" or "solid" that children articulate. This will help facilitate the discussion of the connection between the macroscopic and microscopic characteristics of states of matter (next step in lesson).

    - *From our investigations with the Thermoscope, what did we find out about liquids?*
        - Ideally, their summary will include the following ideas:
            - Solids are made up of particles that:
                - Are packed together in a regular pattern
                - Stay in place and vibrate
                - Take up space
            - Solids:
                - Stay at the bottom of their container
                - Do not spread out to take the shape of their container
                - Are matter
            - Examples of solids are:
                - Wood and stones
        - Matter that is made of particles that are very close together, arranged in a pattern, and do not move (or bounce) around the container but vibrate in place are called <u>solids</u>.

27. Next, help children review the connection between the **<u>macroscopic</u>** characteristics to the **<u>microscopic</u>** characteristics. Lead a discussion that begins with liquids:
    - *Let's consider the liquids. What did we observe with our eyes about the oil and dish soap? (teacher should refer back to the poster that has the characteristics of liquids:*
        - take up space but don't have a definite shape;
        - they changed their shape to take the shape of whatever container they are in.
    - *What did we see when we looked at the Thermoscope model of particles that make up liquids? What did you do when you modeled, in our jar on the carpet, the particles that make up liquids?*

[Children should say that the particles are close together but move (or bounce) around slowly at the bottom of their container.]

- *Ok, so we know that the particles are close together, but they move around slowly and bump into each other. They also stay at the bottom of the jar. So, why do you think that a liquid takes the shape of its container?* [The particles in a liquid move around slowly, so they will move and spread out to take up the shape of the bottom of container.]

28. Continue the discussion by focusing on solids:
    - *Now let's consider the solids. Remember we said that the wood and the stone:*
        - *take up space and they have a definite shape;*
        - *they did not change their shape when we put it in a different container.*
    - *What did we see when we looked at the Thermoscope model of particles that make up solids? What did you do when you modeled, in the jar on our carpet, the particles that make up solids?* Children should say that the particles are packed very close together and do not move around; they jiggle in place.
    - *So, why do you think that a solid has a definite shape?* [The particles in a solid are packed tightly together and do not move around in a container (they jiggle or vibrate in place), so they will not change their shape. They keep their shape (i.e., they have a "definite" shape).]

29. Summarize the "big idea":
    ★ ***How the particles of matter move and how they are arranged helps us understand the characteristics of matter.***

30. Segue to the next investigation:
    - *So, we have learned that how the particles of matter move and how they are arranged helps us understand the characteristics of that material.* We learned about liquids, and we learned about solids. But, we have one more type of matter to investigate…

Part C: Gases

1. Introduce the investigation of gases:
    - *I have one more example for us to look at.* Pull out a plastic bag that is blown up with air in it.
    - *What do you think is in the bag? Do you think there is anything in the bag?* [Children may say nothing. They may say yes, there is air in the bag.]
    - *How can we find out if something is in the bag?* Children may say you can press on it, you can open it up to feel something come out, or you can use the Thermoscope. If any child does not think there is something inside, let them press on different parts of the bag to see that it does not go flat.

2. Once all children agree there is something in the bag, ask them:
    - *Does the air take up space? How do you know?* [Children should answer that it takes up space because the bag cannot be pressed down flat without opening the bag and letting what's inside (the air) out.]
    - *So, is the air inside the bag a type of matter?* [Yes.] *Even though we cannot see it?* [Yes, one way we know it is matter is that it takes up space.]

- *Do you think the air is a liquid, a solid, or something else? Why do you think so?* [Allow children to give their ideas.]
- *How can we find out?* [The Thermoscope!]

3. ***Before using the Thermoscope*** app on the iPad, allow children time to imagine and draw in the green circle in their science notebooks on page 12 their prediction–what they think they may see when they use the Thermoscope app on the iPad to see whether air is a solid, liquid or something else. Encourage children to discuss their ideas with each other, and ask them questions to elaborate when appropriate.

4. The teacher should walk around to each of the small groups to listen to children's ideas, encourage them to discuss their ideas with each other, and ask them questions to elaborate when appropriate.

5. If time permits, have a large group discussion in which children describe their predictions. Use this discussion as a springboard to help children focus on their upcoming observation:
   - *You have expressed several good ideas [name a few]. Next, we will make our observation on the Thermoscope. Let's make sure we look for [name some features that students mentioned in their predictions, questions that need to be resolved. For example, if a child predicts that the particles that make up the air will move or be arranged much differently than the particles that make up solids or liquids, the speed and arrangement of particles would be something that the children could make sure to examine.]*

THERMOSCOPE INSTRUCTIONS

Before Class:
- Connect each iPad to Wi-Fi.
- Open the Thermoscope app if not already open on the iPad.
- Make sure the home screen is visible.
- Choose the icon that shows swirls of air.
- Hide the models by tapping the small icons showing an eye with a line through it.
- The temperature should remain around 24C or 76F.

In class:
- When ready to view the air model, children should tap on the eye icon next to either hand lens. The models are the same.

6. Using the Thermoscope app on their iPad, have each small group of children tap the eye next to one of the hand lenses for air and observe on the screen the model of particles that make up air. Ask children to discuss with their small group or partner:
   - *What do you see on the screen? What words would you use to describe what you see?*

7. Ask the children to draw and write about their observations in their science notebooks on page 13:

- *Describe what you observe (what you see) about the particles that make up **air**. What are some things that you see?* [The particles are far apart from one another, farther apart than the particles in a liquid. They are moving around more quickly than the particles that make up the oil and dish soap. They are the same size.]

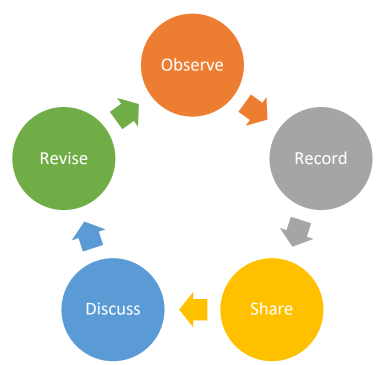
Teacher Note

What if children say something about the number of particles? Children may say that there are fewer particles than they saw with the solid and liquid. While they may *see* fewer particles in the lens, there are not necessarily fewer particles that make up gas. The model can show only so many particles of gas at once in the circle because the particles are much farther apart.

- *Is air matter? How do you know?* [Yes, it takes up space (even though we cannot see it), so it is matter.]

8. In a large group discussion, have children share their pictures and descriptions of the particles that make up air that they saw from the Thermoscope. Children should note that the particles that make up air:
   - are far apart, much more than liquids.
   - move around quickly and bump each other.
   - take up space.

- If children do not identify these characteristics, it is okay to prompt them with questions. Rather than pointing out what may be wrong with their drawings, prompt children to go back and compare their drawing to the Thermoscope model. Example questions:
   - *What do you notice about the arrangement (or spacing) of the particles? Are the particles far apart or close together in the Thermoscope model? How does your model compare to the Thermoscope model?*
   - *What do you notice about the movement of the particles? Are the particles in the Thermoscope model moving? What are some words we can use to describe their motion? How are the particles moving in your model?*
   - *What do you notice about the size of the particles? Are the particles in the Thermoscope model different sizes or the same size? How does that compare with your model?*



- *How are the particles that make up air **similar to** the particles that make up oil, dish soap, stone, and wood?* [They take up space; they are the same size.]

- *How do the particles that make up air **differ from** the particles that make up oil, dish soap, stone, and wood?* [The particles that make up air are far apart and they move around quickly, bumping each other. The particles that make up liquids don't move around as fast and are closer together; the particles that make up solids wiggle/jiggle/vibrate but stay in place.]

9. *Allow children the opportunity to revise/refine their observation drawing based on the discussion.*

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

- *From our investigations of the solids and liquids, do you think air is a solid or a liquid or something else?* [If children say it is a solid or it is a liquid, ask them about their observations; for example, *we saw that the particles of a solid are packed close together and just jiggle. Did the particles in the air do that? How were they different?*]

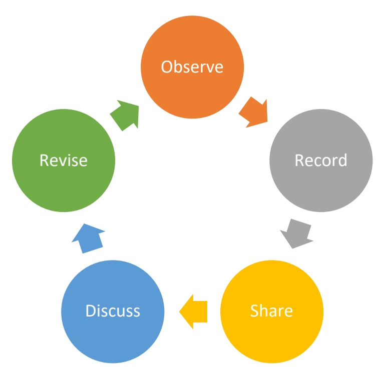
10. Continuing in the large group, let student know:
    - ★ ***Materials that are made of particles that move around quickly, bump into each other and have a lot of space between particles are a type of matter called <u>gases</u>.***
    - ★ ***Earlier in the lesson, we observed that the air took up all of the space in the bag—the gas spread out to take the shape of its container (the bag). Now that you have seen (using the Thermoscope) a model of the particles that make up a gas, why do you think gases spread out in their container?*** [The idea here is to help children connect a macroscopic property (i.e., gases spread out to take up all of the space in their container) to the microscopic particle behavior (i.e., the particles move around quickly, bump into each other, and move far apart; they will bump into each other and take up all of the space that they have in the container.)
    - *Air is a gas. Can you think of something else that is a gas?* [Children may be familiar with helium because of <u>helium</u> balloons. They may have seen someone breathing with assistance from an <u>oxygen</u> tank.]

Teacher Note

This is a *KEY IDEA!* Help children **connect a macroscopic property** (i.e., gases spread out to take up all of the space in their container) **to the microscopic particle behavior** (i.e., the particles move around quickly, bump into each other, and move far apart; they will bump into each other and take up all of the space that they have in the container).

11. Next, ask the children to use the Particle Modeler to create a model that looks like their observation of the Thermoscope model of particles that make up air (in their science notebooks on page 13, in the green circle).

12. After the children have had time to make their model with the Particle Modeler, have a large group discussion in which you allow some of the children to share their Particle Modeler model. As children show their models, allow the class to discuss the models— for example,
    - *How does [children's names] Particle Modeler model look like their drawings or the Thermoscope model?* (e.g., Are the particles in the same arrangement? Are they moving similarly?
    - [If the Thermoscope model or their drawing looks different from the Particle Modeler model] *What suggestions do you have for [children's names] to revise their Particle Modeler model?*



13. Allow children the opportunity to revise/refine their Particle Modeler models, based on the discussion.

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

❖ Making a Human Model: Gases

14. The last model is a human model. Have the children (8-12 children at a time) make a human model of gases. Ask children:
    - *How do you think you could make a* <u>*model*</u> *of gases if you are the particles that make up a gas? What would you be doing?* Explain that you have the shape of a container taped off in the room. Ask children to think about how they would model what they saw on the Thermoscope if they were the particles.

15. Mark off a large container shape (rectangle) on the ground with masking tape, leaving an opening on one side, like a jar would have. The marked area represents an open jar. Children will pretend they are matter in the jar. Individuals will be the particles that make up a gas.

<u>Student-Directed Model</u>

Instead of directing children to make the model, allow children to develop an initial human model based on the model that they saw on the Thermoscope screen. Begin by prompting them to think about how they will "be" the particles that make up a gas:

- *How can you make yourselves behave like the particles you saw on the Thermoscope for air? What were the particles doing?*

Then, **allow children who are watching** to offer suggestions to refine the model. The children (and the teacher if needed) may ask probing questions:

- *What did you notice in the Thermoscope models about the arrangement (or spacing) of the particles that make up air?* [They are far apart, moving quickly; bumping into each other; taking up all of the space in the container.] *How are you moving in your human model? How are you arranged? Are you staying in one place or moving all around the container and bumping other particles like the particles in the Thermoscope models?*
- *When we observed air in a container, where was the air?* [The air was spread out to take up the space in the entire container.] *Even though we could not see the container on the Thermoscope, where do you think the particles in your human model should be*? [all over their container.]
- *What do you think the air particles will do if we take the lid off?*

This process may be continued until the class (including the teacher) is satisfied with their human model. If children are having problems generating ideas the activity can be transitioned from student-directed to teacher-directed.

9. After children have made a model with which they are happy, engage children in a discussion in which they generate a summary of the characteristics of gases that they modeled.
    - Create a chart for gases. You may wish to (1) add more examples (that the children provided); (2) add the particle structure and behavior; and (3) show both the macroscopic properties we can

see without models and the microscopic particle structure and behavior we see with models. An example is below:

	Gases (air, helium)
Observations without using models	○ Do not have a definite shape. ○ Fill up the shape of their container. ○ Take up space.
Observations about particles using models	○ Particles are far apart. ○ Particles move quickly all around and bump into each other.

Part D: Wrap-Up

1. Bring all of the materials (bottle of oil, dish soap, wood, stone, and bag of air) in front of the group. Lead a discussion in which the children compare and contrast all of the materials, noting the defining characteristics of each state of matter.
    - *We have been examining all of these materials:* oil, dish soap, wood, stone, and air.
    - *We found out that*
        - *the oil and dish soap are liquids*
        - *the wood and the stone are solids*
        - *and the air is a gas.*
    - *How are all of these materials the same?* [They all take up space; they are all matter. They are all made of particles.]
    - *How are solids and liquids similar?* [The particles in both stay at the bottom of the container.]
    - *How are liquids and gases similar?* [They both take the shape of their container; the particles in liquids and gases move around.]
    - *How are solids, liquids and gases different?*
    - *We have been learning about solids, liquids, and gases. Anything that is a solid, liquid or gas takes up space and is made of teeny, tiny particles that we cannot see with only our eyes (we need some kind of tool like a Thermoscope). Solids, liquids, and gases are all types of matter. Scientists call them "states" or "phases" of matter.*

2. Let's put it all together! On Page 14, ask the children to draw their final model of
    - the particles that make up a solid
    - the particles that make up a liquid
    - the particles that make up a gas

❖ Scavenger Hunt: Optional

3. Tell children that they are going to be on a scavenger hunt. Each pair of children will get a card that identifies one state of matter. The pair should hunt around the room for one example of the state of matter listed on their card.

4. When a pair has found an example of their state of matter, they should come back to the circle and quietly discuss with each other why they think their example is a solid, liquid, or gas (what are the characteristics?).

    - One option at this stage is to have the pair make a model of their state of matter using the Particle Modeler.
    - Another option at this stage is to have the children choose (from a set of laminated cards) the appropriate state of matter card and the appropriate particle model card.

5. When all pairs are ready, allow each of the pairs to share the state of matter on their card and the example they found in the room. Ask each pair to explain how they know their example is an example of the state of matter on the card. The other children can ask questions if they would like. Finally, ask the pair to identify the particle model that corresponds to their example (using the laminated cards with the particle models). *Does the class agree*?

APPLICATION ACTIVITY: PHASE CHANGES (Melting)

Pre-Activity Preparation

Guiding Questions

1. How does temperature relate to states of matter?
2. How do states (phases) of matter change from one to another?
    a. What happens to the arrangement and movement of particles in a solid when the temperature increases?

Major Concepts

1. Changes in the states of matter occur when the temperature of matter changes.
2. There are specific temperatures at which substances change phase:
    a. Solids melt into liquids when the temperature increases because their particles begin to vibrate more quickly, the tightly packed begin to particles loosen and the space between particles increases. The particles move around more freely across space and are arranged in a less orderly pattern.

Learning Goals

Children will be able to:

1. identify a model of particles from a hot material (higher temperature; contains fast moving particles).
2. identify a model of particles from a cold material (lower temperature; contains slower moving particles).
3. state that matter changes when its temperature changes.
4. draw a particle model (and/or use the particle modeler) and verbally explain why solids melt into liquids when the temperature increases.

Children's Naïve Ideas

1. Matter expands when heated because the particles that make up matter expand. (More accurate: Matter expands when heated because the particles (i.e., molecules) vibrate more quickly, loosen the bonds, and increase the space between particles.)

Materials for Pre-Lesson

For class:

- Roll of painter's tape or masking tape

For each group:

- ☐ 6-cup cupcake tin
- ☐ Plastic bin or cake pan in which the cupcake tin will fit
- ☐ 2 plastic stirrers
- ☐ 1 small scoop of coconut oil (>1/8 tsp)
- ☐ 1 chocolate chip
- ☐ 1 Lego
- ☐ Foil pan
- ☐ Cup of very warm water
- ☐ Thermoscope set
- ☐ Paper towels for clean up

- ☐ **For each child:**
- ☐ Science notebook
- ☐ Pencil

APPLICATION ACTIVITY: PHASE CHANGES (Melting)

How does temperature relate to states (phases) of matter?
How do states (phases) of matter change from one to another?

Overall Opening

Convene the children in a large group. Introduce the upcoming investigation:

- *Over the last few days, we have been investigating **states of matter**—solids, liquids, and gases. You observed some characteristics that are visible (that we can see with our eyes) and you observed some characteristics that we need to use the Thermoscope models to see—the particles that make up matter.*
- *Have you ever noticed that materials can **change** from one state of matter or another state of matter? Let's think of some examples:*
    - *What happens when you take a scoop of ice cream outside on a hot day?*
    - *What happens to candle wax when we light the wick?*
- *What are some other examples you can think of?* [If children cannot think of anymore, it is okay to move on.]
- *In our last investigation, we will see how matter changes from one state to another.*

❖ Melting

1. Tell the children they will be working with some solids. Show them the cupcake tin with the materials that each group will have at their table. Name the materials: (1) solid coconut oil, (2) a Lego block, and (3) a chocolate chip.

2. Ask the children to name the materials, and then help them use their knowledge of solids to answer:
    - *Based on what we have investigated over the last few days, do you think these items are all solids? How do you know?* [They don't change shape and they stay at the bottom of the container.]
3. As a reminder, ask children to draw in their notebooks on **page 15** the model of solids they learned in the previous lesson. Children should note that the particles that make up solids:
    - are packed close together.
    - arranged more orderly than particles that make up a liquid.
    - stay in place and jiggle, wiggle, or vibrate.
    - take up space.

4. The lead into the predictions:
    - *What do you think will happen when we increase the temperature of these materials—of solids?*
    - If children do not know what "increase temperature" means, let them know if means "get warmer." The higher the temperature, the warmer it is. Allow children to provide some of their ideas.

5. Provide children with the rules/guidelines for the investigations:
    - *First, you will write what you think will happen—our predictions—when we warm (increase the temperature of) the coconut oil, Lego, and chocolate chip.*

- *Then, you are going to see—observe--what happens to these solids when we increase the temperature. To increase their temperature, we will use very warm water. We will have to be very careful.*
- *A helper or I will come around and set the cupcake tin in container that has very warm water.* ***You are not allowed to touch the very warm water, and you are not allowed to touch the sides of the plastic bin where the very warm water is. Only the bottom of the cupcake tins can touch the water.***
- ***Also, you may not eat or even take a tiny taste of any of the materials!!***

6. Have children break into their small groups to make predictions on page 16 of their science notebooks. Each group will have at their table a cupcake tin with three materials in the cups: (1) solid coconut oil, (2) a Lego block, and (3) a chocolate chip.
   - *First, we will make our predictions. So, I would like everyone to go to their group's table and turn to the page* ***16*** *in your science notebook and look at the green circles.*
     - *What do you think will happen to the particles that make up* **coconut oil** *when we increase the temperature? (when it gets hotter?) Draw in the green circle for coconut oil what you think will happen (your prediction) to the particles that make up coconut oil when we increase the temperature.*
     - *What do you think will happen to the particles that make up a* **Lego block** *when we increase the temperature? (when it gets hotter?) Draw in the green circle for a Lego block what you think will happen (your prediction) to the particles that make up a Lego block when we increase the temperature.*
     - *What do you think will happen to the particles that make up a* **chocolate chip** *when we increase the temperature? (when it gets hotter?) Draw in the green circle for chocolate chip what you think will happen (your prediction) to the particles that make up a chocolate chip when we increase the temperature.*

7. The teacher should walk around to each of the small groups to listen to children's ideas, encourage them to discuss their ideas with each other, and ask them questions to elaborate when appropriate.

8. Have a large group discussion in which children describe their predictions. Use this discussion as a springboard to help children focus on their upcoming observation:
   - *You have expressed several good ideas [name a few]. Next, we will make our observation on the Thermoscope. Let's make sure we look for [name some features that students mentioned in their predictions, questions that need to be resolved. For example, if a child predicts that the Lego will not melt but the rest will, then children can focus on which ones melt and which ones do not.*

9. After children have had time to confer with their partners and record their predictions, measure the temperature of the water.
   - *Let's measure the temperature of the water. How do we know the water is very warm?*

10. Put the cupcake tin in a bin with approximately an inch of warm water. Have children observe what happens to the different materials.
    - *Observe the materials as they sit in the tub of warm water. You may use a coffee stirrer (or toothpick) to gently move the material to see if anything is happening. However, you may not use the coffee stirrer (or toothpick) for anything else.* ***Do not poke anyone.***

11. When the coconut oil has melted, and the chocolate has softened, ask children about their observations:
   - *What changes did you observe?* [The coconut oil turned to liquid; the chocolate chip became soft and like at thick liquid; the Lego stayed the same.]
   - *Which materials changed?* [The coconut oil, chocolate chip]
   - *How did they change?* If children do not note that some of the materials changed from solid to a liquid, you may wish to prompt them:
     - *We observed that the materials started out as a solid. What state of matter is the coconut oil now? The chocolate chip is changing, too. Is it still all solid?*

Teacher Note

Depending on the temperature of the water, the brand of materials, and how long the children let the solids melt, the chocolate chips may soften but not melt completely.

Teacher Note

The **rate** of melting is not important. It is okay if children mention something about how fast each material melts, but do not emphasize this point.

12. In a whole class discussion, link the phenomenon that children observed to the science term "melting":
   - *When a solid changes into a liquid, we say that the solid* ***melts****. The process is called* ***melting****.*
   - *How do we know when a solid has melted?* [The solid material changes to liquid.]
   - *What caused the solid to melt?* [We increased the temperature.]
   - *Did all of the materials melt?* [No, the Lego did not melt. The chocolate chip did not melt completely, but it got soft.] *Why do you think they did not all melt*? [It wasn't hot enough for the Lego to melt.]
   - *Would you like to use a Thermoscope to figure out why things melt?*

13. Each group will use the Thermoscope to see what happens when solid coconut oil melts.

THERMOSCOPE INSTRUCTIONS

Before Class:

- Connect each iPad to Wi-Fi.
- Open the Thermoscope app if not already open on the iPad.
- Make sure the home screen is visible.
- Choose the icon that shows coconut oil.
- Hide the model by tapping the small icons showing an eye with a line through it.
- The temperature should remain around 21C or 70F.

In class:

- When ready to view the coconut oil model, children should tap on the eye icon to the left of the hand lens.

14. The teacher will walk to each group and do the following:
    - Remove the cupcake tin from the water and place it on paper towels.
    - By the time the teacher has gone around to each group once, the cupcake tin should have cooled on the paper towel.
    - The teacher then will walk around a second time and place a teaspoon of coconut oil in an empty cup of the cupcake tin.

15. Once the teacher has provided a teaspoon of coconut oil to each group, the children will put Probe A into the coconut oil and observe on the Thermoscope screen the model of particles that make up **solid** coconut oil. Ask children what they see on the Thermoscope screen:
    - *What do you see on the screen?*
    - *Do the particles that make up coconut oil behave like a solid, liquid, or gas? How do you know?*

16. Have the children draw and write in their science notebooks on page 17 about their observations of the Thermoscope model of the particles that make up coconut oil (solid). Give them time to carefully observe the motion and draw.
    11. *In your student notebook on page 17, draw in the **green** circle what you see in the Thermoscope model.*
        - *What are some characteristics of the particles **before we warm them—before we increase the temperature**?*
            - *Is coconut oil a solid, a liquid or a gas **before it became warm**?* Write that name of the state of matter on the line below the green circle.

17. Once children have observed the model of particles that make up solid coconut oil**,** the teacher will walk around to each group and:
    a) Pour a cup of warm water in the water bin.
    b) Place the cupcake tin in the water bin, while the children keep probe a in the coconut oil. THE CHILDREN SHOULD WATCH THE THERMOSCOPE SCREEN as the cupcake tin is placed back in the water. The children should see the transition from a model of solid coconut oil to a model of liquid coconut oil.

Teacher Note

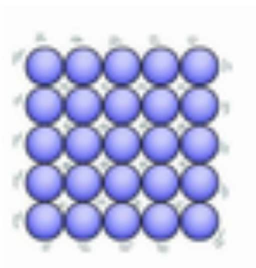
It can be hard for little hands to keep the probe from touching the bottom of the cupcake tin. One option for this part of the melting activity is for the teacher to do this as a **demonstration**. In addition, the melting happens quickly, so it is fine to do the demonstration twice. Just make sure to start new demonstrations with a pan that has cooled off! ☺

18. Once children have seen on the Thermoscope screen that the particles that make up coconut oil transitioned from a solid structure to a liquid structure, ask children to confer with their partner to describe what they saw.
    - *Before we share our observations as a whole class, talk with your partner about what you just saw on the Thermoscope screen—what happened to the particles that make up coconut oil?*
    - *In your student notebook on page 17, draw in the **purple** circle what you see in the Thermoscope model.*
        - *What are some characteristics of the particles **after they became warm**?* [Children may say: There are many particles. They are packed very close together. They are jiggling, wiggling or vibrating. They do not move around like the particles that make up the oil and

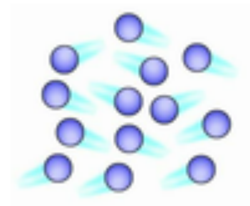
dish soap. They stay in place. They are the same size as each other.]

○

- *Did the coconut oil become a solid, a liquid or a gas* ***after it became warm****?* Write that name of the state of matter on the line below the purple circle.



increase temperature; *particles ABSORB energy;* they begin to move around, more freely and bump into each other; space between particles increases; particles have a less orderly arrangement

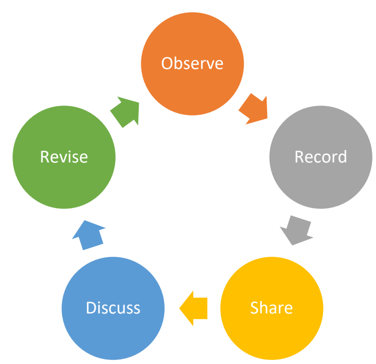


PARTICLE MODEL OF MELTING

Teacher Note

This model is for the teacher to know the "goal" model. When children share their models and discuss them as a class, the children may choose to revise their models. <u>Their revisions should be based on what children learn and recognize for themselves</u>, as opposed to being told what to do.

19. Lead a whole class discussion in which you help children make sense of what they saw. Allow some of the pairs to share their model of melting with the class. Allow children in the audience to ask questions. The teacher may also ask probing questions such as:
    - *How did you describe the particles that make up solid coconut oil* ***before they became warm****?*
    - *What happened to the particles that make up the solid coconut oil when we put the coconut oil in warm water?* [Children should refer to the observation that the particles started out packed together and jiggling or vibrating—like particles that make up a solid. Then, they jiggled or vibrated faster until the particles broke free from their rigid structure and start moving around and bumping into each other-- like particles that make up a liquid.]
    - *What did we do to the temperature of the coconut oil when we put it in the water?* {We made it warmer; **we increased the temperature**.]
    - *What did the increase in temperature do to the particles that make up coconut oil?* [The increase in temperature made the particles move around more and start bumping into each other.]



20. Allow children the opportunity to revise/refine their models, based on the discussion.

Teacher Note

If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

21. Relate an <u>increase</u> in temperature to <u>absorbing</u> energy:
    - *When we heat the solids, their particles* ***<u>absorb</u>*** *the heat* ***<u>energy</u>****.*
    - *Think about a time when you sat out in the sun. Did you absorb the heat energy? How do you know? [We get hot].*

- *When the particles that make up solid coconut oil absorb energy, the particles move faster. They begin to jiggle and vibrate so much that they break free from their rigid structure and start moving around more. They start bumping into each other. When the particles start moving around more and bumping into each other, the coconut oil no longer behaves like a solid.* ***When the particles begin moving around faster and more freely, what does the solid coconut oil turn into?*** [Liquid coconut oil]
- *What do we call the process of turning a solid into a liquid?* [Melting]

Teacher Note

It is important to adopt the language of "**absorb**" energy and "**release**" energy, rather than "add heat" and "remove/take away heat." Using "add heat" and "remove heat" often leads children to think that heat is a physical substance that can be added or removed (e.g., like adding milk to cereal). Since heat is the form of energy we are referring to in this lesson, you can say "energy", "heat energy," or "energy in the form of heat."

Understanding that *as the substance's temperature increases, energy is absorbed* is a pre-cursor to understanding energy transfer (conduction, convection, radiation), and conservation of energy. If in the future, you are interested in expanding this unit to included modeling- based inquiry instruction about the concepts of energy transfer and conservation of energy to this unit, we would love to explore children's development of understand these ideas with you and your classroom!

22. Relate the coconut oil melting to the chocolate chip:
    - *Now that you know how solid coconut oil turns into liquid coconut oil, can you tell me how the chocolate chip melted?*
    - *Why do you think the chocolate chips became soft?* [The particles that make up chocolate chips absorbed enough energy to loosen and vibrate more, but there was not enough energy for the particles to start moving around and bumping into each other like the liquid coconut oil.]
    - *Why do you think the Lego did not melt? What would we have to do to turn the Lego into a liquid*? [Make it hot enough for the particles to move fast enough to break away from each other, start moving around more freely and bumping into each other.]

❖ Making a Human Model: Melting

23. Have children make a human model of a solid changing to liquid. The student-directed model is preferred, as student have to think for themselves about how they will model the phase change based on what they know about their model of a solid and model of a liquid.

    <u>Student-Directed Model</u>
    Instead of directing children to move their arm and move around more freely, try to engage the class by asking what they think should happen to the particles when heat is absorbed. You can scaffold the feedback with hints and prompts such as:
    - *Think about the differences between solids and liquids? Are the smallest particles of a liquid closer together or farther apart than those of a solid?*
    - *Do the smallest particles of a liquid move about in space more or less than those of a solid?*

24. In their science notebooks on page 16, have individual children construct, draw or use dot stickers to model that when we increase the temperature of a solid, the solid <u>melts</u> into a liquid.

25. Finally, student partners will collaborate on using the **Particle Modeler** to show and save a model of the particles that make up each state of matter example that they found in the classroom.

26. After the children have had time to make their model with the Particle Modeler, have a large group discussion in which you allow some of the children to share their Particle Modeler model. As children show their models, allow the class to discuss the models— for example,
    - *How does [children's names] Particle Modeler model look like their drawings or the Thermoscope model?* (e.g., Are the particles in the same arrangement? Are they moving similarly?
    - [If the Thermoscope model or their drawing looks different from the Particle Modeler model] *What suggestions do you have for [children's names] to revise their Particle Modeler model?*

27. ***Allow children the opportunity to revise/refine their Particle Modeler models, based on the discussion.***

> **Teacher Note**
>
> If a child chooses to revise her/his models, the teacher and assistants should try to describe on the page the revisions that the child makes.

❖ How do we know that solid coconut oil melted into liquid coconut oil??

28. Some children may think that the coconut oil melted into water. To help them recognize that solid coconut oil melts into liquid coconut oil, children will watch the liquid coconut oil solidify back into solid coconut oil. Ask children:
    - *What do you think will happen to the particles that make up **this liquid** when we decrease the temperature? (make it colder?)*

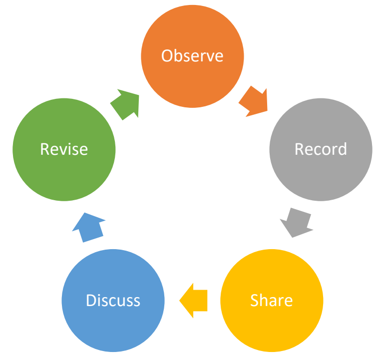
29. The children will put Probe A into the liquid coconut oil and observe on the Thermoscope screen the model of particles that make up **liquid** coconut oil. Ask children what they see on the Thermoscope screen:
    - *What do you see on the screen?*
    - *Do the particles behave like a solid, liquid, or gas? How do you know?*

30. Once children have observed the Thermoscope model of particles that make up liquid coconut oil**,** the teacher will walk around to each group and:
    - Pour ice water in the water bin.
    - Place the cupcake tin in the ice water bin, while the children keep probe a in the coconut oil. THE CHILDREN SHOULD WATCH THE THERMOSCOPE SCREEN as the cupcake tin is placed back in the water. The children should see the transition from a model of liquid coconut oil back to a model of solid coconut oil.

> **Teacher Note**
>
> It can be hard for little hands to keep the probe from touching the bottom of the cupcake tin. One option for this part of the activity is for the teacher to do this as a **demonstration**. I

31. Once children have seen on the Thermoscope screen that the particles that make up coconut oil transitioned from a solid structure to a liquid structure, ask children to confer with their partner to describe what they saw.

- *What happened to the particles that make up the liquid (coconut oil) when we put the liquid (coconut oil) in cold water?* [Children should refer to the observation that the particles started out moving around and bumping into each other-- like particles that make up a liquid, but as they cooled, the particles slowed down, came closer together until they were neatly arranged and jiggling or vibrating—like particles that make up a solid.



- *What material is the solid?*[coconut oil]. *If the liquid became solid coconut oil when we cooled it with ice water, then what must the liquid be?* [Liquid coconut oil]. *Does water change to coconut oil when we cool it?*
    - ***When a material changes state—for example, from a solid to a liquid—the particles that make up the material are the same particles whether the material is a solid or a lquid. The particles simply change their arrangement and motion.***
- *What did we do to the temperature of the coconut oil when we put it in the cold water?* {We made it colder; we decreased the temperature.]
- *What did the decrease in temperature do to the particles that make up coconut oil?* [The decrease in temperature made the particles slow down and stop bumping. They moved around less and just vibrated.]

32. Relate a <u>decrease</u> in temperature to <u>releasing</u> energy:
    - *Remember that we learned that when we heat the solids, their particles **<u>absorb</u>** the heat **<u>energy</u>**. What do you think happens when we <u>cool liquids</u>?*
        - *What happened to the particles?* [They slowed down]
        - So, if absorbing energy makes the particles move faster, what do you think happens to make the particles move slower? [They have less energy; they let go of their energy; they release energy]
    - *When we cool liquids, their particles **<u>release</u>** the heat **<u>energy</u>**.*
    - *When the particles that make up liquid coconut oil release energy, the particles move slower. They do not bump each other as much, and they slow down to form a neatly arranged structure and vibrate. When the particles slow down to form a neatly arranged structure and vibrate, the coconut oil no longer behaves like a liquid.* ***When the particles begin slow down to form a neatly arranged structure and vibrate, what does the liquid coconut oil turn into?*** [Solid coconut oil]

Teacher Note

It is important to adopt the language of "**absorb**" energy and "**release**" energy, rather than "add heat" and "remove/take away heat." Using "add heat" and "remove heat" often leads children to think that heat is a physical substance that can be added or removed (e.g., like adding milk to cereal). Since heat is the form of energy we are referring to in this lesson, you can say "energy", "heat energy," or "energy in the form of heat."

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CONCORD CONSORTIUM INSTRUCTIONS FOR THERMOSCOPE AND PARTICLE MODELER

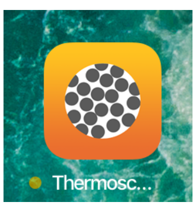
Getting Started with the Thermoscope

The Thermoscope is an app for “seeing” temperature. It is a *microscope for temperature* that provides students a simplified visualization of particle movement that makes the temperature differences between two materials visible. The Thermoscope contains particle models for solids, liquids, and gasses. It can also demonstrate melting and freezing—transitions between solids and liquids.

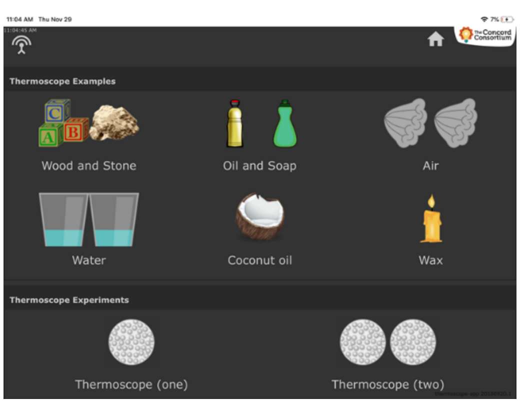
The Thermoscope probes gives students the tactile experience of measuring and touching the temperatures of objects in the real world while seeing their particle movement. The Thermoscope app can also be used without the probes by varying temperatures using on-screen sliders.

The two Thermoscope temperature probes are contained in a small plastic deli container and communicate with iPads and other devices using Bluetooth (so be sure that Bluetooth is activated on your iPad). The container should **not** be opened in the classroom. Thermoscopes are identified with unique “emoji” symbols.

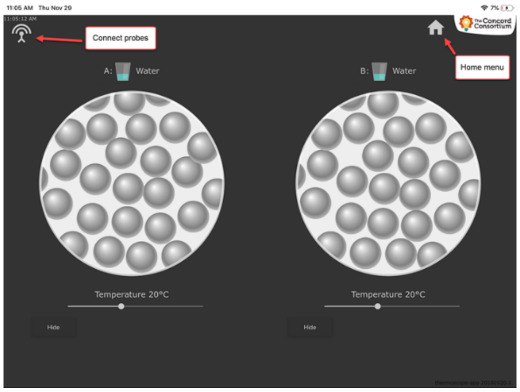
Connecting the Thermoscope Probes with Your iPad



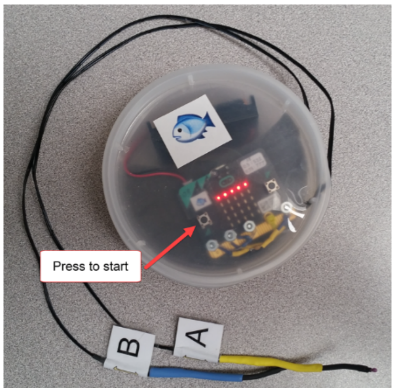
Tap the Thermoscope icon to start the app on your iPad. Then dismiss the splash screen with another tap.



You are now at the Home menu from which you can select your desired experiment setup. Tap the two cups of water.

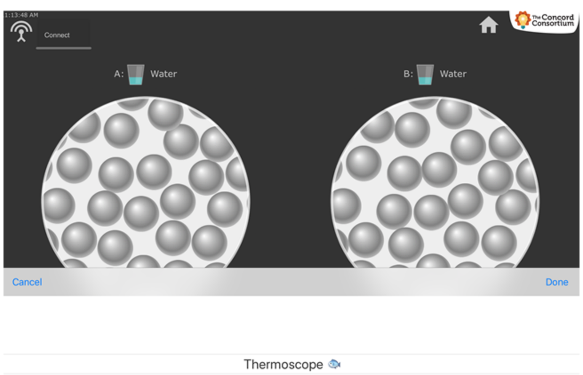


You'll see two models of water particles. As a simulation, you can change the models' temperatures with the slider. But let's measure real temperatures with the Thermoscope probes.

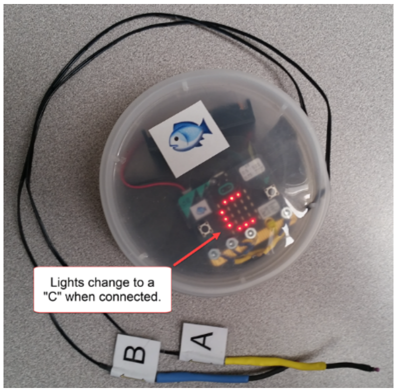


Turn on your Thermoscope probes by pressing down on the flexible cover close to the smaller emoji symbol inside the container. Five lights in a row show that the Thermoscope is ready to be connected.

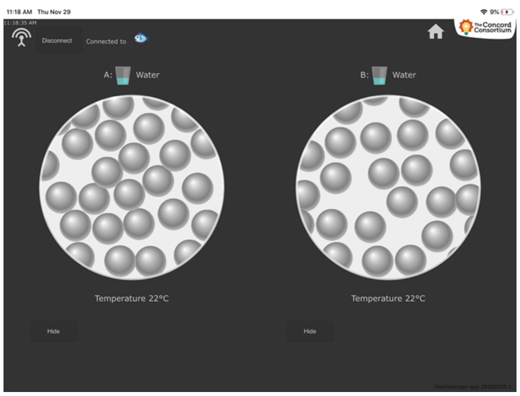
On the iPad, tap the radio button in the upper left corner, and then tap the **Connect** button that pops up.



A list of available but unconnected Thermoscopes will show at the bottom of the screen. Select the icon of the Thermoscope probe that you are connecting, and press **Done**. Notice what happens.



The lights on the Thermoscope probes will change to a “C” for connected.



The Thermoscope screen shows the emoji of the Thermoscope that is connected. The sliders are replaced by the temperature readings of the probes. The motion of the particles reflects the temperature measured by the probes.

Readings from the yellow probe, labeled “A” correspond to the model in the circle on the left and the blue probe, labeled “B” to the model on the right.

To get good readings, measurements of the probes require that the tip of the probe is immersed in the materials to be measured. Probes may be immersed in liquids up to temperatures that can be tolerated by touching (and beyond). Simply contacting the surface of solid objects will not necessarily give an accurate reading. It is better that probes are surrounded by the material they are to measure.

Disconnecting the Thermoscope and Additional Notes

To disconnect the probes from the Thermoscope, tap **Disconnect** or press the top of the deli container on the Thermoscope probes. **Simply closing the iPad will not disconnect the probes, and they will continue to run using the battery’s power.**

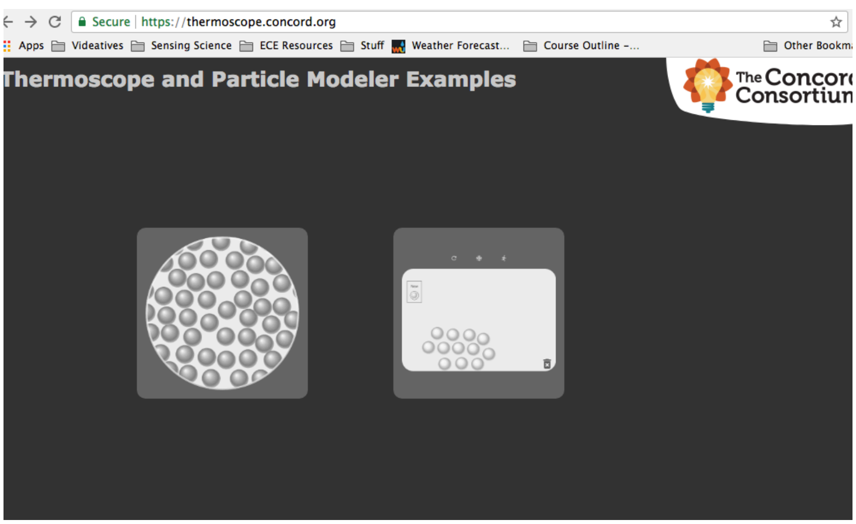
Once the Thermoscope probes are turned on, they will turn themselves off automatically after a minute and a half if they are not connected to a Thermoscope app. You will notice that the five lights on the Thermoscope probes will blink off one at a time toward the end of the timeout period. Once connected, however, the probes will stay on as long as they are not disconnected through the app or directly turned off by pressing the deli container top. If they are disconnected through the app, the probes will automatically turn off after 90 seconds.

Several other features are available on the main screen of the Thermoscope. Each model window may be hidden or activated so that attention can be focused. Different model setups can be selected from the Main menu by pressing the "House" icon in the upper right corner. Doing this will not disconnect the probes.

The only reason to open the deli containers with the Thermoscope probes is to change the batteries. They are rated for about 150 hours of operation, so they should rarely need new batteries. They use two "AA" batteries.

Running the Thermoscope on a Computer

With some limitations, it is possible to run the Thermoscope on a computer through the Chrome web browser. Probes may be connected to a Mac running the latest version of Chrome. (Be sure that Bluetooth is enabled on the Mac.) The Thermoscope can be run on PC's, however, the Chrome browser on PC's does not yet allow connecting a Bluetooth device of this type so the probes cannot be used. Instead, use the sliders beneath the models to simulate temperature changes.



The Thermoscope's web address is **https:\\thermoscope.concord.org**

On the web the Thermoscope is coupled with the Particle Modeler. Select the icon on the left (above) for the Thermoscope and the right for the Particle Modeler.

Getting Started with the Particle Modeler

The Particle Modeler app is a playground for experimenting with the building blocks of matter. Drag particles around, then see how they move in a microscopic world. Transfer energy in or out of the model or trap them in a container. Watch what happens and discover important ideas about the states of matter: solids, liquids, gasses, and changes of state.

On your iPad, tap the **Particle Modeler** icon which will bring you right to the modeling window. The modeling window presents a beaker-shaped container inside a white working area.

While the Particle Modeler is stopped, particles can be dragged from the **Add** menu onto the working area and arranged in any way, but with one exception: particles cannot be placed on top of one another or on top of the beaker walls. If this happens, no harm is done. A message appears and the overlaying particle jumps back to its previous position.

Once **Run** is tapped, particles in the modeling window move under the influence of two forces:

- Particles fall under the force of gravity.
- Particles move under the influence of the forces that are known to exist between particles.

There are no frictional forces in the Particle Modeler. This is how particles in matter work! If a particle is moving, it will continue to move until it bumps into another particle or the wall of the modeling window or the container. When particles bump, they can change the speed and direction of each other, but the overall energy between them is unchanged. Technically, we say that energy is conserved.

But you **can** change the energy of the particles in the modeling window! There are two buttons that allow you to either move energy into or out of the modeling window.

The **Heat** button moves some energy into the system at the bottom of the beaker. It does it by speeding up the particles near the bottom of the beaker. Once **Heat** is pressed some very fast-moving particles came in contact with the bottom of the beaker so that the slower particles in the beaker would gain some speed by being bumped by these fast particles.

The **Cool** button moves some energy out of the system at the bottom of the beaker. It does it by slowing down the particles near the bottom of the beaker. Once **Cool** is pressed very slow-moving particles came in contact with the bottom of the container so that the faster moving particles in the container bump the slower ones and transfer some of their speed to them.

More about Energy in the Particle Modeler

When the **Heat** button is pressed the particles are said to **absorb** energy (energy is transferred into the system). When the **Cool** button is pressed the particles are said to **release** energy (energy is transferred out of the system). **We try not to say that energy is added or subtracted, even though these words are commonly used.** These words give the impression that energy is a substance that may be hot or cold that can be poured in or tapped off. So, if energy is not a substance, what is it?

In the Particle Modeler, energy is the sum of two things:

- The collective motion of all the particles. The higher the average speed of the particles the more energy they have, and the hotter they are. (This is kinetic energy.)
- The position of the particles. The higher the particles in the modeling window, the more potential they have to create motion through falling because of gravity. (This is gravitational energy.) There is also energy between particles due to the forces between them that may cause them to attract or repel depending on how far apart they are. These "inter-particle forces" hold the particles of solids and liquids together and hold energy that has potential to move particles.

The second bullet above might seem quite subtle or mysterious. Let's take it apart.

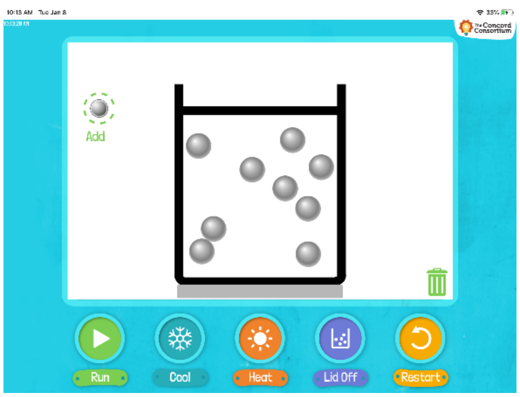
Using the Particle Modeler, try arranging a collection of particles first at the top of the modeling window, and run the model. Then clear the model and arrange new particles along the bottom, resting close to the lowest surface, and run the model. If you try this, the particles in the first run will bounce around wildly, whereas in the second run they will probably just move sideways bumping back and forth or even sticking together. In the first run, the gravitational energy of the particles placed high in the window becomes the energy of motion. By starting with the particles up high and having them move under the influence of gravity, they become fast. Collectively, we can say that the particles are quite hot. Separate particles flying randomly indicates a gaseous state.

In the second run there is very little energy due to gravity because the particles were placed close to the model's lowest possible height. This allows the effect of the forces between particles, which are really quite weak, to become visible. They make the particles behave in unexpected ways. For instance, they may stick together forming larger structures or move as if they are connected by an invisible rubber band. It is these forces that give rise to the states of matter of liquids and solids. These states in which the particles stay close together require that the collection of particles is relatively cool in temperature.

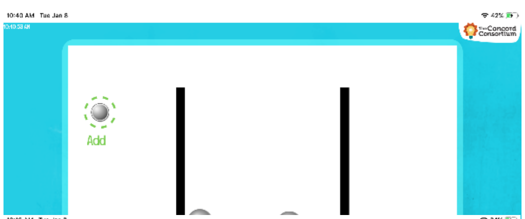
States of Matter in the Particle Modeler

The Particle Modeler is designed to be a tool for children to experiment with the smallest bits of matter. For this, they will be challenged to create models of particles in specific states of matter. It is possible for students to stumble into making correct models of the states of matter by pressing the buttons without a lot of thought. But they should also be able to explain how these models are made and how to create them. They can be challenged to see how many ways they can be made.

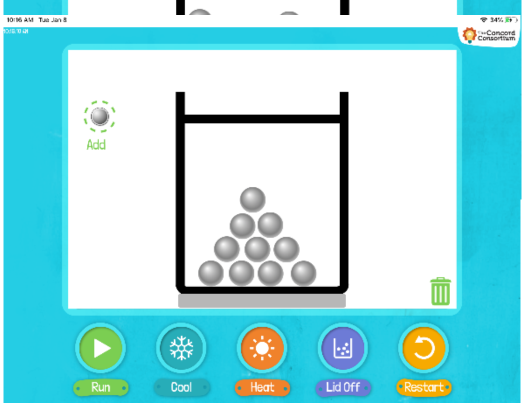
Here is a tour of possible particle models of the different states of matter. Still pictures of particles can never capture one of the most important lessons of particle behavior—that particles, even in solids, never stop moving. However, the patterns of the different states, should be recognized by students in many forms.



A model gas. Here the beaker lid turned on. The beaker lid provides an extra dimension for experimentation. Students can experiment with confining a number of particles in a smaller space. Does that affect their motion? How does it change when the top is removed? The top also allows experimenting with different groups of particles some inside the container and some outside. Will they affect each other? (Hint: the forces between particles do penetrate the beaker.)



A model liquid. In this model, the particles move over one another, and so are constantly changing shape. The particles have attraction for each other, but not enough to keep them locked in a rigid structure.



A model solid. It is easy to build a solid simply by hitting the Cool button many times, however, can students create interesting shapes. How big a solid can they build?

Changing State

Students should be able to explain what methods that they have used to change one state of matter to another (phase change). Can they describe from the point of view of particles what freezing and melting and evaporation and condensation are? How do they take place? Is there more than one way to change state?

There are other interesting questions about state change. If you create a solid with a specific shape, and then melt it, can you get it back into that shape? What properties of particles allow the states to be made?

Running the Particle Modeler on a Computer

You may explore with the Particle Modeler on device other than the iPad, preferably using the Chrome browser. The web-based version of the Particle Modeler has many more features than the iPad app, however, they will not be described here. Go to **https:\\thermoscope.concord.org** and tap the icon on the right. Then on the menu, tap Container Demo to run the version of the Particle Modeler that is in the app.