Thermal Energy

How can containers keep stuff from warming up or cooling down?

OpenSciEd

MIDDLE SCHOOL SCIENCE

How can containers keep stuff from warming up or cooling down?

Thermal Energy: Cup Design

OpenSciEd Unit 6.2

How can containers keep stuff from warming up or cooling down?

Thermal Energy: Cup Design

OpenSciEd Unit 6.2

The development of this material was supported by the Bill & Melinda Gates Foundation, Carnegie Corporation of New York, Charles and Lynn Schusterman Family Foundation, and William and Flora Hewlett Foundation.

This unit was adapted from *Energy: How can we design a device to warm something up?*, originally co-developed by San Francisco Unified School District and SCALE at Stanford University 2017–2018. Used with permission. *Energy: How can we design a device to warm something up?* was developed with funding from Lucas Education Research, part of the George Lucas Education Foundation.

Unit Development Team

Lindsey Mohan, Unit Lead, BSCS Science Learning
Zoe Buck Bracey, Writer, BSCS Science Learning
Emily Harris, Writer, BSCS Science Learning
Ari Jamshidi, Writer, Stanford University
Abe Lo, Writer, BSCS Science Learning
Michael Novak, Writer & Reviewer, Northwestern University
Tracey Ramirez, Writer, Charles A. Center at UT-Austin
Dawn Novak, Pilot teacher, Maple School
Tyler Scaletta, Pilot teacher, North Shore Country Day School
Katie Van Horne, Assessment Specialist
David Fortus, Unit Advisory Chair, Weizmann Institute of Science

Production Team

BSCS Science Learning

- Kate Herman, Copyeditor, Independent Contractor
- Stacey Luce, Editorial Production Lead
- Valerie Maltese, Marketing Specialist & Project Coordinator
- Alyssa Markle, Project Coordinator
- Chris Moraine, Multimedia Graphic Designer

OpenSciEd

James Ryan, Executive Director
Sarah Delaney, Director

Developers Consortium Leadership

Daniel C. Edelson, Director
Audrey Mohan, Associate Director

Professional Learning Center at Boston College

- Katherine McNeill, Director
- Renee Affolter, Assoc. Director

Instructional Materials Center at BSCS Science Learning

- Daniel C. Edelson, Director
- Audrey Mohan, Assoc. Director

Field Test Implementation and Evaluation Center at Charles A. Dana Center, The University of Texas at Austin

- Carolyn Landel, Director
- Sara Spiegel, Assoc. Director, Implementation
- Carol Pazera, Assoc. Director, Evaluation

Field Test Evaluation Center at Digital Promise

- Andrew Krumm, Director
- William Penuel, University of Colorado, Boulder, Co-Director

Instructional Materials Center at Northwestern University

- Brian Reiser, Director
- Michael Novak, Assoc. Director

State Steering Committee

California

- Kathy DiRanna
- Phil Lafontaine

Iowa

- Kris Kilibarda
- Tami Plein

Louisiana

- Jill Cowart
- Lydia Hill
- Breigh Rhodes

Massachusetts

- Erin Hashimoto-Martell
- Nicole Scola

Michigan

- Mary Starr

New Jersey

- Michael Heinz

New Mexico

- Yanira Vazquez
- Shafiq Chaudhary

Oklahoma

- Tiffany Neill
- Megan Cannon

Rhode Island

- Phyllis Lynch
- Kate Schulz

Washington

- Ellen Ebert

Field Test Teachers

California
Dawn Arbogast
Michelle Baptista
Laura Barker
Monica Cordisco
Sarah Couris
Kia Gregory
Bruce Hansen
Bruce Jennings
Anaya Pierre
Heidi Preece
Gilly Ryan
Robert Seagraves
Robert Sherriff
Destiny Westbrooks

Iowa
Heather Clark
Gabe Davis
Darin Dowling
Angie Goemaat
Melissa Johnson
Jolonda Mihalovich
Molly Reisz
Shelly Streigle
Chelsea Thordarson
Jen Wilson

Michigan
Denise Church
Jeremy Giles
Shelly Jacobs
Lisa Kaluzny
Karen Mundt

Massachusetts
Julie Callanan
Maria Citrin
Charles Hickey
Sharon McKenna
Deserea Meristil
Jamie Mitchell
Elizabeth Packhem
Roselynn Rodriguez

Oklahoma
Rennie Brewer
Cherish Buel
Sharolyn Davis
Kerensa Doolen
Kelli McDonald
Kristi McMurtry
Tracy Roberts-Hoover
Shelby Stapleton

Rhode Island
Nikki Gardner
Michael Romano

Washington
William Baur
Shawna Brown
Marcia Garrett
Kelly Hixon
Gina Hopkins
Tammy Mendoza
Lynn Nelson
Jerry Papers
Geoffrey Reilly
Chelsea Walsh
Theresa Williams

New Mexico
Kathleen Arias
Brandi Bowerman
Cindy Colomb
Kelley Day
Azlee Hatch
Raymond Heath
Tammy Hinckley
Michala Mecklenburg

New Jersey
Nicole Casamento
Laura Ehlers
Marilou Liedtka
Lauren Pasanek
Allison Russo
Kim Tota

Louisiana
Bridget Bush
Emily Caulfield
Joshua Cox
Brittany Flynn
Karen Ford
Brenna Geer
Kylie Martin
Belinda Mire
Lindsay Duet
Sarah Parkerson
Janie Pierce
Laurie Ratcliff
Marike Svoboda

TABLE OF CONTENTS

Unit 6.2 How can containers keep stuff from warming up or cooling down?

UNIT OVERVIEW

How can containers keep stuff from warming up or cooling down?

This unit on thermal energy transfer begins with students testing whether a new plastic cup sold by a store keeps a drink colder for longer compared to the regular plastic cup that comes free with the drink. Students find that the drink in the regular cup warms up more than the drink in the special cup. This prompts students to identify features of the cups that are different, such as the lid, walls, and hole for the straw, that might explain why one drink warms up more than the other.

Students investigate the different cup features they conjecture are important to explaining the phenomenon, starting with the lid. They model how matter can enter or exit the cup via evaporation However, they find that in a completely closed system, the liquid inside the cup still changes temperature. This motivates the need to trace the transfer of energy into the drink as it warms up. Through a series of lab investigations and simulations, students find that there are two ways to transfer energy into the drink: (1) the absorption of light and (2) thermal energy from the warmer air around the drink. They are then challenged to design their own drink container that can perform as well as the store-bought container, following a set of design criteria and constraints.

Through these investigations students:

- build on what they know about the particle nature of matter from 5th grade to develop a particle model of solids, liquids, and gases that include both structure and movement of particles as it relates to the temperature of the substance.
- plan and carry out investigations to systematically test the different parts of the cup system, tracking the flow of matter and energy into or out of the cup system.
- develop a model of temperature as the average kinetic energy of a group of particles.
- model the transfer of energy from light to kinetic energy of particles when light is absorbed.
- model thermal energy transfer between substances through particle collisions, or conduction, to change the average particle motion in a substance.
- revise their models to include factors that minimize energy transfer by reducing the absorption of light and decreasing the opportunities for particle collisions.
- apply what they have learned about features that can slow energy transfer to design, build, test, and revise a cup system to keep a drink cold.

Focal Disciplinary Core Ideas (DCIs): PS1.A, PS3.A, PS3.B, PS4.B, ETS1.A, ETS1.B

Focal Science and Engineering Practices (SEPs): Developing and Using Models, Planning and Carrying Out Investigations, Constructing Explanations and Designing Solutions, Engaging in Argument from Evidence

Focal Crosscutting Concepts (CCCs): Systems and System Models, Energy and Matter, Structure and Function

Building Toward NGSS Performance Expectations

MS-PS1-4:
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-PS3-3:
Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

MS-PS3-4:
Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

MS-PS3-5:
Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object.

MS-PS4-2:
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

MS-ETS1-4:
Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

How students will engage with each of the phenomena:

HANDS-ON/LAB ACTIVITIES	VIDEOS OR IMAGES	DATA SETS	READINGS	COMPUTER INTERACTIVES

UNIT STORYLINE

How can containers keep stuff from warming up or cooling down?

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr>
<td>

LESSON 1

3 days

Why does the temperature of the liquid in some cup systems change more than in others?

Anchoring Phenomenon

</td>
<td>

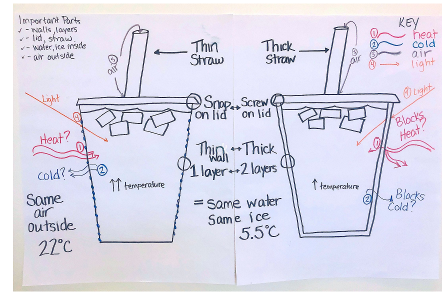
Makers of a fancy plastic cup claim it keeps a drink cold for longer than a regular plastic cup.

</td>
<td>

We observe an iced drink in a regular cup warming up more quickly compared with an iced drink in a fancy cup. We develop systems models to explain what is happening in the two cups that one can better maintain the temperature of the drink. We brainstorm related phenomena and ask questions about design features that influence how well an object can keep something hot or cold. We figure out:

- The cup system includes the different parts of the cup and the water and air inside the cup. All of these parts work together (interact) to form the system.
- Some systems have structural features that help maintain the temperature of a substance inside the system, keeping the substance hot or cold longer compared with other systems.
- Heat can enter the cup system and/or cold can leave the cup system, and maybe gases can escape the system too.

</td>
<td>



</td>
</tr>
<tr><td colspan="4">

⇓ **Navigation to Next Lesson:** We figured out that the fancy cup does keep a drink colder for longer than the regular cup. We are curious about the different parts of the cup systems and want to see if certain parts are more helpful in keeping the liquid inside cold. With more data to examine, we think we'll have a better understanding of the cup systems and how they work.

</td></tr>
<tr>
<td>

LESSON 2

2 days

What cup features seem most important for keeping a drink cold?

Investigation

</td>
<td>

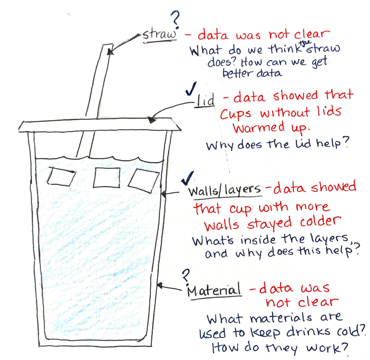
There are features of a cup that are important for keeping a drink cold.

</td>
<td>

We plan and carry out an investigation to figure out 2 things. First, what cup features are important for keeping a drink cold? Second, how would changing the cup features cause the drink to warm up faster? We collect, organize, and publicly analyze data from our investigation to identify patterns to determine which cup features help maintain a drink's temperature. We figure out:

- Some systems have structural features that are designed to help maintain the temperature of a substance inside the system.
- The cup features that seem to play a significant role in keeping a drink cold are a lid, double walls, and maybe the type of cup material.

</td>
<td>



</td>
</tr>
<tr><td colspan="4">

⇓ **Navigation to Next Lesson:** A cup with a lid and double walls keeps a drink cold for longer than one without a lid and only a single wall. We wonder whether the same cup features also keep a drink hot.

</td></tr>
</table>

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 3

2 days

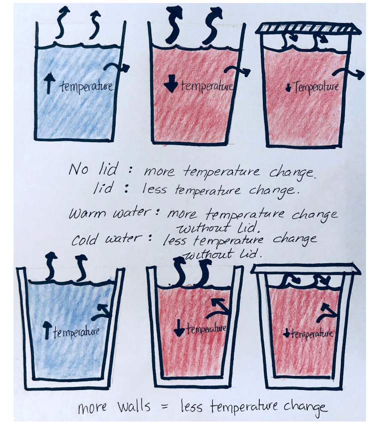
How are the cup features that keep things cold the same or different for keeping things hot?

Investigation

Students test whether cups that can keep liquids cold can also keep liquids hot.

We look at the order of cups based on their ability to keep liquids cold. We investigate whether these same features are able to keep liquids hot. Based on our findings, we revise our explanation from Lesson 1 to explain how particular cup features help to keep liquids hot and/or cold. We ask additional questions about the cup features now that we know more. We then design an experiment to investigate our questions and ideas about how the lid works. We figure out:

- Cups that can keep liquids cold are also able to keep liquids hot.
- Cups with lids are able to keep liquids hot and cold better than cups without lids.
- Cups with more walls or layers will be able to keep liquids hot and cold better than cups without lids.



⇓ **Navigation to Next Lesson:** We saw that one clear difference in the results was apparent when the hot liquid was in containers without lids. We have some initial ideas about why lids matter for hot liquids. We want to test a lid versus no lid (closed versus open) cup system to see how the lid helps keep heat, cold, or gases from entering or leaving the system, which we believe is causing the drinks to warm up or cool down.

LESSON 4

3 days

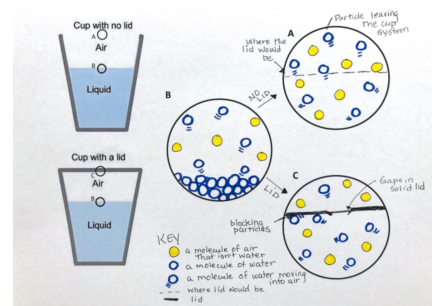
How does a lid affect what happens to the liquid in the cup?

Investigation

Hot liquid in a cup with a lid changes temperature less than in a cup without a lid. The amount of matter lost to the surroundings due to evaporation is less too. A completely closed system loses no matter to the surroundings, even though the liquid in it still changes temperature.

We plan and carry out investigations to determine the effect of a lid on temperature change and mass change of a hot liquid in a cup. We calculate the mean for two cup systems to compare the temperature drop and mass change in each condition. We develop and use a particulate model of liquids and gases to explain the mass loss in an open system. We figure out:

- The lid helps to maintain the temperature of a hot liquid inside the cup.
- The lid slows down matter loss from the system.
- Liquids and gases are made of particles. Particles in gas have a lot of space between them but those in liquids do not.
- The smallest particle of water is a molecule. Molecules of water in liquid go into gas over time (evaporation).
- An open system has space for matter to enter or exit. A closed system is one in which no matter can enter or exit.
- The hot liquid cools down even when we prevent most matter from leaving the cup system by using a lid.



⇓ **Navigation to Next Lesson:** In this lesson we figure out that the lid does help keep the hot liquid from cooling down and this is related to how the lid helps to close the system and keep matter from evaporating. Now that we know the lid mostly closes the system, we wonder if any matter could be leaking out through the walls.

Lesson Question | Phenomena or Design Problem | What we do and figure out | How we represent it

LESSON 5

1 day

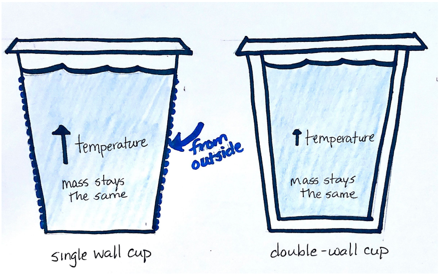
Where does the water on the outside of the cold cup system come from?

Investigation

Observe and measure closed cup systems containing cold liquids before and after water droplets form on the outside surface of the cup system.

We construct an investigation to support or refute the claim that the formation of water droplets (condensation) on the outside of a cup of cold water comes from water leaking through the cup walls. We measure the mass of a cup of cold water before and after condensation forms on the outside. We also observe condensation on the outside of a cup of cold water that has been dyed using food coloring. We use our observations and data to construct an argument to refute the claim that water droplets on the outside of the cup come from inside the cup system.

- The water droplets that form on the outside of a cup of cold water come from the air outside the cup, not from the inside of the cup.
- Water droplets often condense on a cold surface when humid air comes in contact with the surface.
- Liquids do not move through solids.
- Matter does not enter or leave a closed system; therefore, the mass of a closed system does not change.



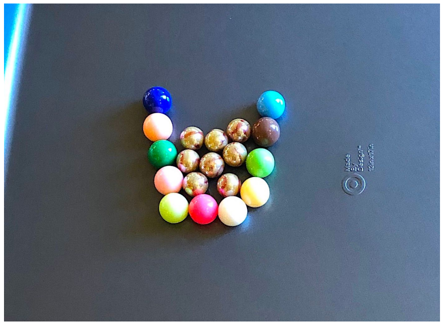
⇓ **Navigation to Next Lesson:** In this lesson, we figured out that matter cannot go through the walls of the cup. When we have a lid, the cup system is mostly closed but not completely closed. We are wondering if a liquid warms up or cools down over time in a completely closed system.

LESSON 6

2 days

How can we explain the effect of a lid on what happens to the liquid in the cup over time?

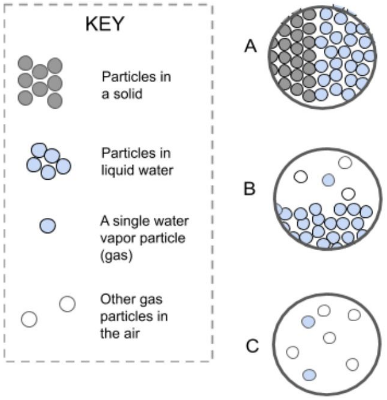
Putting Pieces Together



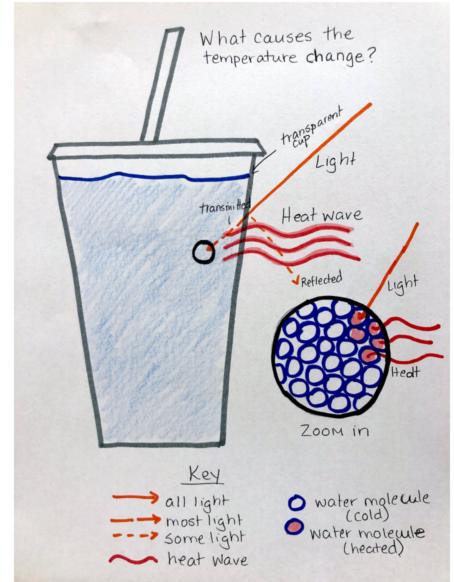
A completely closed system loses no matter to the surroundings, even though the liquid in it changes temperature over time.

We use a model to show why water molecules cannot leave the cup at some points in the cup system but can at other points. We complete an individual assessment that includes making predictions about whether a cup with a new lid design will keep a drink cooler than a cup with an old lid design, developing a plan for collecting data to see if the amount of liquid changed in either cup over time and developing a model to explain why one cup system would lose more mass than another. We figure out these things:

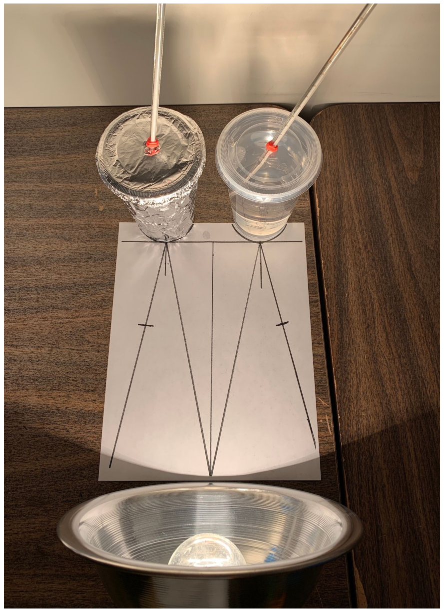
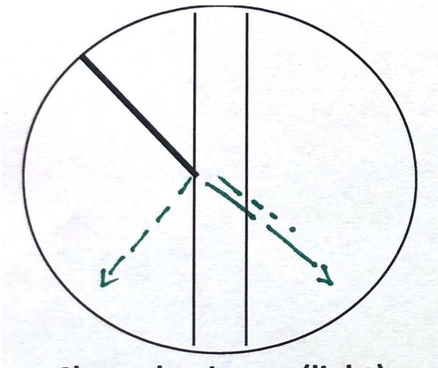
- Liquids, gases, and solids are made of particles of matter.
- Particles in a gas have a lot of space between them, but particles in liquids and solids do not.
- Liquids and gases are made of particles that can move around freely, but solids are made of particles that cannot.



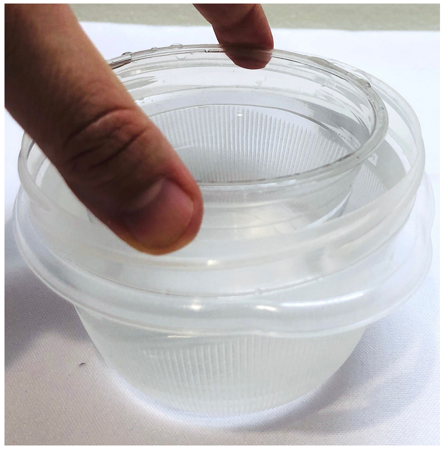
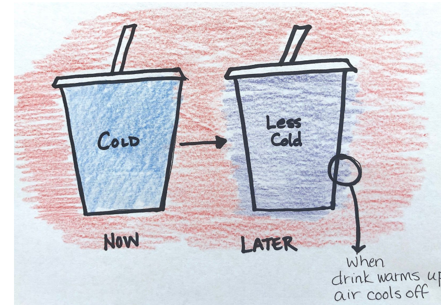
⇓ **Navigation to Next Lesson:** In this lesson, we learned that the lid decreases the temperature change in the liquid in the cup as it cools down and keeps the liquid that goes into the air from escaping from the cup. But even when we prevent any matter from getting into or out of the container (a closed system), the liquid's temperature still changes. How is that possible?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 1 day **If matter cannot enter or exit a closed system, how does a liquid in the system change temperature?** Problematizing	 *Other possible interactions could cause a temperature change in the liquid inside the closed cup system.*	We consider what we know about the components (or structures) of the closed cup system, how they function, and how they interact with one another and with other objects and substances outside of the cup system to determine what else might a temperature change in the liquid inside. We develop models to represent our ideas about interactions between energy (light, heat, or cold) and the closed cup system. We use these models to explain the temperature change, and we determine ways to test our ideas to figure out how energy interacts with the closed cup system. We figure out: • Since most of the matter does not enter or leave the cup system with a lid, light and heat or cold may interact with the system to cause a temperature change in the liquid inside. *note: students will likely use “heat waves” as an initial representation for heat, and this is OK at this point in the unit. From lessons 8-14, students develop their understanding of heat, and the way they represent it in their models.	

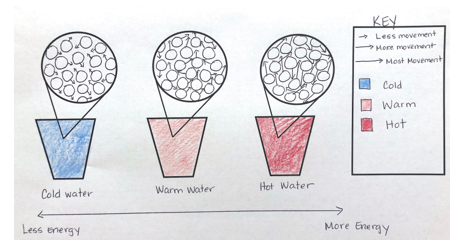
⇓ **Navigation to Next Lesson:** In this lesson, we focus on how light and heat or cold could cause the liquid inside the closed cup system to warm up or cool down. We are more confident that the temperature change has to do with one or both of these mechanisms. Next we will investigate light to see if light can help us account for the liquid warming up.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 8 2 days **How does a cup's surface affect how light warms up a liquid inside the cup?** Investigation	 *Water warms up differently in cups with various surfaces when light shines on the cups, and it warms up in a completely dark condition too.*	We carry out an investigation to test the interaction between light and the cup surface in warming up the cold water inside the cups. We shine light on cups with walls of different materials and colors and measure the amount of incoming, reflected, and transmitted light, and we also place some cups in a completely dark condition. We figure out that the water in all the cups warms up, even cups in the dark condition, but it warms up more in the cups in the light conditions. We wonder about additional mechanisms by which the water inside the cups warms up.. We figure out: • Light can transfer energy into a system. • When light that shines on a surface is not reflected or transmitted, it is absorbed, which warms the matter it shines on. • Temperature changes in the water can still occur even if light does not transmit through the cup wall and even if there's no light.	

⇓ **Navigation to Next Lesson:** In this lesson, we gathered evidence that light is part of the explanation for the cold water warming up, but light is not the whole story. We also thought heat and cold were involved, and it makes sense to look more at heat and cold because our cups in the dark condition warmed up too.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 1 day **How does the temperature of a liquid on one side of a cup wall affect the temperature of a liquid on the other side of the wall?** Investigation	 *The temperature increases and decreases inside a cup system are correlated with temperature decreases and increases outside the cup system.*	We brainstorm how to test whether heat or cold is entering or leaving a cup system. We plan and carry out an investigation to place the cup in a water bath and measure the temperature inside and outside the cup to see if heat or cold is moving between the two systems. We figure out that when there is a temperature change inside the cup system, there is also a temperature change outside the system. We conclude that heat or cold moves through the cup wall and that the greater the temperature difference between the cup and water bath systems, the more energy is transferred between the two. We figure out: • When the temperature of a sample of matter in one system decreases, the temperature of the matter in the neighboring system increases. • When the temperature difference between two neighboring systems is great, more energy transfers between them. • Heat or cold can move through the wall of the cup system.	

⇓ **Navigation to Next Lesson:** We gathered evidence that heat and cold can move through the cup wall to change the temperature of water inside and outside the cup. If the temperature difference between the inside and outside is great, more heat or cold moves (energy). We are not certain what heat and cold are, but we know that we can change the temperature of water by exposing it to something else that is hot or cold.

LESSON 10 2 days **What is the difference between a hot and a cold liquid?** Investigation	 *Candy breaks into pieces and dissolves more quickly in hot water than cold water. Food coloring moves around and spreads out more in hot water than cold water. When water is shaken vigorously, the water warms up.*	We investigate the differences between hot and cold liquids at the particle scale. A video showing candy dissolving in hot, warm, and cold water motivates us to investigate how water behaves differently at varying temperatures by adding food coloring to hot, room-temperature, and cold water. After collecting qualitative evidence that correlates movement in water to temperature, we read about a historical study supporting the idea that movement of water particles and temperature are closely connected. All three sources of information reinforce the ideas that (1) liquids are made of particles and (2) particles move more when a liquid is hotter and less when it is colder. We figure out that: • The movement of particles is related to the temperature of the water, with particles in colder water moving less than particles in hotter water.	

⇓ **Navigation to Next Lesson:** In this lesson we reviewed that a liquid is made of particles and figure out that the particles move more when the liquid is hotter and less when the liquid is colder. Since we also know that liquids such as water may change temperature over time, we now wonder how and why particle movement changes over time.

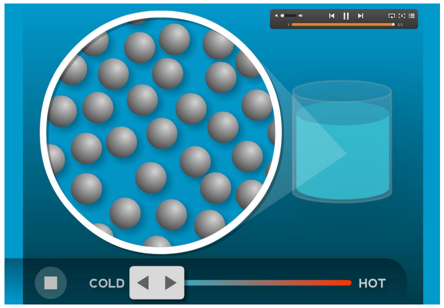
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 11

1 day

Why do particles move more in hot liquids?

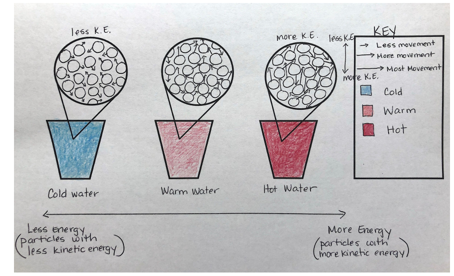
Investigation



A simulation shows that particles move slower when a liquid is cold and faster when a liquid is hot.

We wonder what happened in the *Food Coloring Lab* at the particle scale and how this relates to energy. We make observations from a simulation and obtain evidence that hot liquids have particles that move faster and cold liquids have particles that move slower. We call this energy of movement *kinetic energy*. We spray perfume on one side of the classroom and smell it on the other side, evidence that particles in gas move freely like particles in liquids. We use new ideas about kinetic energy to explain our previous lab observations. We revisit our original iced drink warming up in the regular plastic cup and wonder where the kinetic energy came from. We figure out:

- A particle's speed is related to how much kinetic energy it has.
- The particles in hot liquids and gases have more kinetic energy than the particles in cold liquids and gases.
- Liquids and gases are made of particles that can move around freely.



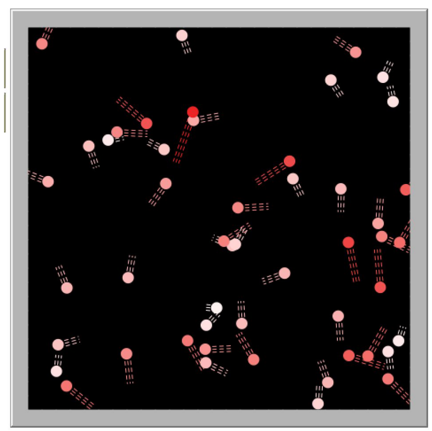
⇓ **Navigation to Next Lesson:** In this lesson, we figured out that particles in hot substances don't just move more, but they also have more kinetic energy compared to particles in cold substances. This made us wonder about our original iced drink as it warms up and particles in the water gain more and more kinetic energy. Where does this energy come from and how does it get into the drink?

LESSON 12

2 days

How does the motion of particles compare in a sample of matter at a given temperature?

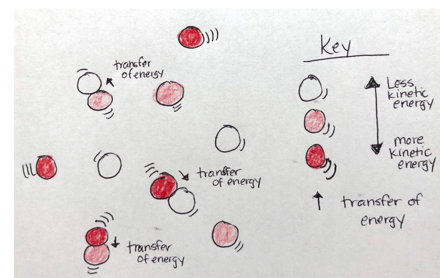
Investigation



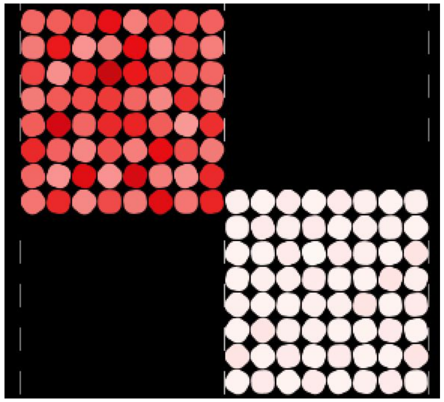
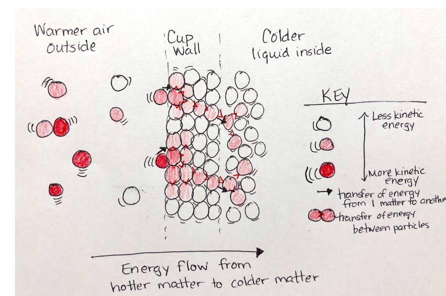
When particles collide, they transfer their kinetic energy to each other, and in a sample of matter at the same temperature, the particles have different speeds.

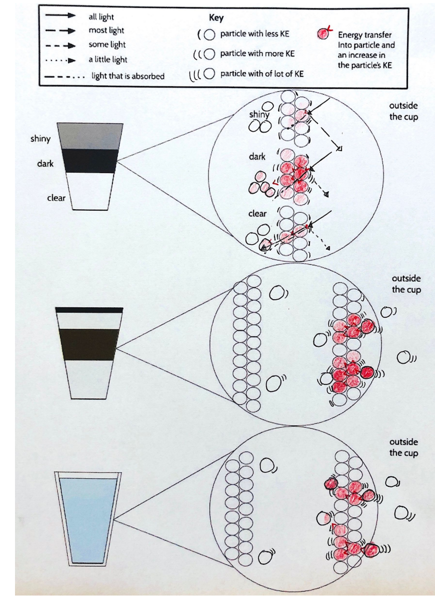
We use a simulation to investigate how individual particles in a sample of gas do not have the same kinetic energy, and how the kinetic energy of each particle is constantly changing as they collide with one another. We argue that temperature is a measure of the average speed of the particles in a sample of matter, and that the total energy of that sample is the sum of the kinetic energy of all the particles in the sample combined. We figure out:

- Not all particles in a sample of matter have the same kinetic energy.
- Kinetic energy is transferred from one particle to another in a particle collision.
- Temperature is a measure of the average kinetic energy of the particles in a sample of matter.
- The total kinetic energy of a sample of matter is the sum of the kinetic energy of all the particles in that sample. If you add more particles, the total kinetic energy increases but the temperature (the average kinetic energy) might stay the same.

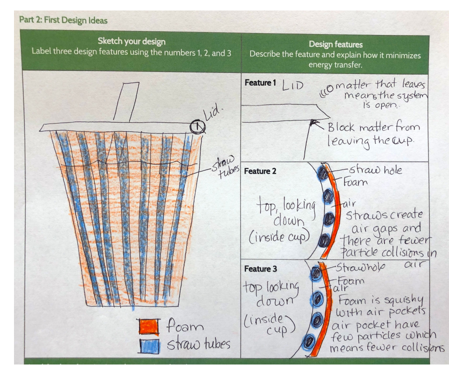


⇓ **Navigation to Next Lesson:** In this lesson, we focus on interactions between the particles in a gas using an online interactive simulation. Next we will investigate how the motion of the particles of the matter on one side of the cup's wall affects the motion of the particles on the other side of the wall.

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr>
<td>LESSON 13
2 days
How could the motion of particles on one side of a solid wall affect the motion of the particles on the other side of that wall?
Investigation</td>
<td>
When a fast-moving glass marble hits a slow-moving glass marble moving in the same direction, the fast-moving marble slows down and the slow-moving marble speeds up. When a moving glass marble hits a line of magnet marbles held in place, the glass marbles on the other side of the magnetic marbles start moving.</td>
<td>We use a simulation to analyze particle speeds before and after a collision. We use marbles to investigate the effects of collisions on particle speeds in different situations to simulate interactions between particles in a gas, a liquid, and a solid. We use a simulation to analyze particle interactions in different solids in contact with each other at different temperatures. We figure out these things:
Particles in a solid vibrate back and forth in place.
Collisions between particles in a solid, liquid, and/or gas can transfer kinetic energy (KE or motion energy) from one particle to another.
The more particles in a sample of matter that are in contact with another sample of matter, the greater the amount of particle KE is transferred from the warmer piece of matter to the cooler pieces of matter over time.
The more particles an object is made of, the more energy must leave or enter the system in order to change the temperature of that object.</td>
<td></td>
</tr>
<tr><td colspan="4">⇓ Navigation to Next Lesson: Energy transfer between the particles in solids, liquids, and gases can explain how warm matter outside a cup can cause a cold liquid inside the cup to warm up.</td></tr>
<tr>
<td>LESSON 14
3 days
Does our evidence support that cold is leaving the system or that heat is entering the system?
Investigation, Putting Pieces Together</td>
<td>
Butter melts when a candle is lit on one side of a strip of aluminum foil.</td>
<td>We sort evidence collected during previous lessons to support or refute claims that temperature changes are due to heat or cold moving into or out of the cup system. We conduct an investigation to collect additional evidence, helping us figure out that heat moves into the cup system, causing a temperature change. We revise our cup system models and apply our new understanding to answer questions from the DQB and explain related phenomena.We figure out:
Temperatures change when energy moves from warmer to cooler matter.
Energy is transferred when higher-energy particles come into contact with lower-energy particles.</td>
<td></td>
</tr>
<tr><td colspan="4">⇓ Navigation to Next Lesson: Now that students understand how cold water inside a system can warm up through particle collisions, students think about how to design a cup and related devices to slow down this process.</td></tr>
</table>

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 15 3 days **How do certain design features slow down the transfer of energy into a cup?** Investigation	 *Certain design features, such as double walls, foam, and reflective materials, slow down or minimize the temperature increase of a liquid inside a cup system.*	We learn about the *Cold Cup Challenge* and look at examples of effective cup designs. We still need to explain how certain features work (i.e., double walls, porous materials, color). We jigsaw the gaps in our knowledge and conduct a gallery walk to share our findings. We reach consensus about mechanisms for energy transfer, which will help us in the design challenge. We figure out: • Shiny/ light-colored materials (feature) prevent light from being absorbed. Absorption of light by particles (mechanism) transfers energy to the cup. • Porous materials with air pockets (feature) slow down the conduction of energy because there are fewer particles to collide across the air pockets. Conduction of energy from particle collisions (mechanism) transfers energy. • A double-walled cup with a vacuum or air between the walls (feature) slows down the conduction of energy because there are fewer or no particles to collide between the walls. This is a similar mechanism as in porous materials.	

⇓ **Navigation to Next Lesson:** In this lesson, the class agrees on important ideas about how certain design features slow down or minimize energy transfer from light and conduction into the cup system. Now students are ready to take on the design challenge and choose design features based on science ideas they have figured out.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 16 2 days **How can we design a cup system to slow energy transfer into the liquid inside it?** Investigation	 *Certain design features slow energy transfer reflecting light or using air pockets or layers.*	We review the Cold Cup Challenge and design our cups, pointing out features we have evidence will slow energy transfer. We build our first cup designs, test them, and evaluate our results compared to the criteria and constraints. We provide feedback to each other to improve our cup designs. We figure out: • The more clearly a design task is defined, the more likely the solution (cup system) will meet the criteria and constraints. • A designed cup needs to be tested and then modified on the basis of the test results that will help evaluate the solution to how well it meets the criteria and constraints of a problem.	

⇓ **Navigation to Next Lesson:** In this lesson, we designed, built, and tested a cup and learned that it does well in certain areas, but can be improved in other areas. We used test results and feedback from peers and our teacher to evaluate our design, which started us wondering about modifications we can make in the next design cycle.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 17

2 days

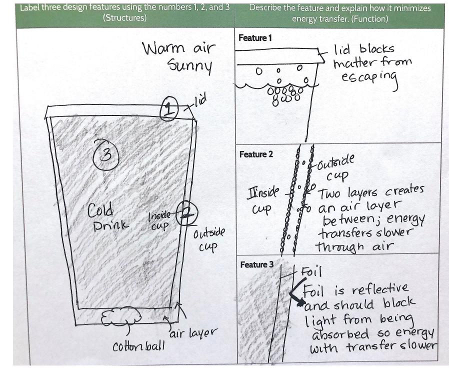
How can we improve our first design to slow energy transfer into the cup system even more?

Investigation

Cup designs that use fewer materials and reduce absorption of light and contact between materials are more effective.

We review our test results and feedback from our first design. We clarify the criteria and constraints and then redesign, build, test, and evaluate a new cup. We make observations from the new data to identify the features of the best performing cups. We figure out:

- Surface materials that reflect more light help cups perform better on the bright light and temperature test.
- Materials used on the cup walls that reduce the amount of contact between layers help cups perform better on the regular light and temperature test.
- The use of fewer materials can still be effective on the two temperature tests, while also reducing costs, diameter, and environmental impact.



⇓ **Navigation to Next Lesson:** We worked in our design groups to modify our cup designs to optimize the cup's performance on various tests. We used the test results from design cycle 1 and 2 to put forth a cup design that best meets the criteria and constraints. We shared our cup and test results with our peers, and are wondering which group's cup best meets the criteria and constraints of the Cold Cup Challenge.

LESSON 18

3 days

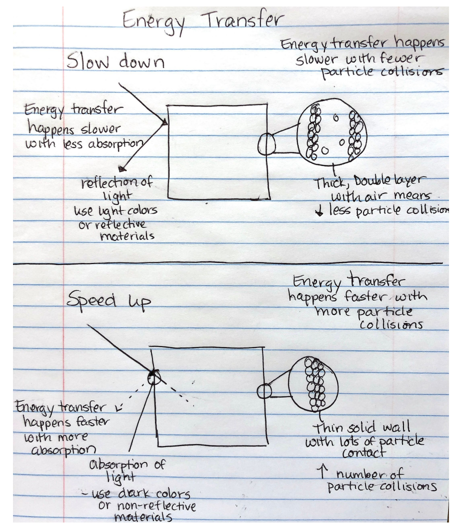
How can containers keep stuff from warming up or cooling down?

Putting Pieces Together

Objects designed to keep things cold or hot share similar design features, like materials that create air insulation and have transparent or reflective surfaces.

We review and interpret test results across our best cup designs. We use evidence to offer suggestions as our class works together to design the Ultimate Cold Cup. We generalize our model to explain patterns to minimize or maximize energy transfer, and use our model to predict how energy transfer could be maximized or minimized in everyday examples. Finally, we revisit the Driving Question Board and discuss all of the questions we can now answer. We figure out:

- The rate of energy transfer between systems speeds up or slows down depending on the number of particle collisions.
- The rate of energy transfer between matter and light speeds up or slows down depending on how much light is absorbed.
- The amount of matter in a substance affects the rate of energy transfer and how much energy is needed to increase the substance's temperature.



LESSONS 1-18

37 days total

TEACHER BACKGROUND KNOWLEDGE

What are the Disciplinary Core Ideas (DCIs) in the context of the phenomenon?

"Disciplinary Core Ideas" are reproduced verbatim from A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. DOI: https://doi.org/10.17226/13165. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K-12 Science Education Standards. National Academies Press, Washington, DC. This material may be reproduced and used by other parties with this attribution. If the original material is altered in any way, the attribution must state that the material is adapted from the original.

In this unit, students will develop and use particle models of a pure substance (water) to explain energy transfer from light and thermal energy. Across the unit, students develop and refine models to explain how objects can change temperature both when matter moves out of a system, and when energy is transferred between objects. Students begin by encountering the anchoring phenomenon of an iced drink in a new (special) cup staying cooler than an iced drink in a regular cup. Students share their initial ideas about matter or energy moving into or out of the cups to explain how the drinks warms up over time. The purpose of the anchor is twofold. First, it is used to probe students' initial ideas of what it means for something to warm up and mechanisms for how this happens in the cup system context. Second, it prompts students to identify the key components of the cup system and how they function to keep the drink cold or allow it to warm up. Defining the system in this way sets students up for making principled decisions about how and why to modify components of the system in their engineering designs to slow energy transfer.

In the first lesson set, students conduct initial investigations into the cups to test cup features (components of the system) they conjecture may be important to keep the drink cold. They test their ideas with both cold and hot water to see how the cup features works in both situations. This motivates 1) the need for more systematic investigations to test the various cup features, and 2) wanting to look closely at the function of the lid (because initial data indicates that the lid is a crucial part of the system). Students design and carry out controlled investigations testing the lid. They figure out that the lid acts to close the system by trapping matter from escaping. They develop particle models to explain evaporation, mostly focused on modeling the structure of solids, liquids, and gases, and the movement of water particles from liquid to gas. Their models at this point are limited to explaining how particles of liquid gain energy and become gas particles moving into the air. Thus, they are left puzzled by the observation that when they completely close the system, the drink still warms up -- even though they are sure that matter can no longer escape or enter the system from gaps in the lid area.

This limitation in their models motivate the second lesson set. In this lesson set, students investigate how energy can enter or leave the system. They investigate their ideas about light first, given they have more background about light from the previous unit (6.1). They investigate how light interacts with the cup walls and lid. Students figure out that the liquid inside cups with reflective walls warm up less than liquids inside cups with transparent and dark-colored walls. Using this evidence, they modify their models for explaining how light interacts with matter to include absorption of light. While these models explain more than their prior models, students find that, even when placed in a completely dark space, the liquid inside the cup warms up. This motivates the need for another mechanism of energy transfer. Students investigate particle motion in warmer and cooler substances via lab investigations and a series of simulations. Through these investigations, they collect evidence that suggests heat enters the cup system through particle collisions with the relatively warmer air outside the cup. Thus, they add this mechanism of energy transfer to their explanations of the phenomena so far.

In the third lesson set, students revisit popular and highly effective design features of cups, such as reflective materials and air insulation, and they model how these features minimize energy transfer by reducing absorption of light or the opportunity for particle collisions. They draw on their models to engage in a design challenge to design a cup that can compete with the expensive store-bought cups in keeping liquids cold. They use what they have figured out about mechanisms of energy transfer and design features that slow this process so that the liquid in the cup keeps its original temperature longer. Students design, build, test, and modify their cup system through two design cycles. At the conclusion of this design challenge, students develop the ultimate cup design together, drawing upon features of successful cups. Then they apply their model for energy transfer to explain related phenomena they experience in their daily lives.

This unit builds towards the following NGSS Performance Expectations (PEs):

- **MS-PS1-4*:** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- **MS-PS3-3:** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer
- **MS-PS3-4**: Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample
- **MS-PS3-5:** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
- **MS-PS4-2***: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- **MS-ETS1-4**: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

*These performance expectations are developed across multiple units. This unit reinforces or works toward these NGSS PEs that students should have previously developed or will develop more fully in future units. In the OpenSciEd Scope and Sequence, PS4-2 is first built in Unit 6.1. In this new context of particle models and energy transfer, students learn more about how absorption of light occurs at the particle level. This unit begins to address changes in state that are part of PS1-4; then changes in state are more fully developed in the next unit, 6.3, on water cycling. In 6.3, students learn that evaporation and condensation occur when energy is added or removed from the substance.

The unit expands students' understanding of particle models and energy transfer, which include these Grade 6-8 DCI elements:

PS1.A: Structure and Properties of Matter

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
- The changes of state that occur with variations in temperature ~~or pressure~~ can be described and predicted using these models of matter. (MS-PS1-4)

PS3.A: Definitions of Energy

- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to MS-PS1-4)
- Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (secondary to MS-PS1-4)
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3), (MS-PS3-4)

PS3.B: Conservation of Energy and Energy Transfer

- When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4)
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material ~~and the frequency (color) of the light.~~ (MS-PS4-2)

ETS1.A: Defining and Delimiting an Engineering Problem

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (secondary to MS-PS3-3)

ETS1.B: Developing Possible Solutions

- A solution needs to be tested and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (secondary to MS-PS3-3)

*There is a strike through parts of the DCI elements that are not developed in this unit. In the OpenSciEd Scope and Sequence, students will develop an understanding of changes in state, particularly as they relate to pressure, in OpenSciEd Unit 6.3, and frequency (color) of light in OpenSciEd Unit 8.4.

The placement of this OpenSciEd Unit 6.2 and associated units are shown in the OpenSciEd Scope and Sequence document.

What should my students know from earlier grades or units?

This unit uses and builds upon Disciplinary Core Ideas (DCIs) that students should have previously developed in OpenSciEd unit 6.1 by working on the following NGSS performance expectations MS-PS4-2

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material ~~and the frequency (color) of the light.~~ (MS-PS4-2)

This unit reinforces and builds from the following Grade 4-5 DCI elements.

PS1.A: Structure and Properties of Matter

- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model that shows gases are made from matter particles that are too small to see and that are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1)

PS3.A: Definitions of Energy

- The faster a given object is moving, the more energy it possesses. (4-PS3-1)
- Energy can be moved from place to place by moving objects or through sound, light, or electrical currents. (4-PS3-2), (4-PS3-3)

PS3.B: Conservation of Energy and Energy Transfer

- Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-2), (4-PS3-3)
- Light also transfers energy from place to place. (4-PS3-2)

Students would benefit from having prior experience doing the following focal science and engineering practices (SEPs) at the 3-5 grade-band level. They include the following:

- Asking Questions and Defining Problems
  - Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.
- Developing and using models
  - Develop and/or use models to describe and/or predict phenomena.
  - Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.
  - Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.
- Planning and Carrying Out Investigation
  - Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
- Constructing Explanations and Designing Solutions
  - Apply scientific ideas to solve design problems.
  - Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.
- Engaging in argument from evidence
  - Construct and/or support an argument with evidence, data, and/or a model.

Having students familiar with using focal crosscutting concepts (CCCs) for this unit at the 3-5 grade-band level would be helpful. They include the following:

- Scale, Proportion, and Quantity
  - Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.
  - Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.
- Systems and System Models
  - A system can be described in terms of its components and their interactions.
- Energy and Matter: Flows, Cycles, and Conservation
  - Matter is made of particles.
  - Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems.
  - Energy can be transferred in various ways and between objects.

- Structure and Function
    - Different materials have different substructures, which can sometimes be observed.
    - Substructures have shapes and parts that serve functions.

What are some common ideas that students might have?

Students will likely bring prior ideas about particles, heat, cold, and light to the study of this unit. Students typically see *heat* and *cold* as properties of objects rather than as the transfer of energy between objects. Students have developed deeply rooted ideas about hot objects (e.g., stove, lightbulb, fire, metal in the sun) and cold objects (e.g., ice and snow, ice cream, ice packs). For example, students believe one can add heat to an ice cube to melt it, and it will no longer be cold. Similarly, many middle students may believe, one could add cold to water to make an ice cube. In contrast, a scientifically accurate model of *heat* is a measure of the energy transferred between two objects or between two substances due to a temperature difference between them. Thus, an object or substance never has heat or cold, which are our subjective experiences of the energy transfer happening between two objects. With the context of the cups, students may think that "heat waves" get into the cup to warm up the water inside it. The transparency of a plastic cup will bring out this idea even more as students will know that light transmits through transparent materials and they may conflate light with heat. Students may argue that the reflectively or color of the cup matters for "blocking" the heat waves. The unit is designed to build on and extend these intuitive ideas. It is OK for students to refer to and write or draw heat as waves until lessons 12, 13, 14 when students have evidence to explain this at the particle level, and they should start transitioning to thinking about heat as the transfer of energy via particle collisions.

Students may also not realize that solids, liquids, and gases are made of particles that are in constant motion. This is particularly tricky for students when it comes to solids, where the particles still vibrate in their fixed location. Likewise, gases present their own challenge since we cannot see them. Students sometimes wrestle with understanding that gases are made of particles that can transfer energy to surrounding visible objects, including liquids and solids. In the context of the anchoring phenomenon example, students will eventually figure out that is the collision of gas particles with higher average kinetic energy outside the cup that transfer energy to the solid particles that make up the cup wall that have with lower average kinetic energy.

Students have likely shared ideas about *air* and *vacuums* as key features of highly insulative cups and devices. With the pervasiveness of double-wall objects in our everyday lives (e.g., thermoses, water bottles, reusable coffee cups), students recognize that the double wall is helping the drink stay cold. Students may not understand how the air or vacuum between the two walls work to slow energy transfer (insulate).

What modifications will I need to make if this unit is taught out of sequence?

This is the second unit in 6th grade in the OpenSciEd Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier or later in the middle school curriculum. These include:

- If taught before OpenSciEd Unit 6.1, supplemental teaching of light interactions with matter, such as reflection and transmission would need to be added. These ideas are fundamental to the model students need to build of energy transfer through particle collisions.
- If taught before OpenSciEd Unit 6.1 or at the start of the school year, supplemental teaching of classroom norms, setting up the Driving Question Board, and asking open-ended and testable questions would need to be added. (These supports are built into 6.1.)
- If taught later in the OpenSciEd sequence after other engineering design challenges, modify the cup design challenge so that students are more involved in defining the problem and determining the criteria and constraints. Currently, Unit 6.2 is students' first introduction to engineering design in the OpenSciEd 6-8th grade sequence. Therefore it is more scaffolded than it would need to be if the unit were taught much later in the middle school curriculum.

What are prerequisite math concepts necessary for the unit?

Beginning in lesson 4 and throughout the unit students focus on pooling and then averaging test results and building an understanding of temperature as a measure of average particle movement. They take measurements in the tenth or hundredth in decimal points, and must consider negative and positive numbers as they mass systems. Prerequisite math concepts that may be helpful include:

- CCSS.Math.Content.5.NBT.A.3 Read, write, and compare decimals to thousandths.
- CCSS.Math.Content.5.NBT.A.4 Use place value understanding to round decimals to any place.
- CCSS.Math.Content.6.SP.A.3 Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.
- CCSS.MATH.CONTENT.6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, debits/credits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation.

Calculating a mean of a data set is a target idea in 6th-grade CCMS. Prior to lesson 4 in this unit, talk to your grade's math teacher to find out when students will learn how to calculate the mean of a numerical data set in math class this year. If they have worked on this already, ask the math teacher for an example data set they worked with and any suggested modification to your anchor chart for calculating a mean. If students haven't yet worked through any examples in their math classes, then the pooled temperature data in this lesson will be an example you save to refer to in future lessons in concert with this anchor chart. Also ask the math teacher if students have worked with using negative numbers to represent quantities in the real world. This will inform your decision about how to represent temperature changes in the pooled class data table.

ASSESSMENT SYSTEM OVERVIEW

Each OpenSciEd unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. The table below outlines where key assessments can be found in the unit. Key formative assessments are identified here, but many more opportunities are embedded in each lesson and guidance for those appears in the following table.
Each OpenSciEd unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. sIn addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial models in science notebooks Driving Question Board	**Pre-Assessment** The student work in lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Revealing these ideas early can help you be more strategic in how to build from and leverage student ideas across the unit. The initial models developed during lesson are a good opportunity to pre-assess student understanding of systems thinking, particle models, and energy transfer. The two most important times to do this include: (1) between day 1 and day 2, after students have developed their initial cup system models and (2) during the Consensus Discussion on day 2 when they develop an initial model for a related system. For the initial cup system models, look and listen for • agreement on the components of the system models (such as the walls, lids, straws, water inside, air inside between the water and the lid, and ice), • agreement that the structural components (parts of the cups) have some similarities (made of plastic) and differences (thin versus thick), and • disagreement about how the drink inside warms up (processes or mechanisms such as heat or light going into the cup and air or cold leaving the cup). These disagreements will motivate the need for further investigations. The Driving Question Board is another opportunity for pre-assessment. Reinforce for students to generate open-ended questions, such as how and why questions, to post to the board, but celebrate any questions students share even if they are close-ended questions. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these kinds of questions into open-ended questions when they relate to the investigations underway.

Lesson 5	Student Assessment
	
	L5 Assessment Scoring Guidance
		Formative
		The *Cold Lemonade on a Hot Day!* activity is a formative assessment that should be completed individually. Look for these ideas from your students:
		• agreement with Regina and an explanation (using words and a diagram) that the water forming on the outside comes from the air, using evidence from the *Water Droplet Investigation* and related experiences.
		• incomplete or inaccurate answers
		    • not using evidence from the investigations to support the claim, even if they choose the correct claim made by Regina.
		    • agreement with Michael and explanation that the clear water on the outside of the pitcher comes from clear water in the ice that was inside the pitcher.
		    • agreement with Sarah and explanation that the water on the outside comes from the inside of the cup but the food coloring particles are too large to get through the walls.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 6	Student Assessment L6 Assessment Scoring Guidance L6 Modeling Rubric	**Formative** This is a formative assessment at the end of a set of lessons. In addition to eliciting ideas about particle movement and liquid, solid, gas interactions, the task asks students to use their understanding of planning investigations and modeling and systems and systems models. The teacher reference document provides a scoring guide and a modeling rubric specific to this unit. This midpoint assessment is important formatively to make sure the class is on the same page and ready to move forward in the unit. At this point, students should be able to reason with particles to explain how an amount of liquid might change in the cup over time and what aspects of a system might affect that change. If students are struggling with the investigation plan or modeling, you might ask them to talk through their thinking. If the class is struggling, discuss the conventions you've agreed upon for modeling and have a class discussion of what common things should be included in a particle model or an investigation plan.
Lesson 14	Student Assessment L14 Assessment Scoring Guidance L14 Modeling Rubric	**Formative** This is a formative assessment at the end of a set of lessons. Students are asked to use their ideas about thermal energy and their understanding of the practices and crosscutting concepts to make sense of a new phenomenon. The teacher reference document provides a scoring guide and a modeling rubric specific to this unit. This midpoint assessment is important formatively to make sure the class is on the same page and ready to move forward in the unit. At this point, students should be comfortable with the following science ideas as well as argumentation, modeling, and systems and systems models: • A particle's speed is related to how much kinetic energy it has. • When particle movement increases it is because energy is transferred into the substance. • When particle movement decreases it is because energy is transferred out of the substance. • When a system is cooling down, energy is transferring out of it. When a system is warming up, energy is transferring into it. • Particles in solids can move back in forth but their movement is confined so it appears like they are vibrating. • When substances are in contact, energy transfer occurs mainly through particle collisions (i.e., conduction), which is when kinetic energy is transferred between particles. • Energy transfers from hotter objects or substances to colder ones. The assessment gives multiple ways of looking into student thinking. If students are struggling with the direction of energy transfer, you might see that in the ways in which students organize evidence in question 1. You can further diagnose where students might be struggling in their thinking by reviewing their particle models of the phenomena. If students are struggling with their models, you might consider asking them to explain their thinking to you.
Lesson 18	Student Transfer Task L18 Assessment Scoring Guidance	**Summative** This lesson includes a transfer task to give students an opportunity to use the 3 dimensions to make sense of a different phenomenon. This is meant to be a summative assessment task for the unit and it gives you a grading opportunity. The task includes a teacher reference with a scoring guide. Scoring guides are meant to highlight important ideas students should be including in their responses. If students share these ideas elsewhere in the assessment, it is up to you to decide if that understanding is sufficiently demonstrated. Student responses will vary because the task is designed as a structured engineering design challenge, however, students must use science ideas and information from the task to support their responses.

When	Assessment and Scoring Guidance	Purpose of Assessment
After each lesson	Lesson Performance Expectation Assessment Guidance	**Formative Assessment** Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.
Occurs in most lessons	Progress Tracker	**Formative and Student Self Assessment** The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time. In this way, the Progress Tracker can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Tracker is meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative "grade" other than for completion.
Anytime after a discussion	Student Self Assessment Discussion Rubric	**Student Self Assessment** The student self-assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try next time to improve such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small group discussions can be more productive.
After Students Complete Substantial, Meaningful Work	Lesson 16, Handout 2, Design Evaluation: Peer Feedback Peer Feedback Facilitation: A Guide	**Peer Feedback** There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving the peer feedback. It should be a formative, not summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.

For more information about the OpenSciEd approach to assessment and general program rubrics, visit the OpenSciEd Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every OpenSciEd lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	Develop an initial model to describe a phenomenon in which a substance changes temperature and identify structural parts of the system that slow down or speed up the temperature change (function). Ask questions that arise from careful observation and can be investigated in the classroom to test how parts of the cup systems contribute to warming up or maintaining the temperature of the substance inside.	**Modeling; Structure and function** The two most important times during Lesson 1 to formatively assess your students' models include: (1) between day 1 and day 2, after they've developed their initial cup system models and (2) during the Consensus Discussion on day 2 when they develop an initial model for a related system. It may be helpful for your students to leave their notebooks in the classroom for you to assess their work. For the initial cup system models, look and listen for • agreement on the components of the system models (such as the walls, lids, straws, water inside, air inside between the water and the lid, and ice), • agreement that the structural components (parts of the cups) have some similarities (made of plastic) and differences (thin versus thick), and • disagreement about how the drink inside warms up (processes or mechanisms such as heat or light going into the cup and air or cold leaving the cup). These disagreements will motivate the need for further investigations. For the related phenomena models on day 2, look and listen for • whether students are able to identify important parts of the new system and include them in their models and • whether students are applying similar processes/ mechanisms to the related phenomena as they applied in their cup models, even if the mechanisms are inaccurate. If your students struggle with identifying important components of the new systems of the related phenomena, add more instructional time to work on this aspect of modeling. To do this, pick one of the related phenomena from the class list. Create a three-column chart with "Important parts", "Not important parts", and "Not sure parts". Have students work together to decide the *important parts* of the system. Draw a sketch using these parts and the *not sure parts* but excluding the *not important parts*. The goal is for students to get more comfortable with figuring out which parts of the system need to be included in the model versus which parts are irrelevant. **Asking questions; Systems and system modeling** As the class builds the Driving Question Board (DQB) on day 3, listen for (1) the kinds of open-ended questions being asked and (2) how the questions relate to the systems models. On day 3, students are directed to develop open-ended questions for the DQB, particularly trying to use how and why prompts. It is important that *all* questions posed by students be placed on the DQB regardless of whether they are open-ended or close-ended. Make note of any close-ended questions and use navigation time throughout the unit to turn them into open-ended questions when they relate to the investigations underway. As students ask questions, have them reflect on any parts of the cup systems or related systems that have few or no questions posted on the DQB. Prompt students to generate more questions in this space so that each important part of the system is to be investigated.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	Plan and carry out an investigation to gather evidence to answer scientific questions about how parts of the cup system relate to the temperature change of the liquid inside. Analyze and interpret data to find patterns indicating which parts of the cup system (features) influence the temperature change of the substance inside the system.	**Planning and Carrying Out Investigations; Systems and System Models** During the *Plan Cup Investigations in Small Groups* and *Carry Out Cup Investigations* activities on day 1, circulate among the groups to check on their plans written in their science notebooks. Look for students to include • the agreed-upon parameters for the fair test and • only 1 changed variable from either of the 2 cup systems tested in Lesson 1. If students are struggling to decide how to change only 1 variable, ask them to begin with 1 of the 2 cup systems (the regular plastic cup or fancy plastic cup) from Lesson 1 and identify 1 thing they'd like to change (e.g., removing the lid, wrapping the cup in foil, placing it under a lamp, etc.). Students are not expected to be exhaustive in their control of other variables, but they should have a reasonable plan for focusing on changing only 1 variable. Students do not need to name variables as independent or control variables in this lesson. They will learn about these types of variables and use this terminology later in the unit. **Data Analysis; Patterns** During the *Analyze Class Data* activity on day 2, circulate among the groups to listen in on their discussion about ways to sort the data and about patterns they identify when they do the sorting. Look or listen for these ideas: • Students may make comparisons between cups with a lid versus no lid. They should be able to identify a pattern that conditions with no lid warm up faster than conditions with lids. • Students may make comparisons between single-wall and double-wall cups. They should be able to identify a pattern that double-wall cups work better than single-wall cups regardless of material. • Students may make comparisons between the presence of a straw versus no straw. They may not be able to identify an associated pattern because the straw is a relatively minor feature. • Students may make comparisons based on cup material type, like plastic versus metal. They may not be able to identify a pattern because the material type is conflated with the number of walls at this point. Later we will test those 2 variables separately. • Students may also make observations of conditions that are represented by only 1 cup. Listen for how students talk about an observation versus a pattern, and probe students about whether they can use a single observation to identify a pattern. It is expected that some students will struggle with finding patterns in the data. This struggle is important for motivating a need to create more systematic investigations going forward. It is OK if this investigation's data seems messy and inconclusive. To help your students avoid frustration, give them the option of identifying an inconclusive result if they don't see a clear pattern. Later in the *Order the Cups by Performance* activity, listen to how students use conclusions from their data analysis to order their cups from best to worst performers. If students struggle, have them revisit the class data to decide how to rank the cups based on the temperature change calculations.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 3	Develop and use a model to explain how the best-performing and worst-performing cup systems affect the temperature change of a substance inside a system. Plan an investigation to investigate how the lid (a structural feature of the cup system) works to slow the temperature change (function) of a substance inside the system.	**Developing and Using Models; Systems and System Models** Students develop models for the best and worst performers at the end of day 1 and share them in small groups at the beginning of day 2. It will be helpful to collect students' notebooks between the two days to see how students are explaining how cup system features can keep liquids both hot and cold. However, some students may want to take their notebooks home to finish their models. Look for students to include new aspects to their models, such as these: • the differences between hot and cold liquids • what is happening when liquids increase or decrease in temperature • how cup features work to slow both the cooling down and warming up of liquids Most importantly, notice whether students' mechanisms for explaining how liquids warm up or cool down are the same or different. It's not important whether students have the "correct" ideas; rather, your assessment can help you understand students' initial ideas about what it means for a substance to have a particular temperature and what mechanisms are involved in changing the temperature of a substance. **Planning and Carrying Out Investigations; Structure and Function** At the end of day 2, students work in small groups to plan an investigation focused on the lid. Between Lessons 3 and 4, examine students' plans for investigating the lid's role in slowing the warming up or cooling down of liquids. Look for the extent to which students: • understand the ways in which control variables affect how a drink cools down or warms up in the cup system and • can plan an investigation and understand how controlling as many variables as possible enhances the validity of the tests when investigating how changing the independent variable affects the cup system. It will be important not only to hear or see students' ideas but also to ask questions to ascertain students' justifications for including particular features in their experimental design. It is important that students aren't just including a single independent variable because they talked about it in class, but rather, because they understand why it is important to change only one variable while holding other variables constant. It is not important for students to use terminology like *independent variable* or *control variable* until Lesson 4.
Lesson 4	Plan and carry out investigations to determine the effect of a lid on temperature change and mass change in systems that are more open and less open. Analyze and interpret data by applying concepts of probability to calculate the mathematical mean to compare the temperature change and mass change across conditions (patterns) and use these measures to make claims about the effect of the lid. Develop a model to describe why mass is lost in some conditions but not others (open systems versus less-open systems), using a particle model of matter for liquids and gases.	**Planning and Carrying Out Investigations; Systems and System Models** In the previous lesson, students planned an investigation to determine the effect of a lid on temperature change of a hot liquid in a cup. They carry out that investigation in small groups on day 1 of this lesson. They then modify their procedure for that lid investigation in preparation for a slightly different investigation about mass changes occurring in open versus less open systems. Collecting this revised procedure is a good opportunity to assess the planning aspects of this practice. Students carry out the second investigation in small groups on day 2 to determine the effect of a lid on mass change of a hot liquid in two cup systems. The group lab work in the first and second investigations is a good opportunity to assess the carrying-out aspects of this practice. **Analyze and Interpret Data; Patterns** Students apply concepts of probability to calculate the mathematical mean for the two systems to compare the temperature drop and mass change in each condition and use these measures to make claims about the effect of the lid at the end of each investigation on days 1, 2, and 3. Students' calculations on the handout *Procedure: Measuring Changes in Mass in the Cups* and their responses in its *Making Sense* section are a good opportunity to assess the use of this practice in concert with the related science ideas targeted by the lesson-level performance expectations.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		Look for students' growing fluency in their ability to independently calculate an average across this lesson. Calculating statistical measures of central tendency (mode, mean, and median) is a new skill in 6th grade, based on the CCMS. (Use of the mode and median will be introduced in OpenSciEd units 6.3 and 6.4.) Students also use negative numbers in this lesson to represent temperature and mass decreases in the systems. However, if students have not already worked with these ideas and skills in math class or are concurrently developing them, don't expect students to have mastered them yet. Talk with your math teachers to determine your students' development with respect to averages and negative numbers. **Developing and Using Models; System and System Models** Students model what is happening to the particles in the liquid water in the system to explain why mass is lost in open systems). They draw a model to account for this at the end of day 1. They use manipulatives to model matter at a microscopic scale at the boundary between the surface of the liquid and the air above it at the end of day 2. The models that students draw on the handout *Initial Model of Mass Loss in the Cup with No Lid* provide a good pre-assessment of students' particulate-level understanding of evaporation, which is a target idea they should have developed in 5th grade in NGSS. In this model look for these ideas: • water being made of particles of matter • particles of water going into the air from the surface of the liquid (evaporation), leaving fewer particles of water behind in the liquid over time Students' responses to the first question on the handout *Explanations and Predictions of Lids and Covers* are a good opportunity to assess the use of these ideas after they have been (re)established/agreed upon by the class at the end of day 3. In the responses look for these ideas: • Water is made of particles of matter. • Particles of water go into the air over time (evaporation), leaving fewer particles of water behind in the liquid. • Particles of water in the air can't go through a solid lid. • Particles of water in the air may be able to go through gaps in the solid parts of the system (e.g., the straw hole or where the lid meets the walls of the cup). This is also an opportunity to determine if students have a particulate model of matter for solids from 5th grade. This model will be (re)established in Lesson 6. But you can pre-assess student understanding of it now, by looking for this idea in their responses to questions 1 and/or 4 on *Explanations and Predictions of Lids and Covers*: • The cup's solid walls and lid are also made of particles. These particles are so closely spaced together that gas particles can't fit between them to get into or out of the system.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance

Lesson 5	Collect and analyze different forms of data to identify patterns across our data sources that serve as evidence that condensation that forms on the outside surface of a cold cup system comes from the air outside the system.
	
	Construct an argument to support the claim that water forming on the outside surface of a cold cup system comes from the air outside the system and is not leaving the system through the walls.
		Analyzing and Interpreting Data; Patterns; Systems and System Models
		During the *Discuss Observations and Data in a Scientists Circle* activity, listen as students share what they developed for the analysis and conclusion questions for both parts of the *Water Droplet Investigation*. Prompt students to identify patterns from the evidence that point to condensation coming from the air outside the cup.
		
		For *Part A*, listen for students to claim that the mass increase is due to water from the outside air condensing on the cup surface. If students are missing this connection, probe what they would expect to happen to the measured mass if the water droplets came from inside the cup (e.g., the mass would stay the same or go down).
		
		For *Part B*, listen for students to use evidence that since the water droplets are clear and the water inside the cup is colored, the water on the outside cannot come from inside the cup.
		
		If students continue to struggle with one or the other of these investigations, point them to their observations during related experiences in which water droplets formed on a surface where there was no water to begin with (e.g., dew forming on grass in the morning, condensation on windows where it was cold inside and warm outside).
		
		Engaging in Argument from Evidence; System and System Models
		The *Cold Lemonade on a Hot Day!* activity is a formative assessment that should be completed individually.
		
		Look for these ideas from your students:
		• agreement with Regina and an explanation (using words and a diagram) that the water forming on the outside comes from the air, using evidence from the *Water Droplet Investigation* and related experiences
		• incomplete or inaccurate answers
		    • not using evidence from the investigations to support the claim, even if they choose the correct claim made by Regina
		    • agreement with Michael and explanation that the clear water on the outside of the pitcher comes from clear water in the ice that was inside the pitcher
		    • agreement with Sarah and explanation that the water on the outside comes from the inside of the cup but the food coloring particles are too large to get through the walls
		
		If students select the correct claim but do not support it with evidence, consider practicing with them how to write an explanation that draws on evidence and/or showing students examples of explanations written using evidence.
		
		If students choose Michael or Sarah as the claim they most agree with, and the data from the current investigations is not convincing to them, consider conducting a follow-up investigation. Chill an empty plastic or metal cup overnight and then make observations of the empty cup the following day. Remove the cup from the cooler and place it into the classroom air. Watch and observe that water continues to collect on the surfaces of the chilled cup even when there is no water inside the cup.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance

Lesson 6	Develop and use a particle model of matter for solids, liquids, and gases to show how structural differences in a cup system allow water molecules to leave the system at some points in the system but not at others.
	
	Plan an investigation and in the design, identify the controls, the tools needed to gather the data, and how much data are needed to support a claim about how much liquid (matter) leaves two different cup systems over 30 days.
		Planning and Carrying Out Investigations; Systems and System Models
		In this lesson, students independently plan an investigation in which they identify the controls, what tools are needed to gather the data, and how much data are needed to support a claim about how much liquid (matter) leaves two different cup systems over 30 days. They do this as part of their individual summative assessment at the end of day 2, when they answer Question 2 on *Explaining the Effect of Different Lid Designs*.
		
		Look for the following responses to Question 2:
		• If Alex wants to use the mass of the liquid as her dependent variable, what other steps should she take to get the data she would need?
		    • Measure the mass of both cup systems containing liquid at the start of the investigation.
		    • Wait 30 days and then measure the mass again.
		    • Calculate the change in mass in each cup system (the difference between the mass at 30 days and the initial mass).
		• If Alex wants to use the liquid level as her dependent variable, what other steps should she take to get the data she would need?
		    • Mark the height of the liquid level in each cup system after 30 days.
		    • Measure the vertical distance between the two lines marked on each cup, or measure the height of each line on each cup, and then calculate the change in liquid level in each cup system (the difference between the height at 30 days and the initial height).
		• To compare the two cups, what should Alex keep constant in her investigation?
		    • the amount of liquid used in both cups
		    • the temperature of the liquid used in both cups
		    • Other variables students may mention include:
		        • the type of material both cups are made of
		        • the size of the cups
		        • the type of liquid used in both cups
		
		If students struggle with this, have them go back and identify each of the variables they kept constant in Lessons 3 and 4, how many measurements they took in those investigations to calculate a difference, and how many trials they measured to determine a mean.
		
		Developing and Using Models; System and System Models; Patterns
		Students model what is happening to the particles in the liquid water and how these particles interact with particles in the solid plastic wall, using the hands-on activity with marbles and the zoom-in diagrams of different points in the cup system on day 1 of this lesson. They develop and use similar representations as part of their individual summative assessment at the end of day 2 when they answer Questions 3, 4, and 5 on the assessment handout. Question 5 helps problematize that mass loss is correlated with more rapid temperature change in the liquid and therefore may be the cause (or part of the cause) of this increased rate of temperature change. But it is not recommended that you assess that question. Instead assess the joint responses to Questions 3 and 4 and look for the elements identified in *Rubric for Model in Lesson 6 Assessment*.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 7	Develop two models to show relationships among the parts of the mostly closed cup system and how light and heat or cold (i.e., mechanisms) cause the liquid inside to warm up or cool down (effect).	**Developing and Using Models; Cause and Effect** Near the end of the lesson, students are asked to **construct models** that represent their ideas of how different types of energy (light and heat or cold) interact with the closed cup system to cause a temperature change in the liquid inside. They are asked to **make claims** that describe how they think each type of energy causes the temperature of that liquid to change. They are also asked to support each claim with evidence and reasoning. Students come to this task with limited classroom knowledge of heat and how it interacts with matter; however, they are asked to think about prior experiences with heat and cold and to relate those experiences to explain what might be happening as heat interacts with the cup system. In contrast, students have investigated light in the unit on *Light and Matter*, so they should have a greater understanding of how light interacts with a variety of materials and what happens when it does so. They do not necessarily need to represent various materials in this lesson, though they can. The focus is on the transparent cup. When analyzing students' models of light's interactions with the cup system, look for evidence of student understanding of the following concepts: • Light travels in straight lines. • Light reflects, transmits, or is absorbed in varying amounts when it shines on the cups. • If all or part of the light is absorbed, that light energy may be related to the temperature change or may turn into heat. Because students have not learned about heat energy yet, when you analyze their models of heat and the corresponding claims, look for evidence that students are using their prior day-to-day experiences. Examples include these: • Hot or warm objects cool down; cool or cold objects warm up. • When hot or warm objects come into contact with cool or cold objects, the cooler objects warm up and the warmer objects cool down. • Temperature tells us how warm or cool something is. Students' models and claims can give you valuable information that can be used to adjust instruction in the next lesson. Possible adjustments include these: • If students are struggling with applying their understandings of light to this context, you may need to revisit ideas from *Light and Matter* and guide students in thinking more deeply about how to use what they know in Lesson 8. • If students struggle with using personal experiences with heat to construct a model that predicts how heat might interact with the cup system, you may need to demonstrate how to use personal experiences with heat and cold to construct a model. • If students are struggling with writing a claim, or if they fail to support their claims with evidence and reasoning, they may need additional support. This could include providing sentence stems, providing a CER graphic organizer, or allowing students to work in pairs or small groups to write claims supported by evidence and reasoning.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	Develop and use models to describe how light transmission through, reflection off, and absorption by cup walls causes changes in the temperature (effect) of water inside the cup.	**Developing and Using Models; Cause and Effect** Use the models drawn on day 2 to examine students' ideas about how the various cups' surfaces influence how much light transmits through, reflects off, or is absorbed by the cup wall and warms up the water inside. Look closely at students' responses to the questions on their handout in addition to their drawn models. Look for ideas such as the following: • how differences in light's interaction with the cup wall account for the observed temperature differences • how differences in light's interaction with the water inside the cup account for the observed temperature differences • how the process of absorption is described in words and represented in the models • how the water in the cups in the dark condition warmed up even though no light was present Students will revisit light in Lesson 15 to develop a more complete explanation of how light absorption by particles is a transfer of energy from light to movement of particles, which results in particles with more kinetic energy. For now it is OK if students refer to absorption as a general transfer of energy at the macroscale as opposed to the particle scale.
Lesson 9	Carry out an investigation to measure temperature inside and outside a cup system to test whether heat or cold moves through the wall of the system.	**Planning and Carrying Out an Investigation; Systems and Systems Models** The *Water Bath Lab and Discussion* is a whole-class activity (a small-group alternative option is also provided) to review and reteach about planning investigations, depending on where you have seen your students' progress and struggles. Give students an opportunity to contribute ideas to the investigation plan before offering or confirming procedures to be followed. In addition to monitoring their thinking about variables, a fair test, and procedures, also pay attention to how they discuss the water inside the cup system and the water outside the system and the idea of heat or cold moving between the two. Listen for the extent to which students can do these things: • identify a testable question given the water bath setup • discuss reasonable procedures for obtaining an accurate temperature measurement • identify important control variables • explain how manipulating the temperature of the water outside the cup system affected the temperature of the water inside the system • explain how manipulating the temperature of the water inside the cup system affected the temperature of the water outside the system • conclude that heat or cold moved through the cup wall If students struggle with understanding how this lab provides evidence of heat and cold moving through the cup wall, brainstorm everyday experiences of these same processes, such as feeling the cold of an iced drink or the heat from a warm cup, placing an ice pack on an injury, heating air in an oven to cook food, boiling water to cook an egg inside the shell, feeling cold when your mouth touches ice cream, and sitting in a hot bathtub. Use the related experiences as a way to establish patterns across phenomena in which we sense heat or cold moving. Note that students will not establish the directionality of the movement until Lessons 13 and 14, so maintaining the idea that cold moves right now is OK.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 10	Develop models based on evidence to explain that matter is made of particles that are in motion, and though the individual particles are not visible to the eye, their collective behavior can be observed as more or less movement depending on the matter's temperature.	**Developing and Using Models; Scale, Proportion, and Quantity** During the *Food Coloring Lab* on day 1, students discuss what is different about cold and hot water based on evidence. Then students develop a model to predict what happens when food coloring is added to room-temperature water. Look for these ideas: • Food coloring, when dropped into water at any temperature, moves or spreads out. • In cold water, the food coloring moves around or spreads out less than in hot water. • In room-temperature water, the food coloring should spread out more than in cold water but less than in hot water. If students are struggling to notice those details, consider repeating the lab outside of class and filming the movement of the food coloring to play back and discuss on day 2. Sometimes with classroom distractions removed, students can focus better on a video and notice details that they previously overlooked. Near the end of day 2, students will have had several opportunities to discuss three sources of information regarding the relationship between water's temperature and the movement of particles in the water. The students' science notebook drawings should indicate the following: • Cold water and hot water both contain particles that move around. • The number of particles in the cold water and the hot water should be equal. • The particles in the cold water are moving less than the particles in the hot water. Circulate around the room to view students' drawings and get a sense of whether you need to pause and discuss any information source in more detail. If necessary, collect the notebooks to examine the drawings more closely and provide feedback. If students are struggling to grasp the connection between water movement and temperature from the reading, consider finding a video demonstration or online simulation of Joule's experiment and apparatus. This may be particularly useful for emergent multilingual learners.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 11	Construct an explanation about why food coloring moves more in hot water than in cold water using the idea that at the particle scale, particles in liquids at warmer temperatures have more kinetic energy than particles in liquids at cooler temperatures.	**Constructing Explanations; Scale, Proportion, and Quantity** At the end of the lesson, students construct an explanation to answer the question "Why do particles move more in hot liquids?" They do so in the context of explaining the results of Lesson 10's *Food Coloring Lab*. Students use the new ideas they develop in this lesson that particles in hot liquids not only move more than particles in cold liquids, but they also move faster and thus have more kinetic energy. They record an individual explanation in their science notebook. Examine students' explanations to see that they are connecting ideas about kinetic energy and particles moving faster in warm and hot water to explain the spread of the food coloring. Look for students citing evidence from the simulation to back up their claims that particles in hot water move faster. If students struggle to connect these ideas, visit the following simulations to help students trace atoms: • Molecular view of a liquid: http://bit.ly/molecular-view-liquid • Molecular view of a gas: http://bit.ly/molecular-view-gas Mark two atoms and then press "Play". Allow students to watch the simulation as a way of helping them explain how the food coloring (and the perfume sprayed into the air) can spread throughout the sample of matter. If students use ideas about the speed of particle movement accurately but do not use the term *kinetic energy*, they have mastered the conceptual ideas. Continue to reinforce that *kinetic energy* is the scientific term for particle movement and give students practice using this new term in subsequent investigations and discussions. If students use the vocabulary but it's unclear whether they know what it means, press them to elaborate on how kinetic energy connects to particle movement.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 12	Carry out an investigation to look for patterns in data generated by using an interactive simulation of the particles in a gas (which are too small to be observed) to observe the kinetic energy of individual particles and the transfer of energy when they collide. Analyze and interpret data to mathematically represent the cause-and-effect relationships between the average kinetic energy of the particles of a gas, the temperature of the gas, and the total kinetic energy of all the particles in the gas.	**Developing and Using Models** In this lesson, students manipulate an online interactive simulation to learn about the interactions between the particles of a gas. They use the simulation to generate data, then look for patterns in the data to identify cause-and-effect relationships between the kinetic energy of individual particles and the transfers of energy that occur when those particles collide. At the end of day 2, students use their Progress Tracker to document what they have figured out using words and/or pictures, and to document the evidence that supports their thinking. The Progress Tracker is used as an assessment of student learning. When analyzing students' thinking and the evidence they use to support it, look for evidence of student understanding of the following concepts: • Not all particles in a sample of matter have the same kinetic energy. • Kinetic energy is transferred from one particle to another in a particle collision. • Temperature is a measure of the average kinetic energy of the particles in a sample of matter. • The total kinetic energy of a sample of matter is the sum of the kinetic energy of all the particles in that sample. If you add more particles to the sample, the total kinetic energy increases but the temperature (the average kinetic energy) might stay the same. Students' Progress Trackers can give you valuable information that can be used to adjust instruction in Lesson 13. For example, if students are struggling with applying their understanding of the transfer of energy that occurs when particles collide, they may need to revisit that idea. It is foundational to understanding how energy transfers between the liquid inside the cup system and the outside air. **Analyzing and Interpreting Data and Using Mathematics and Computational Thinking** As students manipulate the interactive simulation, collect and analyze the data, and explain what they observe, they use mathematical reasoning to figure out the relationship between the kinetic energy of individual particles of a gas, the temperature of the gas, and the total kinetic energy of all the particles in the gas. Students share what they figure out using their Progress Tracker, and they support their thinking with evidence from the data they collected using the simulation.
Lesson 13	Carry out investigations using a particle model of matter (with marble manipulatives and computer simulations) to generate evidence that one way the temperature of matter changes over time is that kinetic energy is transferred in collisions between the particles (matter) within and between solids, liquids, and gases.	**Carrying Out Investigations and Using Models; Patterns, Cause and Effect, Matter and Energy** In this lesson, students carry out investigations using a particle model of matter with marble manipulatives on day 1 and computer simulations on days 1 and 2 to generate evidence that one way the temperature of matter changes over time is through the transfer of kinetic energy in collisions between the particles (matter) within and between solids, liquids, and gases. The responses to the "Making Sense" question on the handout *Investigating Particle Collisions in Different States of Matter* provides a good opportunity to evaluate progress toward this lesson-level performance expectation. Look for these ideas: • Collisions between particles in a gas and a liquid can also transfer kinetic energy (KE or motion energy) from one particle to another. • Collisions between particles in a gas can transfer kinetic energy (KE or motion energy) through particles in a solid to particles in a liquid on the other side of the solid. • Collision between particles can cause a warmer object to cool down and a cooler object it is contact with to warm up If some students are struggling with these ideas, visit these students during their investigations on day 2 and facilitate discussions around their work in activities #5 and #6 to help them reason about particle collisions transferring KE to neighboring particles in solids. When you are working with these students, you might decide to curtail or skip doing activities #7 and #8 with them, or you might want to work through a portion of them together.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 14	Develop and use models to track how energy spontaneously transfers out of hotter regions and into colder ones and causes changes in the water's temperature within the cup system. Construct written arguments supported by empirical evidence and scientific reasoning to support claims describing how energy spontaneously transfers out of hotter regions or objects and into colder ones.	**Developing and Using Models; Tracking energy flow in the cup system** Use students' models drawn on day 2 to examine students' ideas about how energy transfers from the air, through the cup walls, and into the water. Look for ideas about the direction of the energy transfer and that this energy transfer occurs when higher-energy particles collide with lower-energy particles. Students will use models of energy transfer to design cups to minimize energy transfer from the air into the water in Lesson Set 3. **Construct Written Arguments** Use the assessment guidance provided in *Lesson 14 Assessment Scoring Guide* and *Rubric for Model in Lesson 14 Icing Injuries Assessment* to assess students' ideas about energy transfer in the assessment *Icing Injuries Assessment*.

Lesson 15	Obtain and use information from scientific texts to evaluate the function of certain design features in minimizing energy transfer into a system.
	
	Develop a consensus model for explaining two mechanisms for energy transfer into a system, and design features that minimize energy transfer into a system.
		Obtain and Use Information from Scientific Text; Structure and Function
		In day 1, students look at existing cup designs and consider what makes them work. This is an opportunity to assess how well students are making connections between why a feature or structure works (function) and evidence from their previous investigations to support their thinking. Circulate around the room and ask questions that will challenge students to provide evidence from earlier in the unit; for example, if a student says, "The double-walled cup works because it makes thermal energy transfer into the cup slower," ask, "What evidence do you have for that?" If students are struggling to make these connections, consider using the whole-class discussion that follows for making those connections explicitly. Add a row labeled "Evidence from our investigations" to the table that the class makes together during that discussion, and fill it in as students suggest features of the existing designs.
		
		Developing and Using Models; Energy and Matter
		On day 3, students work as a class to develop consensus models to explain mechanisms of energy transfer into the cup systems and how design features slow this process.
		
		Through this discussion, be mindful of formatively assessing the different dimensions that students are engaging with:
		• Consider whether students are connecting ideas about particle motion and kinetic energy to the different mechanisms of energy transfer via conduction (particle collisions) or radiation (light absorption).
		    • If students are struggling with disciplinary core ideas, focus them on the previous models they developed, especially from Lessons 6, 11, and 14.
		• Consider whether students are able to use model representations that they've agreed upon to represent their thinking. When students enter the design challenge in the next lesson, they will need to be able to model their design choices and explain how they minimize energy transfer without the scaffolding you are providing here.
		    • If students are struggling with modeling your thinking, use questioning to elicit their ideas and then brainstorm what kinds of representation they feel would best represent those ideas in a model.
		• Consider whether students are using energy as a way of explaining the flow into the cup system.
		    • Cue students to focus on kinetic energy of particles and energy from light as a way to track the energy flow into the cup systems.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 16	Design a solution for a cup system with features (structures) to slow energy transfer into the liquid inside the cup (function). Carry out investigations to collect data to evaluate the performance of cup systems that slow energy transfer given the criteria and constraints of the problem, and to modify design features (structures) based on test results (functions).	**Designing Solutions; Structure and Function** In *Part 2: First Design Ideas*, students work with their group to propose a cup design. They must identify at least 3 design features they believe will slow energy transfer into the cup system. They are prompted to describe the feature and how it functions to slow energy transfer. Look for students to share examples, such as: • The use of metallic and other reflective colors or materials that will reflect light and minimize its absorption. • The use of foam that contains air pockets that will slow down conduction. • The use of two cups stacked within each other to create a double wall with an air gap between. Students may also believe that thickness matters and create a dense or thickly wrapped cup. They may also believe that 'more' is better and utilize a lot of supplies and materials in their first creation. Do not correct any of the students' design, but circulate among their groups to prompt them to pay attention to the criteria and constraints for the design challenge. Students will have an opportunity to revise their designs in Lesson 17. Thus, this first round of design is simply a chance for them to test their initial ideas about what will work. Make certain to provide written feedback on each group's design on day 2 of this Lesson or prior to Lesson 17. You can provide feedback using the *Design Evaluation: Peer Feedback* modified for teacher feedback as opposed to peer feedback. **Plan and Carry Out Investigation; Structure and Function** On day 2, students use *Part 3: Test 1* to carry out 5 tests on their first cup design. The test results they gather help them evaluate the performance of their cup, and will help them pinpoint certain design features that need to be modified. When students gather their test results, provide time for them to work together to evaluate their design in light of the criteria and constraints. Listen for students to consider the following: • High temperature change in the bright light condition may mean they need a different outside surface material to reflect light. • High temperature change in the regular light condition may mean they need to re-evaluate the cup wall material, the thickness, and the amount of contact between materials. • High cost or high waste means they need to rethink the type and numbers of materials being used. • Too large of a diameter means they need to rethink the thickness of their cup. If students struggle with identifying how to evaluate their cup design, return to the criteria and constraints together. For each criterion and constraint, look at the corresponding test that would provide the best information. After reviewing the test results, consider modifications to the cup features (structures) based on the results. Prompt students to think about how the modification to the cup feature would potentially alter the function in slowing energy transfer. Discuss each criterion and constraint individually to help students make connections between the criterion and constraint, the test result, and the options for modification based on the results. Providing written feedback to each group on *Part 3: Test 1* can be beneficial to groups as they redesign their cups in Lesson 17.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 17	Design a solution that is modified based on test results to improve the features (structures) to better slow energy transfer (effect) by reducing the absorption of light or opportunity for particle collisions (function/cause). Carry out investigations to collect data to evaluate the performance of cup systems that slow energy transfer given the criteria and constraints of the problem, and to propose ways to optimize design features (structures) based on the test results (functions).	**Design a Solution; Structure and Function** In *Part 5: Redesign Ideas*, students work with their design group to propose modifications to their first cup design. They must identify at least 3 design features they believe will slow energy transfer into the cup system. They are prompted to describe which feature they are modifying, where this modification will improve the cup's performance (which test), and how they believe it will help. Look for students to share examples, such as: • Changing the outside surface material to reflect more light. • The addition of materials that contain air pockets that will slow down conduction. • The use of two cups stacked within each other to create a double wall with an air bap between. • Using fewer materials to lower costs, reduce thickness, and reduce environmental impact. • Creating more air gaps or air layers between materials to try to better use air insulation with fewer resources. Students now have test results to work with. Some groups may be focused on improving their cup's performance on the criteria, while other groups may be focused on better meeting the constraints. As students work with their groups, circulate around to groups to provide oral feedback to each group. At this time, use probing questions to learn about the modifications each group has decided to make and what they expect the modification will do with respect to the tests. Make certain to provide written feedback on each group's redesign on day 2 of this Lesson or prior to Lesson 18. You can provide feedback using the *Design Evaluation: Peer Feedback* modified for teacher feedback as opposed to peer feedback. **Plan and Carry Out Investigation; Structure and Function** On day 2, students use *Part 6: Test 2* to carry out the 5 tests on their redesigned cup. The test results they gather help them evaluate the performance of their cup, and will help them compare their design ideas and performance to other group's designs and performance. When students gather their test results, provide time for them to work together to evaluate their redesigned cup in comparison to the first cup design (*Part 7: Evaluate your 2nd Design*). Look for students to explain why certain changes to their cup helped it perform better or caused it to perform worse on the second set of tests: • Use of too many materials in the first round caused problems with costs, environmental impacts, or thickness (diameter). Fewer materials reduce these issues. • Use of too many materials in the first round caused problems with too much contact that helped energy to transfer. Reducing points of contact and making more air gaps slowed energy transfer. • Use of certain colors or materials on the surface caused too much absorption of light and changing the surface color or material to reflect more light slowed down energy transfer. If students struggle with interpreting their results and evaluating the performance of their redesigned cup, help students focus in on one test result at a time, first comparing the diameter test between their first design and 2nd design. Repeat for each test, focusing on comparisons of one test result at a time. Breaking complex tasks down into smaller discrete steps can help students who may be overwhelmed with evaluating their cup as a whole system with results from multiple tests.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 18	Develop a model based on patterns in performance that can be used to predict ways to minimize or maximize energy transfer into or out of a variety of systems. Evaluate a design solution for a disaster blanket that includes several design features (structure) to minimize energy transfer (function) that could result in body heat loss.	**Developing and Using a Model; Patterns** On day 1, the students will work together to develop the Ultimate Cold Cup design. From this design, and their experiences in the unit, they will extrapolate a generalized model for energy transfer. Monitor students' progress in developing generalized models. On day 2, students will continue to revise the generalized model for explaining energy transfer to related phenomena in their daily lives. During the Consensus Discussion on day 2, listen for students to share scientific principles related to the following: • Energy transfer speeds up with more contact and slows down with less contact; thus, energy transfer happens faster within and between solids and slower within and between gases. • Energy transfer speeds up with more light absorption and slows down with less light absorption. • The amount of matter and type of matter that is warming up or cooling down affects how fast energy transfer happens and how much energy is needed. These scientific principles may look like the following design features in students' models: • Solids transfer energy well, while thick solids transfer energy slower than thin solids. • Air does not transfer energy well, so materials with air pockets and layers with air between will slow energy transfer. • More solid surface area in contact means more opportunities to transfer energy through particle collisions. • Dark materials and less reflective materials absorb more light faster than light and reflective materials. If students struggle to come up with a generalized model that can explain a suite of related phenomena, prompt students to ask the same set of questions for every phenomenon. This set of questions should allude to the kinds of things the generalized model should be able to answer: • What type of matter is the object made of, and does this facilitate particle collisions? • How much matter (thickness) does the energy need to transfer through to get into or out of the system? • How reflective, transmissive, or absorptive is the material? • How much matter is needed to stay warm or cold? Or how much matter do we need to warm up or cool down? **Designing Solutions; Structure and Function** On day 2 there is a transfer task that is meant to be a summative assessment task for the unit, and it gives you a grading opportunity. The task includes a teacher reference, *Reference for Disaster Blanket Design Assessment*, with a scoring guide. Student responses will vary because the task is designed as a structured engineering design challenge; however, students must use science ideas and information from the task to support their responses. Look for students to include the following ideas: • Question 1: the temperature difference between people and the ground, the direct contact and transfer of energy between the people and the ground, and the size difference between a person and Earth. • Question 2: type of matter and whether it speeds up or slows down energy transfer, the amount of matter (thickness), and the interaction of light with matter. • Question 3: suspension in air decreases contact and slows down energy transfer because there are fewer particles to transfer energy. Use the scoring guidance to help you identify where students are successful or need more practice with respect to the 3 dimensions. Keep in mind that there is not a correct answer with respect to the blanket choice but, rather trade-offs to consider. Students should, however, justify their choice with scientific principles.

LESSON 1: Why does the temperature of the liquid in some cup systems change more than in others?

PREVIOUS LESSON *There is no previous lesson.*

THIS LESSON

ANCHORING PHENOMENON

3 days

We observe an iced drink in a regular cup warming up more quickly compared with an iced drink in a fancy cup. We develop systems models to explain what is happening in the two cups that leads one to be better than the other at maintaining the temperature of the drink. We brainstorm why certain objects are better at keeping things cold or hot by considering features of each object's design. We ask questions about design features and other factors that influence how well an object can keep something hot or cold, and we generate a list of investigations to test these factors.

NEXT LESSON *We will test some of our initial ideas about the cup features that we believe are most important in maintaining a drink's temperature. We will collect and analyze data from small-group investigations to determine which features are supported by evidence as important to keeping a drink cold.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Develop an initial model to describe a phenomenon in which a substance changes temperature and identify structural parts of the system that slow down or speed up the temperature change (function).

Ask questions that arise from careful observation and can be investigated in the classroom to test how parts of the cup systems contribute to warming up or maintaining the temperature of the substance inside.

WHAT STUDENTS WILL FIGURE OUT

- The cup system includes the different parts of the cup and the water and air inside the cup. All of these parts work together (interact) to form the system.
- Some systems have structural features that help maintain the temperature of a substance inside the system, keeping the substance hot or cold longer compared with other systems.
- Heat can enter the cup system and/or cold can leave the cup system, and maybe gases can escape the system too.

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**INTRODUCE STUDENTS TO THE REGULAR CUP AND FANCY CUP** Introduce students to the warming up of an iced drink in a regular plastic cup. Show students the fancy cup that is claimed to keep the drink colder longer.	A	1 16-oz regular plastic cup, 1 16-oz fancy plastic cup
2	5 min	**BRAINSTORM HOW TO TEST THE TWO CUPS** Elicit students' ideas about how to test whether the fancy cup keeps a drink colder for longer than the regular cup.	B	1 16-oz regular plastic cup, 1 16-oz fancy plastic cup
3	20 min	**GATHER IN A SCIENTISTS CIRCLE FOR THE COLD CUP TEST** Convene a Scientists Circle to collect observational data and temperature data on the two cups. During the test, compare the two cups' structural features.	C	chart paper or whiteboard, markers, Cold Cup Test
4	12 min	**DEVELOP SYSTEMS MODELS FOR THE TWO CUPS** Have students work individually to draw systems models to explain why the water in the regular cup warms up more quickly than the water in the fancy cup.	D-E	chart paper or whiteboard, markers
5	5 min	**SHARE INITIAL CONCLUSIONS AND ASSIGN HOME LEARNING** Have students return to the claim and share initial conclusions. Pose the lesson question and assign students to identify related phenomena at home.	F	
				End of day 1
6	8 min	**NAVIGATION** Have students review the temperature data and observations from the *Cold Cup Test*. Prompt students to write conclusions from the data and be prepared to share with partners and then the whole class.	G	
7	5 min	**REVIEW NORMS AND SET EXPECTATIONS** Have students review the classroom norms and set expectations for their work together on a consensus model. Prompt students to pick one norm to focus on for today.	I	
8	15 min	**DEVELOP A CONSENSUS MODEL FOR THE TWO CUPS** Convene a Scientists Circle to develop a consensus model to explain why the two cup systems work the way they do.	J-K	chart paper, markers
9	10 min	**BRAINSTORM RELATED PHENOMENA** Record students' ideas of related phenomena and related objects that do a good job at maintaining the temperature of the stuff inside them.	L	Related Phenomena poster, markers
10	8 min	**NAVIGATION** Have students use their ideas from the consensus model to develop a model for one of the related systems.	M	
				End of day 2
11	8 min	**CONDUCT A GALLERY WALK TO EXAMINE MODELS** Have students open their science notebooks to their related phenomenon model and complete a gallery walk to view their classmates' work.	N	

Part	Duration	Summary	Slide	Materials
12	5 min	**DEVELOP QUESTIONS FOR THE DRIVING QUESTION BOARD** Direct students to look at their models for the cup systems and their model for the related phenomenon to develop questions about structures and mechanisms that seem important to figure out.	O	note cards, markers, tape, classroom consensus model
13	20 min	**DEVELOP THE DRIVING QUESTION BOARD** Convene a Scientists Circle to construct the Driving Question Board (DQB) around students' questions.	P	Driving Question Board
14	10 min	**PLAN IDEAS FOR INVESTIGATIONS** Create an Ideas for Investigations poster and record the class's thoughts on how to figure out the answers to our initial questions as we move forward.	Q	chart paper, markers
15	2 min	**NAVIGATION** Work with students to brainstorm how to investigate the cups next to gather more data.		

End of day 3

Lesson 1 • Materials List

	per student	per group	per class
Cold Cup Test materials			• 1 16-oz single-wall plastic cup with straw (regular cup) • 1 16-oz double-wall plastic cup with straw (fancy cup) • pitcher of 800 mL iced cold water • 2 thermometers • 500-mL beaker • additional ice • timer
Lesson materials	• science notebook • note cards • markers • tape		• 1 16-oz regular plastic cup • 1 16-oz fancy plastic cup • chart paper or whiteboard • markers • chart paper • Related Phenomena poster • classroom consensus model • Driving Question Board

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare a Similar, Different, Makes Us Wonder chart on chart paper or whiteboard space prior to starting day 1.

Prepare a Related Phenomena poster on chart paper prior to starting day 2.

Determine where to set up the Driving Question Board and prepare markers, note cards, tape, and an Ideas for Investigations poster prior to starting day 3.

Day 1: *Cold Cup Test*

- **Group size**: Whole class
- **Setup:** The night before the lab, make enough ice for all sections of science completing this unit. The day of the lab, make pitchers of cold water using the ice (chill to 6°C or colder) so that you have 800 mL per class section (roughly 400 mL for each of the two cups). Have a pitcher of cold water, the single-wall plastic cup, the double-wall plastic cup, two thermometers, and a 500-mL beaker nearby for the demonstration.
- **Notes for during the lab:** Make sure to have ice on hand if you need to make additional cold water.
- **Safety:** Warn students to be careful with glass thermometers, as any breakage may cause cuts and scrapes.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

Students encounter the anchoring phenomenon as an iced drink in a regular plastic cup watering down and warming up more quickly compared with an iced drink in a fancy plastic cup. Students develop systems models to communicate their ideas about important structural parts of the cup systems and mechanisms that can explain how and why the drink in the regular cup warms up while the drink in the fancy cup stays a little colder. The purpose of the anchor is twofold. First, it is used to probe student understanding of how something warms up or cools down and how an object's structure could mediate this process. It leverages students' related experiences of other objects that are designed to keep things cold or hot so that students begin to identify similar structural components or processes that may be important for explaining the phenomenon. Second, the anchor allows students to ask questions they can investigate over the course of the unit to better understand how the cups and related systems work to maintain the temperature of something inside them for a longer period.

Where We Are NOT Going

This unit is an engineering design unit and students will complete an iterative design cycle for cups in the latter half of the unit. If the engineering design is introduced too early, students become focused on their design ideas and whether their designs work without first establishing a principled reason for developing those designs. This unit is sequenced so that students consider the designs currently used for cups and related systems before developing their own designs.

As students observe the *Cold Cup Test* on day 1, they may become immediately curious about the condensation that occurs on the outside of the regular cup. Encourage students to include in their models their ideas about how those water droplets form, but avoid spending too much time on condensation in this lesson. Prompts might include, *It sounds like you think something could be leaving the inside of the cup. What are all the things that could be leaving from the inside?* Students will investigate whether water leaves the inside of the cup through the wall during Lesson 5.

After studying light and matter in the previous unit, students may have ideas about the transparency, reflectivity, and color of cups and related systems because they may believe light is warming the water inside the cup. These kinds of questions will naturally lead to investigations about energy transfer via radiation and how certain surfaces facilitate or slow this process. Encourage students to ask these questions if they surface, but keep in mind we will not return to these questions until later in the unit (Lessons 8 and 15).

LEARNING PLAN for LESSON 1

1 · INTRODUCE STUDENTS TO THE REGULAR CUP AND FANCY CUP

5 min

MATERIALS: 1 16-oz regular plastic cup, 1 16-oz fancy plastic cup

Introduce students to the regular cup and fancy cup. Share the story about your iced drink warming up in a regular plastic cup. The story can be based on a scenario that makes sense in your context and that your students may find meaningful.✱ Importantly, revise **slide A** to match the story you want to use to situate the phenomenon.

Ask students to turn and talk with a elbow partner for 1 minute about two questions:

- *Why does the drink in the regular cup warm up?*
- *How could the fancy cup keep the drink from warming up?*

Elicit a few initial ideas from students. Listen for these ideas:

- The regular cup is made of thin plastic, while the fancy cup is made of thicker plastic. Thicker is probably better.
- The fancy cup has more walls or layers, and that may help keep the drink cold.
- They are almost the same cup, so there may not be much of a difference.

Say to students, *It seems strange that the fancy cup would work so much better. The two cups seem pretty similar. Let's test the cups and gather some data to see if the claim that the fancy cup works better is actually true.*

ADDITIONAL GUIDANCE

If you want to modify the anchor, keep the following questions in mind as you brainstorm ways to approach the anchor scenario:

- Is it going to be meaningful for my students?
- Is it going to motivate students to want to explain how things warm up, cool down, or maintain their temperature over time in the given context?
- Is it going to help students connect their observations of the cups to their experiences with related phenomena and related systems?

An example modification: If reducing single-use plastic is an important issue for your students, set up the anchor around avoiding non-recyclable straws. Without a straw, the lid on the regular cup must be removed to take a sip, but then the drink warms up more quickly, thus the need for a reusable cup and straw. This version of the anchor is well-connected to the content of the unit, and could be motivational to students.

ADDITIONAL GUIDANCE

Refer to the cups as the regular cup and the fancy cup. Avoid using the terms *single-wall* and *double-wall* during today's lesson. Wait until your students have established that the regular cup has only 1 wall and the fancy cup has 2 walls before describing the cups as single-wall and double-wall.

✱ ATTENDING TO EQUITY

Students will find the anchoring phenomenon more compelling if it is presented in a meaningful scenario rather than a contrived one. Motivate the comparison of the fancy cup and regular cup using a drink (e.g., iced water, coffee, tea, soda, or other beverage) or a local vendor that may be popular among your students. Ask the vendor to donate cups with their logo to use in your students' investigations. Most importantly, do not dwell on the set of cups presented in the anchoring scenario. Instead, after day 1 move on to the suite of experiences students have had with drinks that warm up and water down quickly.

2 · BRAINSTORM HOW TO TEST THE TWO CUPS

5 min

MATERIALS: science notebook, 1 16-oz regular plastic cup, 1 16-oz fancy plastic cup

Brainstorm how to test the two cups to evaluate the claim. Tell students to find a new page in their science notebook to brainstorm how to test the cups.✱ Display **slide B**. Remind students of the claim that the fancy cup is supposed to keep a drink colder for longer than the regular cup. Ask students these questions:

- *How could we test this claim?*
- *What evidence could we collect to prove or disprove the claim?*

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

SCIENCE NOTEBOOK

This is the first use of the science notebook for the new unit. You may need time to organize a new section in the notebook. How to set up the section will vary depending on how you've structured the components of your notebooks, such as the table of contents and how to note the start of a new unit. It is recommended to have students do the following:

- Reserve a blank page at the start of the unit, to be titled on day 3 of this lesson when students are given the unit question.
- After the title page, reserve 2 pages (4 pages front-to-back) for the table of contents (unless all tables of contents are at the front of the notebook).
- Reserve 10 pages (20 pages front-to-back) for the Progress Tracker pages.
- Number the pages so everyone begins the first investigation of the unit on the same page number.

Remind students that the notebook is their tool for recording their observations, evidence, and ideas to share with the classroom community. They should see it as a space to brainstorm and record their thinking as well as a place to show how their thinking changes as they learn more.

Give students 1 minute to stop and jot their ideas for how to collect evidence to evaluate the claim. Have students turn and talk for another minute to share their thinking with a partner. Then bring students back to the whole group and elicit a short list of evidence they'd want to collect.✱ This may include these ideas:

- measuring the temperature of each drink for an amount of time
- recording how long it takes for each drink to warm up
- watching to see if the ice melts faster in one cup than in the other
- watching to see if the drinks get watered down

Say, *OK. These sound like reasonable things we can do in the classroom right now. Let's go ahead and collect some of this data. Maybe it's worth buying the fancy cup if the evidence shows us it's better.*

It is important to involve students in deciding the kinds of evidence that need to be collected to support or refute a claim ("What do we need to know?") and in defining the strategies and/or methods used for collecting observations or data ("How will we come to get the information we need?"). Students will do both of these things as they set up the *Cold Cup Test*. If students want to test whether the drinks water down or the ice melts, consider adding food coloring to the water in the pitcher.

3 · GATHER IN A SCIENTISTS CIRCLE FOR THE COLD CUP TEST

20 min

MATERIALS: Cold Cup Test, science notebook, chart paper or whiteboard, markers

Gather in a Scientists Circle and set up the *Cold Cup Test*. Say to students, *Since we have only one set of cups, let's form a Scientists Circle so we can all see them as we gather observations and temperature data. Bring your science notebooks with you because we have a lot of ideas already about how this could work and we need to document some of these ideas together.*

SCIENTISTS CIRCLE

Your students may be familiar with the Scientists Circle from the previous unit. Remind students of the norms for participation and the logistics for forming and breaking down that space. A Scientists Circle includes these important features:

- students sitting so they face one another to build a sense of shared mission and a community of learners working together
- celebrating progress toward answering students' questions and developing more complete explanations of phenomena
- focusing on where students need to go next and how they might go about the next steps in their work

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

This initial investigation should have some controls in place, but it should also reflect the real-life anchor scenario. Students will get to set up more systematic investigations where they identify independent, dependent, and control variables over the course of the unit. However, they must first recognize a need for setting up controlled experiments after they have done some "messing around" with the system.

Work together to set the test conditions.✱ After students are settled in place, tell them that before we test the two cups we need to think about how to make it a "fair test". Spend about 2 minutes asking students what they think could make the test unfair and what they need to do to ensure a fair comparison between the two cups. Listen for ideas like these:

- *If one has more ice, that could keep it colder longer.*
- *If the cups have water that is different temperatures, the one with the colder water will stay colder for longer.*
- *If one has more water, it may take longer to warm up.*

Set up the experiment using students' suggestions about what variables to control, such as the amount of water and number of ice cubes.

Set up science notebooks together. Before you begin the test, work with students to decide how often to record a new temperature measurement, which then affects the data table's design. Have students set up their data table just below their stop and jot, using **slide C** as a guide. Tell students to fill in the table based on what the class decides as the interval between each temperature reading, with the first reading at 1 minute and subsequent measurements every 8-10 minutes for about 30 minutes. Adjust **slide C** as necessary.

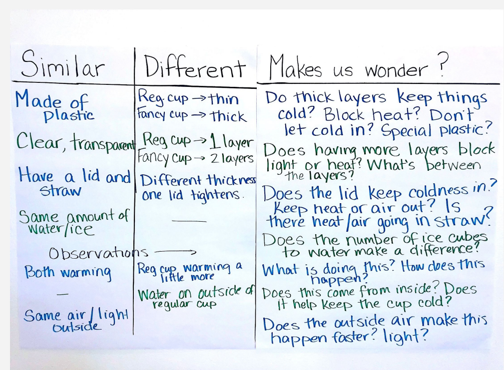
Start the investigation of the two cups. Retrieve your pitcher of iced cold water (6°C or colder), two thermometers, and a measuring cup. Pour equal amounts of water (400 mL) into each of the two cups. Place a thermometer in each cup (through the straw hole if necessary), place the lids on the cups, and wait 1 minute before taking the first temperature reading.

Take and record the first temperature measurement. Have multiple students read the temperature in order to practice reading a thermometer and agreeing on the temperature. Direct students to record the first temperature measurement in their data table, and also to give the investigation a title, *Cold Cup Test*, that can be recorded in the table of contents at a later time. Set a timer for the next temperature measurement.

ADDITIONAL GUIDANCE

While students are in a Scientists Circle, they will need to multitask: recording temperature measurements from the *Cold Cup Test* and participating in discussions about the two cup systems. Set a timer to remind the class to record a new temperature measurement at the agreed-upon interval (e.g., every 8-10 minutes). Return to the discussion after each measurement is recorded. If students need practice reading a thermometer, use each measurement interval as an opportunity to have several students practice reading the temperature on the thermometers and agreeing on the temperature together.

Make a Similar, Different, Makes Us Wonder chart. As students wait for the next temperature measurement, have them brainstorm through a discussion of what they notice is similar and different between the two cups, and what this makes them wonder about how the cups work. On chart paper or a whiteboard, draw a three-column observation table with "Similar" written atop the first column, "Different" written atop the second column, and "Makes us wonder?" atop the last column. There is no need for students to copy this table in their notebook, but have it visible to students for all of Lesson 1.



Say to students, *Until we get some data, it's hard to tell if one is better than the other and if so, how much better. But we can start thinking about how these two cups are designed differently. All we can see right now is how they look similar or different. Let's make some observations together of how these cups are structurally similar and different. This could give us clues about what is going on once we have some data.*

Make visual observations of the cups. After the second temperature measurement, allow students to take turns moving closer to the two cups to make observations. It is likely that students will notice condensation appear on the outside of the regular cup but not on the fancy cup. Encourage students to make a note of this observation now. Allow students to touch the cups too (note: students may want to touch something at room temperature to have a baseline for what constitutes "cool" versus room temperature). They can use this time to confirm or notice other structural similarities or differences between the cups. Consider adding these to your class chart if time permits.

Once all students return to their seats, allow several students to share what they observed. Listen for observations such as these:

- There was water on the outside of the regular cup.
- The fancy cup felt dry on the outside.
- The regular cup felt cool to touch.
- The fancy cup felt cool but not as cool as the regular cup.

Elicit from students a few of their experiences with drink containers, when their cups or water bottles have done similar things as the regular cup and fancy cup. Encourage students to make connections between what they are observing with the regular and fancy cups and their personal experiences with similar phenomena.

Continue to record temperature data for at least 30 minutes even as students transition to modeling the two cups in the next activity. You can collect data beyond 30 minutes for more pronounced results. Remember to share this data with students at the start of day 2.

4 · DEVELOP SYSTEMS MODELS FOR THE TWO CUPS

12 min

MATERIALS: science notebook, chart paper or whiteboard, markers

Motivate the need to diagram the two cups. Have students remain in a Scientists Circle and continue to collect temperature data. Display **slide D**. Remind students, *When scientists are trying to understand a phenomenon, they think of it and study it in terms of systems.*✱ *They identify the important parts of the system and how those parts work together. This can give them clues about what to pay attention to and test. Let's think of our cups as systems. We'll call one the regular cup system and the other, the fancy cup system.*

Ask students to turn and talk to a partner, responding to the questions on the slide:

- What are the parts of the cup systems?
- What does each part do in the cup system?
- How do the parts work together to keep a drink cold?

Lead an Initial Ideas Discussion about the parts of the cup systems.✱ As a whole group, generate a list of important parts of the cup systems and record on a whiteboard or chart paper. Remind students, *When we are identifying important parts of the system, let's ask ourselves what would happen if the part were not there. Would it change the outcome? If so, the part is probably important.* Make a quick sketch of the important parts of the cup systems as students share each part.

KEY IDEAS

Purpose of the discussion: See if we can agree upon the important parts of the system and some mechanisms that we think could be causing the drink to warm up.

Listen for these ideas:

- Important parts are the walls, lids, straws, water inside, air inside between the water and the lid. (Students may or may not want to include ice.)
- Heat is entering the cup or cold is leaving the cup.
- Air is escaping through the straw or the straw hole in the lid.
- Light is going through the plastic cup because it's transparent.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SYSTEMS AND SYSTEM MODELS

Throughout the unit, the focal crosscutting concept of Systems and System Models will be used to help students generate questions about phenomena and to guide them in developing explanations. Students should build on what they learned about systems when they studied light and matter. Help students set up their initial models as systems models, identifying the important parts of each system and how those parts work together to keep a drink cold. On day 2 of this lesson, students will think about what is happening inside the cup systems and with the cups' structural parts as the drink warms up.

✱ STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

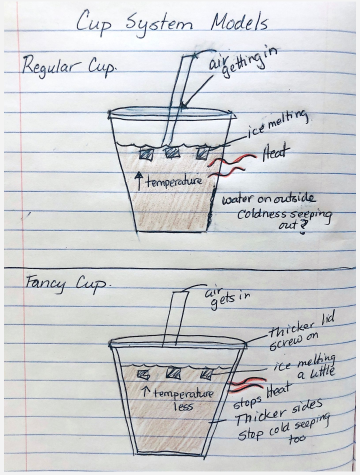
If a student says something about the double-wall cup being "airtight" or *"a vacuum,"* ask, *Wait--you mean there is air in here?* or *What does "vacuum" mean?* and *Could there be a vacuum in here?* Many

As students share, probe their thinking about what each part does in the system, focusing particularly on parts that they have identified as slightly different between the two cup systems.

Suggested prompt	Sample student responses
How does the lid work, and does it function differently between the two cups?	*The lid keeps the drink inside and keeps the air from touching the drink.* *The lid screws onto the fancy cup, but it just pops onto the top of the regular cup. The fancy lid is thicker too.*
How do the walls keep the drink cold, and is this different between the two cups?	*The walls keep the air outside the cup from touching the drink. The walls can block sunlight if they are different colors.* *The walls are thicker in the fancy cup.* *There are more walls in the fancy cup, and the regular cup is just one thin wall.*

Display **slide E**. Prompt students to make similar sketches in their science notebook, now turning the sketches into models that try to explain why the drink in the regular cup warms up over time and if/how the fancy cup could slow the warming process. Remind students of the words *system* and *model* that they added to their word walls in the previous unit on light and matter. Models should

- try to explain what is happening that leads the drink inside to warm up or not warm up as fast and
- use symbols, color, and words to help communicate these ideas.



As students work, circulate around the classroom to make sure they are not just sketching the cups but are explaining parts of the cups that help/do not help keep the drink cold.

After 5-6 minutes, say to students, *Next class we will work on our models more. Think about your models tonight, and you'll have a chance to add more details tomorrow if you think of something important you forgot to include. Let's get a final temperature measurement and see if our data supports the claim that the fancy cup works better.*

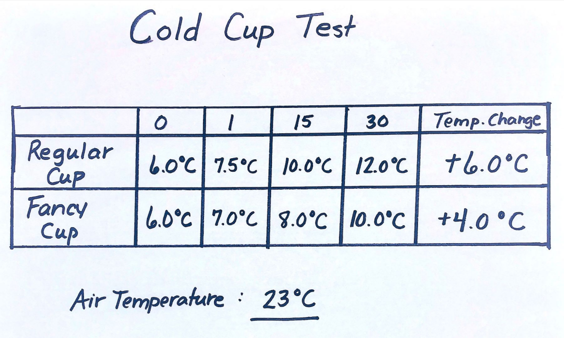
Wrap up data collection for the cup systems. Take the final temperature measurement for the cups and calculate the temperature change from the first measurement to the last. Make certain to save at least 5 minutes at the end of your class period to have a short debrief and to assign home learning.

Sample data from two classrooms:

students may share features of cup designs that they have heard about, but they may not know how the feature functions in the cup system. You can say things like, *You think having air or a vacuum has something to do with it? Whoa--interesting.* Then redirect students to focus on sketching the parts of the system, but leave the air/vacuum as a question mark for further investigation.

	Temperature (°C)				Temp change
Time	1 min	10 min	20 min	30 min	
Regular cup	5.5	6.5	8.0	9.0	+3.5
Fancy cup	5.5	6.0	7.0	7.8	+2.3

Room temperature 22°C



Cold Cup Test

	0	1	15	30	Temp. Change
Regular Cup	6.0°C	7.5°C	10.0°C	12.0°C	+6.0°C
Fancy Cup	6.0°C	7.0°C	8.0°C	10.0°C	+4.0 °C

Air Temperature : 23°C

5 · SHARE INITIAL CONCLUSIONS AND ASSIGN HOME LEARNING

5 min

MATERIALS: None

Share initial conclusions from the *Cold Cup Test*. Display **slide F**. Ask students to share conclusions they may want to draw from the data in response to the claim. This should be a brief sharing, as the navigation at the start of day 2 will revisit the conclusions from the *Cold Cup Test*. Listen for ideas such as these:

- The water in the fancy cup stays a little colder than the water in the regular cup.
- The outside of the regular cup feels wet, but the outside of the fancy cup feels mostly dry.
- The outside of the regular cup feels colder, so we think cold could move through the walls.

Pose the lesson question, "Why does the temperature of the liquid in some cup systems change more than in others?" Say, *Sounds like we have a good start on what these two systems are about and some ideas about how each part works. Let's come back tomorrow and see what we agree upon and where we need to investigate to learn more.*

Assign home learning to look for similar systems.✱ Ask students to investigate at home to find similar systems designed to maintain the temperature of something inside. The purpose is to see if related systems can help us explain how the cup system works. Students can identify systems designed to keep things cold or hot. Importantly, focus students on systems that do this without using electricity. This will help prevent them from reporting a slew of appliances, like fans, heaters, AC, oven, microwave, and so forth.

Remind students to leave their science notebooks in the classroom so you can look at their models before the next class period.

ASSESSMENT OPPORTUNITY

Use students' initial models for a pre-assessment. Look for

- agreement on the components of the system (e.g., walls, lids, straws, water/air inside, ice),
- agreement that the structural components (parts) of the cups have some similarities (made of plastic) and differences (thin versus thick), and
- disagreement about how the drink inside warms up (processes or mechanisms such as heat or light going into the cup and air or cold leaving the cup). These disagreements will motivate the need for further investigations.

✱ ATTENDING TO EQUITY

This home learning opportunity will help students broaden their thinking to related phenomena beyond the initial two cups. Prompt students to think about other cups they use regularly at home and school, as well as related objects and systems at home that function in a similar way as the tested cups. This broadening to related phenomena will give students an opportunity to leverage their everyday, out-of-school experiences to augment their classroom learning. This should make the anchoring phenomenon more personally meaningful to each student.

End of day 1

6 · NAVIGATION

8 min

MATERIALS: science notebook

Review temperature data. Display **slide G**. As students get settled for the class, ask them to review their temperature data and observations of the two cup systems. If you collected additional data beyond the class period, this is the opportunity to share that data with the class. Remind students of the claim that the fancy cup keeps a drink colder for longer.

Prompt students to add conclusions to their science notebook below their data table. These conclusions should reiterate the ideas briefly discussed at the end of the previous class. Look for ideas such as these:

- The water in the fancy cup stays a little colder than the water in the regular cup.
- The outside of the regular cup feels wet, but the outside of the fancy cup feels mostly dry.
- The outside of the regular cup feels colder, so we think cold could move between the walls, or maybe heat moves.

ALTERNATE ACTIVITY

If you want to give your students practice with interpreting graphs, consider producing a graphical display of the class data for students to analyze and interpret. Replace the data on **slide G** with the graph you make from the class data.

Have students turn and talk to discuss their conclusions with a partner. They can add new ideas to their notes if they hear something from their partner that they think is important.

Discuss conclusions related to the claim. Present **slide H** (modify to add your class' data). Have students report out to the class the conclusions they wrote in response to the claim that the fancy cup keeps the drink colder for longer. Prompt students to use the temperature data and other observational evidence (what they saw, what they felt) to support their conclusions.✱

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

As students engage in this discussion, focus them on how their evidence can be useful for evaluating claims and persuading others about the validity of their ideas. When students are engaged in the work of argumentation and explanation, they should explicitly build from evidence, past experiences, and/or shared observations to support their conclusions.

7 · REVIEW NORMS AND SET EXPECTATIONS

5 min

MATERIALS: None

Choose a norm to work on today. Display **slide I**. As students begin class, direct them to look over the classroom norms once more. Ask students to choose a norm to practice in class today. Then give them a minute to turn and talk to a partner to share the norm they selected.

ADDITIONAL GUIDANCE

Based on the work done in the previous unit, evaluate how well your students did with the classroom norms guiding their work. If students did well with some norms, celebrate that now. If they need additional work on other norms, focus their attention to those norms. Spend a few minutes discussing the norms again and having students share (1) what a given norm would look like if everyone were following it and (2) what it would sound like. Then tell students that the class will practice the ______ norm today as they work on their consensus model.

Remind students of the Communicating in Scientific Ways sentence starters. Direct students to the *Communicating in Scientific Ways* poster or handout. Tell students that they will be developing a consensus model together.✱ Ask them which sentence starters they might want to use to help them talk to one another. Examples include these:

Think of an idea, claim, prediction, or model to explain your data and observations:

- My idea is ...
- I think that ...
- We could draw it this way ... to show ...

✱ ATTENDING TO EQUITY

This is an important opportunity to emphasize that each individual has contributions to make to their community of learners. It is through differences in thinking that the class will grow their knowledge together. Throughout this unit, students will be asked to be open to sharing knowledge products that depict their current thinking and to be open to learning from classmates who share their knowledge too.

Give evidence for your idea or claim:

- My evidence is ...
- The reason I think that is ....

Other examples could come from (1) listening to others' ideas and asking clarifying questions, (2) agreeing or disagreeing with others' ideas, and (3) adding onto others' ideas.

ADDITIONAL GUIDANCE

Establishing norms is an important focus early in the school year. The brief reminder about norms that happens in this moment assumes that your classroom norms have already been established in a previous unit. For more information about OpenSciEd norms and how to establish them in your classroom, refer to the *OpenSciEd Teacher Handbook*.

8 · DEVELOP A CONSENSUS MODEL FOR THE TWO CUPS

15 min

MATERIALS: science notebook, chart paper, markers

Gather in a Scientists Circle to develop initial consensus models. Remind students to bring their science notebooks containing their initial models. Make certain a *Communicating in Scientific Ways* poster or handout is conveniently located for students to see. Take this opportunity to remind the class how we listen to one another, press on one another's ideas, and ask questions of one another, and that it's OK to disagree with ideas but it's important to be respectful.

Shift the focus to explaining why the cup systems work the way they do.✱ Display **slide J**. Project the data the students collected in the previous class period. Say, *We discussed conclusions we can draw from the data, and the evidence we have so far supports the claim that the fancy cup works better. Let's see if we can explain why this is the case.*

Share cup system models with a partner. Have students work with a elbow partner to share their model. Each partner should have 1 minute to share their thinking, then they should switch so the other partner has time to share.

Transition back to the whole group to lead a Consensus Discussion about the cup systems. Display **slide K** if needed. Let students know that the class is going to have a Consensus Discussion.✱ Tell students, *The goal of this discussion is to figure out areas of agreement and disagreement in our initial models. Knowing where we agree and disagree will help us figure out how we might want to proceed in figuring out why the fancy cup works better.*

KEY IDEAS

Purpose of the discussion: Develop an initial classroom consensus model to capture the ideas we agree on, disagree on, and are more uncertain about to explain what happened that made the water in the regular cup warm up faster than the water in the fancy cup.

Listen for these ideas:

- Areas of agreement in what we can see happening in the system:
  - The fancy cup has two walls and this may be related to why it works better.
  - The regular cup is thin with a single wall and this could be related to why it gets warmer.
  - Both cups are made of plastic.
  - Both cups are clear.
- Possible areas of disagreement/controversy:
  - Cold is leaving or heat is entering.
  - Light is causing the warming up.
  - Something is escaping into the air around the lid or straw.
  - The air outside the cup is leaking in.

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Emphasize to students that they will use models for explaining why and how phenomena occur as they do. To be useful, models need to be "applied" to explain something, and models are most helpful when they can help us explain a lot of similar phenomena. Because students have developed only their initial models so far, they may not be able to explain a lot of the anchor phenomenon with confidence, and that is OK. Models are supposed to change as our knowledge grows, therefore students will continue to revise and edit their model over the course of the unit.

✱ STRATEGIES FOR THIS CONSENSUS DISCUSSION

There are two goals of this discussion: (1) to continue to help students build the habit of sharing their ideas publicly and (2) to generate a variety of ideas about what is going on with the regular cup and the fancy cup that students agree with, disagree with, or are uncertain about. It is important to accept all student responses and to encourage students to share their ideas. Highlight areas of disagreement and help students clearly explicate their thinking in these areas. Be careful not to favorably

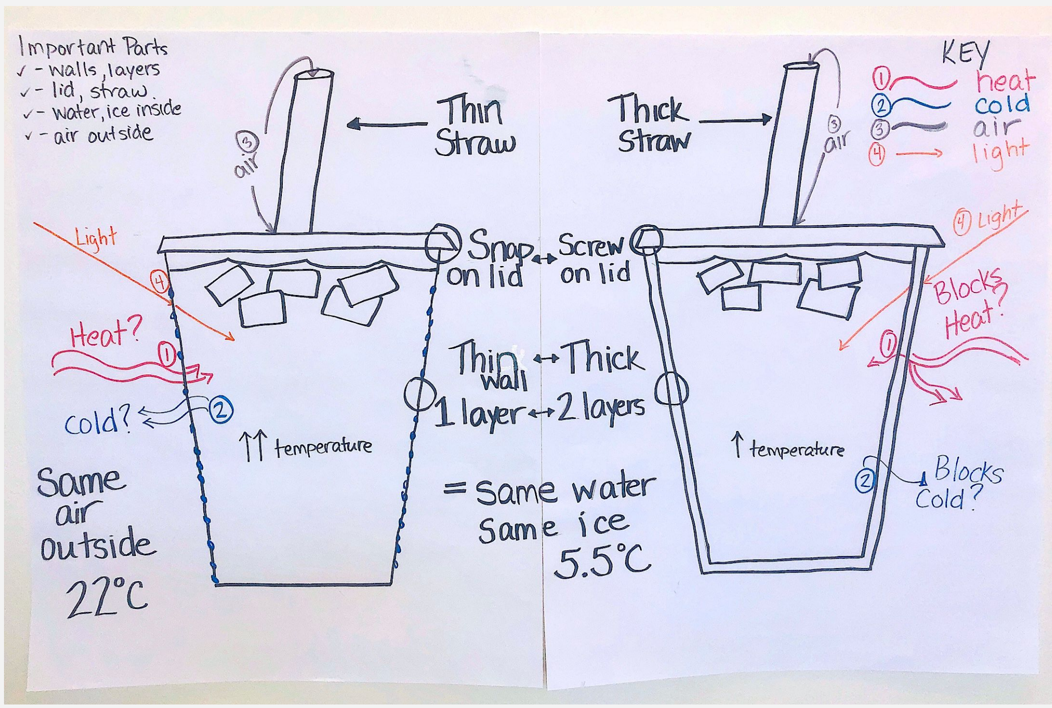
Tell students that as they listen to one another, they should evaluate their work in terms of where their ideas are similar and seem likely to be important as well as areas where they are more uncertain. Consider using color, letter, or number coding as you build the consensus model.✱

Begin the discussion to explain why the drink warms up in the regular cup. Ask a student to volunteer their model of the regular cup for the class to consider. When the student stands up to share, they should say what they included to explain why or how the drink warms up. After the presentation, ask students to look at their own model and the one that was just presented to find similarities and differences between them. Ask a student with a different way of explaining to present their model. Record a consensus model on chart paper, noting what the class agrees upon and does not agree upon to explain the regular cup.

Repeat this same process for the fancy cup. Ask for two or three new volunteers to offer up the way they explained how the fancy cup works to keep the drink from warming up as quickly. Record a consensus model of the fancy cup on the chart paper, noting areas of agreement and disagreement.

Make certain each cup system includes the important parts agreed upon by the class, which include the cup walls, lids, straws, and water and air inside (and maybe ice).

Step back to survey the two cup system models. Ask students, *Did we account for all the important parts we agree upon? Did we explain what we know about the walls, lid, straws, water inside, and air inside?*✱



respond to any one idea over others so as not to "give away" what is actually going on in each cup system.

✱ ATTENDING TO EQUITY

Use color coding and letter or number coding to foreground parts of the model. Create a key to track what colors, symbols, or letters represent different parts of the system. Although color coding is a useful way to quickly reference the parts of the model, letter or number coding helps ensure accessibility for any student who may be color-blind. (See the artifact shown below for an example of color and number coding.)

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

Students will engage in modeling to explain what caused the temperature to change inside the cups. The students will be identifying causes that are unobservable mechanisms or processes happening within the system. As students develop these models, make certain they represent the full system, including (1) structural parts of the cup (also called cup features) and (2) what is inside the cup (include the water, ice, and air). They may want to include what is outside the cup, though the air outside is a separate system that interacts with the cup system. Leverage the systems models students develop as they begin to investigate and manipulate parts of the system to figure out what causes the change in temperature of the liquid inside.

9 · BRAINSTORM RELATED PHENOMENA

10 min

MATERIALS: science notebook, Related Phenomena poster, markers

Remain in a Scientists Circle to brainstorm related phenomena. Display **slide L**. Using students' home learning assigned in the previous class, along with other experiences they have had, the class will develop a Related Phenomena poster to broaden this phenomenon beyond the regular and fancy cups. Guide the conversation with these questions:

- What kinds of systems or objects can maintain the temperature of the stuff inside it without using electricity?
- How do these things work?
- Is it the same or different depending on if cold or hot stuff is inside?

Have students turn and talk about their ideas before sharing out with the whole group.

Develop the Related Phenomena poster. Sharing as a whole group, ask the students to present an experience or an object their partner or other group member shared with them. Accept all student responses and record on the Related Phenomena poster using a three-column table format (see example below).

Try to draw out a wide variety of related phenomena. Remind students to think about objects, like the fancy cup, that do not use electricity to keep things cold or warm.

As students use new terms, probe what the words mean to them but avoid defining any terms in this lesson. Students will earn some of these words over the course of the unit.✱

Apply the consensus model to the related phenomena. Connect the poster to the classroom consensus model by asking these questions:

- *Now that we've thought about other items that do a good job maintaining the temperature of stuff inside them, are there any new things we need to track in our models?*
- *Do you think our ideas in our class model for the fancy cup might apply to some of these other objects too?*

Listen for students to share ideas about these characteristics of the object or system:

- material type (plastic, metal, foam)
- thickness of the walls and lids
- number of walls
- insulated or vacuum layers
- trapping and/or blocking heat or light
- blocking cold from escaping or entering
- amount of stuff inside
- starting temperature inside and outside

ADDITIONAL GUIDANCE

During this discussion, students will share vocabulary words that the class will continue to develop and use throughout the unit. *Avoid defining these words now*, but probe students' understanding of what they mean when students use them. Keep these words on your radar for further development and plan to add them to the word wall when students develop a deeper understanding of them in later lessons. Students will *earn* these words throughout the unit: **heat**, **cold**, **temperature**, **insulate**, **vacuum**, **absorb**, and **claim**. More words will be added to this list as they come up during discussion.

✱ ATTENDING TO EQUITY

A key element of the Anchoring Phenomenon routine is letting students share their experiences with related phenomena. By doing this, students can connect their diverse experiences with a shared phenomenon that is the focus of the unit.

✱ ATTENDING TO EQUITY

When developing new vocabulary, strategies that may benefit emergent multilingual learners include using student-friendly definitions, making connections to cognate words when possible, and showing a visual representation of the word. These strategies apply to both "words we earn" and "words we find out."

10 · NAVIGATION

8 min

MATERIALS: science notebook

Introduce the exit ticket task. Say to students, *Looks like we got a lot of ideas about things that may be important. Let's see if we can use the ideas to brainstorm how a related system works.*

Tell students to find a new page in their science notebook and title the page "Related System Model". Have each student choose one item from the Related Phenomena poster and draw a model in their notebook to explain how *they think* the item works to keep something inside it cold or hot. Display **slide M** and tell students to follow its instructions:

- Step 1: Diagram the important parts of the system--inside, outside, and any important structural features.
- Step 2: Use the model to answer these questions:
    - How does the thing inside warm up or cool down?
    - How do the parts of the system work together to keep this from happening?
- Step 3: Use colors, symbols, and words to help you.

Encourage students to include what they think is happening and to include relevant ideas from the classroom consensus models or their own models for the regular and fancy cups.

ASSESSMENT OPPORTUNITY	Students do not need to know how to explain the system completely right now; rather, they are demonstrating how they would model a new system and what they believe would be important to include. They can note on their models what each part is doing to help the object work and where they are uncertain about whether a part is important.

Ask students to leave their science notebooks in the classroom for you to look at their models before the next class. If students have time, remind them to update their table of contents now.

End of day 2

11 · CONDUCT A GALLERY WALK TO EXAMINE MODELS

8 min

MATERIALS: science notebook

Have students do a gallery walk to view one another's models. Display **slide N**. Direct students to open their science notebooks to the page where they drew their related phenomenon model. Tell students, *The goal of today's work together is to build our Driving Question Board. First, we need to think more about how the cups and related systems work to keep things cold or hot.*

The goals of the gallery walk are to (1) wonder about the different mechanisms that cause the thing inside to warm up or cool down and (2) identify patterns in structural features that seem to be important for slowing or stopping this temperature change.

Give students 5 minutes to circulate to view at least 3-5 other models. Students do not need to take notes during the gallery walk, but they do need to develop noticings and wonderings in their heads to help them generate questions for the Driving Question Board (DQB).

12 · DEVELOP QUESTIONS FOR THE DRIVING QUESTION BOARD

5 min

MATERIALS: note cards, markers, tape, classroom consensus model

Write individual questions for the DQB. Display **slide O**. Remind students that we want to ask how and why questions to figure out how and why the fancy cup and related systems work to maintain the temperature of the stuff inside them. Have students turn and talk with their partners or in small table groups to brainstorm a couple of how and why questions about the cup systems or about a pattern they observed when they looked at related phenomena.

Then pass out one or two note cards and a marker to each student. Ask students to write one question per note card and to try to write open-ended questions to post to the DQB, though close-ended questions are also acceptable. The questions do not all have to start with how or why, but they should be questions that (1) we can answer through investigation and (2) will help us explain how these things work the way they do.✱

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

The purpose of this activity is to support students in asking questions about phenomena that will lead to investigations (SEP). Students should focus specifically on how the temperature change inside a system happens more quickly or slowly based on structural features of the system (DCI). Three crosscutting concepts can be used to help students generate questions about the phenomenon if they get stuck: (1) the different structural components they've identified and how those parts work to maintain the temperature of the substance inside (Structure and Function), (2) the different parts of the system and whether anything is moving from outside the system to inside or vice versa (systems modeling), (3) patterns they identified across related phenomena that seem to be important in helping these objects function the way they do (patterns)

13 · DEVELOP THE DRIVING QUESTION BOARD

20 min

MATERIALS: Driving Question Board

Gather in a Scientists Circle around the DQB. Instruct students to bring their completed questions along with chairs to meet in a Scientists Circle around the DQB. Remember that the backdrop of the DQB could be the classroom consensus model; if not, the classroom consensus model should be posted nearby and a space, such as a bulletin board, can be used for the DQB.

ADDITIONAL GUIDANCE	The Driving Question Board will be central to the sensemaking that happens in the unit. There are a variety of ways to set up the DQB depending on your classroom resources, use of technology, and the number of students you see each day. What works for some will not work for others. Most important is that the DQB is visible to students each day and represents "our shared mission". Students will be using the DQB to assess what they've figured out and identify next steps.

Remind students how to create the DQB (use **slide P** if needed):

- The first student reads his or her question aloud to the class, then posts it on the DQB, near the part of the model the question most relates to.
- Students should raise their hand if one of their questions relates to the question that was just read aloud.
- The first student selects the next student whose hand is raised.
- The second student reads his or her question, says why or how it relates, and posts it near the question it most relates to on the DQB.

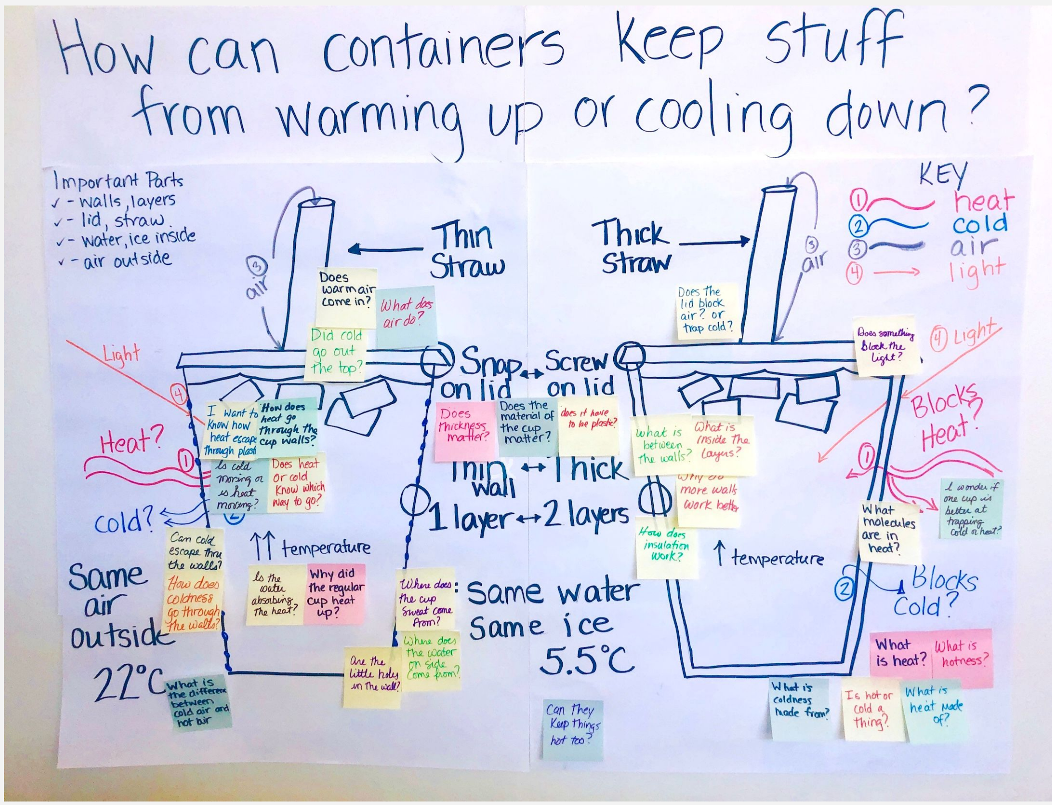
- The student selects the next student, who may have a related question or a new question.
- We will continue until everyone has at least one question on the DQB.

Start the DQB with questions specifically about the regular cup versus the fancy cup. As students share, connect these questions to parts of the initial consensus models for the two cup systems.

Then broaden the DQB to questions related to patterns across the different systems that are designed to keep things hot or cold. Make connections to the cups when possible.

Organize questions into categories. As students share, questions will naturally cluster into similar areas of the model, such as questions about the cup wall(s) and questions about the lid and/or straw. Once students have finished their sharing, ask students to look at the questions for any additional organization that can be done.

Connect the DQB to the unit question. The question for this unit is "How can containers keep stuff from warming up or cooling down?" Ask students if that question could work for their main DQB question posted at the top, or whether they want to modify the main question to capture all the other questions they have posted. Write/modify the agreed-upon driving question at the top of the DQB.

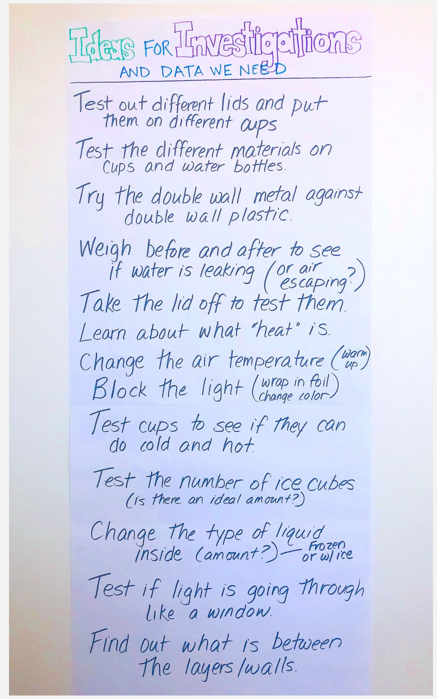


14 · PLAN IDEAS FOR INVESTIGATIONS

10 min

MATERIALS: chart paper, markers

Stay in a Scientists Circle to brainstorm further investigations. Display **slide Q**. Have students turn and talk to a partner about ideas for future investigations to pursue. They could write these ideas in their science notebook, or if time is short, just have them spend a minute generating a couple of ideas aloud with their partner. Then ask students to share their ideas with the whole group, while you record on chart paper a list of these ideas for investigations. This Ideas for Investigations poster will remain public throughout the unit.



To ensure all students share their ideas, say, *To make sure we have everyone's ideas up here, I will pass a marker to the first person on the edge of the circle. The student with the marker should share one of their ideas. I will write it up and number it. That student should pass the marker to the student next to them. The second student then shares an idea, and so on. If a similar idea is on the poster already, the student should say which idea it is and how it is similar. I will then put a tally mark next to that idea.*

The marker is passed all around the circle and all students have a chance to have their thinking represented on this poster. Offer to students that if they have additional ideas that don't end up on the poster, they can raise their hand after we have heard once from everyone in the class (after the marker goes all the way around the circle). Emphasize to students that the Ideas for Investigations poster can change throughout the unit as they learn more. If students think of new ideas along the way, ask them to jot them down in their notebook to add to the poster later.

15 · NAVIGATION

2 min

MATERIALS: None

Decide where to go next. In this last activity in Lesson 1, it is important to remind students of the mission of the class and to motivate a series of investigations. Remind students that the mission of the class is to figure out (1) what causes the stuff inside the cups and related containers to warm up and (2) how the structure of those systems keeps this from happening. Say, *We have accomplished so much. We now have a better idea about which parts of these systems could be really important for explaining what is happening, and you've come up with good questions for us to investigate. I am very excited for us to get started on investigating all of this. Seems like we need to get more data on the cup systems and then test different parts to see how important they are. Let's try this in our next lesson.*

ADDITIONAL GUIDANCE	Remind students to keep their science notebooks organized by writing a title on each page and updating their table of contents. They can do this when they have extra time at the beginning or end of class or during homeroom or homework time.

Additional Lesson 1 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.SL.6.1.c: Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.** When the class is building the Driving Question Board, if a student forgets to explain why or how their question is linked to someone else's question, press that student to try to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off one another's ideas and to help scaffold student thinking. Don't worry if some questions are raised that do not lead to productive investigations. Over time students will get better and better at forming testable questions in the scope of the driving question. This type of activity gives them practice at doing that. If students can't figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question. Today's activities rely on students communicating and articulating their thinking. One tool that may support classroom discussion is the Communicating in Scientific Ways sentence starters. This 1-page document can be blown up and printed as a class poster, printed on 8.5-×-11 paper and posted near students' desks, and/or scaled down and taped into students' science notebooks. To support discussion, reference the sentence starters on the poster and encourage students to use those sentence starters to help them communicate. The sentence starters can be especially useful for helping students engage in scientific talk, particularly students who may feel reluctant to contribute.

LESSON 2: What cup features seem most important for keeping a drink cold?

PREVIOUS LESSON *We made observations and collected temperature data to investigate whether the fancy cup performed better than the regular cup. We found that the fancy cup kept the drink colder for longer. We were not certain what caused the temperature change, but we identified factors that we thought were important. We developed questions and ideas for investigations.*

THIS LESSON

INVESTIGATION

2 days

We plan and carry out an investigation to figure out 2 things. First, what cup features are important for keeping a drink cold (maintaining its temperature)? Second, how would changing the cup features cause the drink to warm up faster? We collect, organize, and publicly analyze data from our investigation to identify patterns that help us determine which cup features work well in maintaining a drink's temperature and which do not.

NEXT LESSON *We will explore whether the same cups that keep liquids cold also keep liquids hot. We will identify cup features that are important for maintaining the temperature of the liquid inside. We will ask more questions about the various cup features and decide which feature to investigate next.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Plan and carry out an investigation to gather evidence to answer scientific questions about how parts of the cup system relate to the temperature change of the liquid inside.

Analyze and interpret data to find patterns indicating which parts of the cup system (features) influence the temperature change of the substance inside the system.

WHAT STUDENTS WILL FIGURE OUT

- Some systems have structural features that are designed to help maintain the temperature of a substance inside the system.
- The cup features that seem to play a significant role in keeping a drink cold are a lid, double walls, and maybe the type of cup material.

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review students' ideas for investigations and what cup features they wanted to test. Have students make predictions about how the features could affect the temperature change of the substance inside.	A	Ideas for Investigations poster, whiteboard or chart paper, markers
2	10 min	**SET UP A FAIR TEST** Prompt students to think about how to test their hypotheses. Discuss and reach consensus on how to keep as many aspects of the tests as similar as possible while investigating each feature.	B-C	whiteboard or chart paper, markers
3	5 min	**PLAN CUP INVESTIGATIONS IN SMALL GROUPS** Prompt students to work in groups of 3 to collaboratively design their cup investigation.	D	
4	20 min	**CARRY OUT CUP INVESTIGATIONS** Prompt the groups to begin their cup investigation. Ask students to collect and record data in their science notebooks. Remind students to clean up after their investigation but to save their cups.	E	colored pencils, Testing Cup System Features
				End of day 1
5	25 min	**ANALYZE CLASS DATA** Review cup investigations and display class data for sorting and analysis. Facilitate a class discussion of the data to identify the most important cup features for keeping a drink cold.	F-G	1 copy of class data (optional), digital copy of class data (if technology is available)
6	8 min	**UPDATE INDIVIDUAL PROGRESS TRACKER** Work with students to set up their Progress Tracker. Have students write and/or draw any new ideas regarding the cup system that came up following the data analysis.	I	
7	8 min	**ORDER THE CUPS BY PERFORMANCE** Facilitate a class discussion around the class data to identify which cup features seem to help keep the drink cold, and use these features to rank the cups in terms of performance.	J	Testing Cup Features cups
8	2 min	**NAVIGATION** Prompt students to look at the cups ranked from best to worst performer and to consider how the cups would perform if the cold liquid were replaced with a hot liquid.	K	
				End of day 2

Lesson 2 • Materials List

	per student	per group	per class
Testing Cup System Features materials		• 1 timer or stopwatch • 1-2 thermometers • 1 500-mL graduated cylinder or beaker • 400 mL cold water	• 20 16-oz single-wall plastic cups with lids • 4 16-oz single-wall metal cups with lids • 2 16-oz double-wall plastic cups with lids (note: students can stack 2 single-wall cups together to make a double-wall cup) • 10 16-oz paper cups with lids • 20 plastic straws • clear plastic wrap • 3-4 pitchers of iced cold water (chilled to ~6°C and enough for each group to have 400 mL for their cup) • cooler with ice and a scoop or cup • aluminum foil • 1 roll of tape • clamp lamp with 100-watt bulb (optional)
Lesson materials	• science notebook • colored pencils • 1 copy of class data (optional)	• Testing Cup Features cups	• Ideas for Investigations poster • whiteboard or chart paper • markers • digital copy of class data (if technology is available)

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Be sure to display the following before day 1 of this lesson:
- class data from Lesson 1
- Ideas for Investigation poster from Lesson 1

After students complete their investigation on day 1, and before they analyze the data on day 2, prepare a table of their pooled data for analysis.

Day 1: Testing Cup System Features
- **Group size**: 2-3
- **Setup:** Based on students' ideas for investigations, provide various materials that students may want to use to conduct their first investigation in this lesson. Avoid styrofoam, foam, or other insulative materials at this point, and focus mostly on the plastic cups and possibly metal cups.
    - Prepare an area with these materials available to all students: 20 single-wall plastic cups with lids, 4 single-wall metal cups with lids, 2 double-wall plastic cups with lids (note: students can stack 2 single-wall cups to make a double-wall cup), 10 paper cups with lids, 20 plastic straws, clear plastic wrap, 3-4 pitchers of iced cold water (~6°C); enough for 400 mL for each group, cooler with ice and ice scoop or cup, aluminum foil, 1 roll of tape (to seal holes in lids if desired)
    - Prepare a lab bin with these materials for each small group of students: 1 timer or stopwatch, 1 thermometer, 1 500-mL graduated cylinder or beaker
    - Prepare to repeat the Anchoring Phenomenon demonstration from Lesson 1 while students test their cups. For this you will need the following materials: 1 single-wall plastic cup with lid (straw optional), 1 double-wall plastic cup with lid (straw optional), 2 thermometers, pitcher of iced cold water (~6°C), enough for 400 mL per cup
- **Notes for during the lab:** Be sure that all cups are tested at the same time. An alternative gallery walk is suggested for group members to do during the investigation while they are waiting to take their temperature measurements. See details later in this lesson plan.
- **Safety:** Warn students to be careful with glass thermometers, as any breakage may cause cuts and scrapes.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students have an opportunity to explore some of their initial ideas around why the fancy cup in the anchoring phenomenon performed better than the regular cup. By changing various features of the cup system, students investigate which features seem to influence the cup system's ability to keep a drink cold. By the end of this lesson, students will notice that the most important features are a cup lid and double walls. However, there will be no clear patterns yet in how a cup's material affects the cup's ability to keep a drink cold.

As part of this lesson, students collaboratively develop a plan for investigating the various features of the cup system, which includes discussing how to design a fair test and how to measure and collect data. After carrying out their investigation, students collect and analyze class data to identify patterns to determine which cup features played an important role and which features seemed to matter less in keeping a drink cold.

Where We Are NOT Going

In this lesson, students take a limited pass through setting up fair tests. The idea is not to impose too many constraints on how to set up this investigation. We are only interested in certain salient features of the cup from the anchoring phenomenon discussed in the previous lesson (i.e., presence or absence of a lid, number of walls, thickness and/or type of cup materials, presence or absence of a straw) that played a significant role in keeping a drink cold--it is not necessary to test every permutation of each cup feature. Avoid allowing this investigation to be an exhaustive testing of material or design types (e.g., styrofoam, vacuum-insulated cups, and so forth).

Though not essential, you may also encourage students to keep track of other observations or ideas from the anchoring phenomenon (e.g., presence or absence of condensation).

LEARNING PLAN for LESSON 2

1 · NAVIGATION

5 min

MATERIALS: Ideas for Investigations poster, whiteboard or chart paper, markers

Navigate from the anchoring phenomenon. Point to the Ideas for Investigation poster. Remind students that at the end of the last lesson, we generated questions and ideas for investigating how particular cup features worked to keep a drink cold.

Tell students, *We think more data will help us identify the things that help keep the drink cold. Let's start by reviewing our ideas for investigations and the various cup features we think may be important. Then, we'll predict what we expect to see if we test these features. What are some cup features you think we should test?* Display **slide A** and prompt students to turn and talk to a elbow partner about these questions:

- Which cup features seemed to matter most?
- What do you think we'll see if we test these cup features?

Record and display students' suggestions. Bring students back together. Ask students to list features that matter most and what they would see, as you record on a whiteboard or chart paper. If no student has yet suggested testing cup features like the lid, number of walls, or material, consider asking the following questions to prompt ideas about those features:

Suggested prompt	Sample student response
If we compare cups with or without lids, what do we expect the data to show?	*It won't make a difference.* *Maybe the drink will warm up faster.*
If we compare cups with different numbers of walls, what do we expect the data to show?	*More walls will keep the drink cold longer.* *Fewer walls will let the cold out faster.*
If we compare cups that are made of different materials, like metal or plastic, what do we expect the data to show?	*Cups made of metal will let the cold out more.* *A plastic cup will keep a drink cold longer.*

Prepare students to begin cup investigation. Explain to students that we can use the ideas they just generated to plan several investigations. The data gathered can then be used to evaluate each hypothesis and determine which cup features are important for keeping the drink cold. Tell students that they will work in groups to select 1 cup feature they want to investigate more, and then they will compare what they find back to 1 of the original 2 cups. For example, if they want to know more about whether the lid really matters, they can test a regular cup without a lid and compare it to the original regular cup with the lid.

However, before planning their investigations, it's important to set up parameters for a fair test, similar to our comparison of the regular and fancy cup in the last lesson.

2 · SET UP A FAIR TEST

10 min

MATERIALS: science notebook, whiteboard or chart paper, markers

Help students set up fair testing procedures. For now, take students through a limited pass at designing fair testing parameters when investigating cup features. Keeping this planning step somewhat open provides students with opportunities to consider which conditions need to be kept constant to improve the validity of their data.✱

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

Review the cup features being tested. Display **slide B**. Remind students that each group needs to decide on 1 thing they want to change about 1 of the 2 original cups and test their new, modified cup system. Tell students that their comparison cup will be 1 of the 2 cup systems they've already studied. Let students know that you will test the fancy cup and regular cup again while they test their cups so they will have comparison data.

First in partners and then as a class, have students brainstorm different cup features that we could modify and test. Though these features may vary by class, they will likely include the following:

- absence or presence of a lid
- absence or presence of a straw
- number of walls
- thickness of walls
- cup material

Tell students that now is the chance to test some of their ideas about whether certain features of the cups actually make a difference.

Establish which testing parameters should be kept constant. Instruct students to think back to the Anchoring Phenomenon setup with the 2 cup systems. Remind them that they need to try to modify only 1 part of the cups, looking at a specific feature, for their new tests. Ask students what other conditions should stay the same for the tests. Prompt students to briefly discuss with partners first and then share with the class. Student responses will vary, but the following should be the minimum parameters agreed upon:

- Begin with water (or water/ice mixture) at the same temperature.
- Begin with the same amount of water (or water/ice mixture).
- Take temperature readings at the same time for all tests (perhaps every 2-3 minutes).
- Run each test for the same duration (perhaps for 15 minutes).

Direct students to find a new page in their science notebook and title it "Testing Cup System Features". Students should record what parameters the class agreed should be held constant (amount of water in each cup, number of ice cubes, and so forth) in all experiments.

Set up the data table. As a class, reach consensus on what the data table will look like. Make a quick sketch of the data table for the class, get verbal agreement from students that this table is satisfactory, and then ask students to draw it into their notebook. The data table will likely look like this:

Time (minutes)	Temperature (℃)
0 (starting temp)	
3	
6	
9	
12	
15	

Remind students how to record temperatures. Display **slide C** and use it to have students practice how to read a thermometer and record temperature data.

In the previous lesson, students engaged in collaborative sensemaking as a whole group, but they did not get to test the cups to test their ideas. Now that students have ideas about what they believe is important, this investigation gives them the opportunity to answer their "what would happen if" questions, which will (1) satisfy some of their curiosity right now and (2) be useful later to motivate the need to figure out how and why they got the outcomes of their investigations.

3 · PLAN CUP INVESTIGATIONS IN SMALL GROUPS

5 min

MATERIALS: science notebook

Have students form groups to write an investigation plan. Display **slide D**. Ask the groups to develop a plan for investigating 1 cup feature.✱ Students should identify which original cup is their group's control cup--either the regular cup or the fancy cup. Then they should brainstorm an investigation plan about the cup feature they want to modify and test and how they are going to test it compared to the control cup. Ask students to write their investigation plan as a brief set of notes under the data table in their science notebook.

ASSESSMENT OPPORTUNITY

The investigation plan that students create will likely include gaps in how to design a fair test, and that is OK. Use this investigation plan as a pre-assessment of what your students already know about setting up step-by-step procedures to follow for an experiment. As you circulate, look to see if students are including (1) what the class agreed upon for a fair test and (2) only 1 variable to be changed in the cup system they plan to test.

While students are writing in their notebooks, circulate among the groups to examine their investigation plans. As groups' plans are almost complete, get the original regular and fancy cups ready for testing as the control. You can start testing those cups when the small groups start their tests.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Make certain the DQB plays an integral part in the planning of the investigations so that students make connections between the questions they asked in the anchor lesson, and the investigations they will conduct in this lesson. Point students to questions on the board such as "what happens if" questions the students may be able to answer with some initial investigating. As students design their investigation plan, encourage them to turn questions posted on the DQB into testable questions they can investigate.

4 · CARRY OUT CUP INVESTIGATIONS

20 min

MATERIALS: Testing Cup System Features, science notebook, colored pencils

Tell students to set up their cup investigations. Remind students to refer to their investigation plan and to follow all fair testing parameters regarding the water's starting temperature and volume. They can record the volume of water just outside their data table.✱

Prompt students to begin investigation and to sketch their cup systems. Remind students to collect and record data in their data table at the established intervals for 15 minutes. During the investigation, instruct students to make a labeled diagram displaying all the parts of the original cup system they chose to test (either the regular cup or the fancy cup). Then have them use a different colored pencil to note the modification they made and how they believe this will influence the temperature of the water inside the cup. This sketch can be used as part of the students' explanation of results.

ASSESSMENT OPPORTUNITY

Use this time now and while students are carrying out the investigations to circulate among each group. When you circulate, use the following probe questions to elicit student thinking:

- *What did you keep the same as the other cups? Why was this important?*
- *Which cup from the original 2 cup systems did you want to compare against? What did your group decide to change?*
- *How do you think changing this part of the system will affect the temperature change of the liquid inside? What do you think this part does to slow down temperature change?*

Listen for students' ideas about the following:

- how the changed part of the system affects the mechanism the students believe is causing the drink to warm up
- whether they controlled the variables they needed to control and how close their group got to manipulating only 1 variable

✱ ATTENDING TO EQUITY

This activity is designed to ensure that all students are positioned to intellectually engage throughout the collaborative sense-making. For this reason, it is important that students are not placed into set roles that are less intellectually engaging, like "materials manager". We recommend using a range of intellectual roles associated with the collaborative learning process (e.g., idea connector, causal checker, evidence wrangler, relevance hunter).

Stop the investigation after 15 minutes. Remind students to clean up and return all materials, except for their cup. Do not throw the cups away. Each group should keep and label their cup "Testing Cup Features" along with a group name or number. These cups will be used again on day 2 and also in Lesson 3.

ALTERNATE ACTIVITY	Explain to students that only 2 group members are required to actually remain at their table to monitor and record the temperature during the 15-minute test. The rest of the group members can do a gallery walk of all the group setups. The students can take turns after 5 minutes so everyone in the group gets a chance to see the other investigations. The idea here is for students to see how other groups set up their test and get a sense of what cup features others are investigating.

Collect cup investigation data. Explain to students that it's important to pool the class data to see if it helps us figure out anything more about the cup systems. Ask 1 member from each group to report their group's data to you. Tell students that you will prepare the class data to analyze next class period. Remind them that group members should be ready to show the diagrams they drew in their notebooks to the class.

Make a class data table before day 2. Outside of class, you will need to construct a class data table (see sample below) displaying each group's data. This data will be displayed in the next class period. Reproducing the class data digitally makes it possible for students to sort the data in different ways. However, if the available technology is limited, make a print copy available to each student. The red font indicates variables that are different from the 2 original cups systems (regular and fancy cup). In some cases the students may have inadvertently changed more than 1 variable, and that is OK for this investigation. Update **slide G** with your class data.

Cup	Cup material	Lid	Straw	Single or double wall	Other change	Temperature (°C) after 1 min	Temperature (°C) after 15 min	Temperature change
reg	plastic	plastic	yes	single	no			
fancy	plastic	plastic	yes	double	no			
1	plastic	plastic	no	double	no			
2	plastic	plastic	yes	single	lamp			
3	plastic	no lid	yes	single	no			
4	plastic	no lid	yes	double	no			
5	metal	plastic	no	double	no			
6	metal	no lid	yes	double	no			
7	metal	plastic	yes	single	no			
8	metal	no lid	yes	single	no			
9	plastic	plastic	yes	single	foil			
10	plastic	plastic	no	single	hole taped			

Note: The primary purpose of this investigation is (1) to allow students to investigate some feature of the cups they believe is important to keeping the water inside cold; this feature could be the lid, straw, thickness of the cup, type of material, number of walls, etc., and (2) to motivate the need for more systematic investigations. Students may or may not want to test materials, like metal, and that is OK at this point in the unit. Ultimately you want Lesson 2 to satisfy students' initial curiosities and help them start to answer questions posted on the DQB. Let students' questions drive what they investigate. However, if you want students to test metal cups you will need to motivate the need to do so by pointing to popular drink containers, such as Thermos and Yeti cups and other water bottles, which are made from metal.

Sample data

Cup	Cup material	Lid	Straw	Single or double wall?	Temperature							
					1 min	10 min	15 min	Change	20 min	25 min	30 min	Change
reg	plastic	yes	yes	single	8	9	10	**+2**	11	11	12	**+4**
fancy	plastic	yes	yes	double	9	10	10	**+1**	11	11	11.5	**+2.5**
1	metal	yes	no	double	7	7	7	**0**	7	8	8	**+1**
2	metal	no	no	single	8.5	10	10.5	**+2**	11	12	12	**+3.5**
3	plastic	no	no	single	8	9.5	10	**+2**	11	12	12.5	**+4.5**

Starting 6.5
Ambient 20C increased to 23C

End of day 1

5 · ANALYZE CLASS DATA

25 min

MATERIALS: science notebook, 1 copy of class data (optional), digital copy of class data (if technology is available)

Prompt student groups to review their data. Say, *Remember that yesterday we set up several investigations to see which cup features may be keeping the drink colder for longer. Let's see what we found out.* Display **slide F**. Tell groups to review their own data in their science notebook first and then discuss their responses to the following 2 questions:

- What conclusions can you draw from your data?
- Do you think that your group's test was valid? How do you know?

Remind students of discussion norms. The class discussion today begins as an Initial Ideas Discussion but shifts toward a Building Understandings Discussion as students come to agreement about what the evidence does and does not support. These discussions are an opportunity for students to voice their ideas supported by evidence from the investigation, but they will not necessarily reach consensus on everything being discussed. Before proceeding with the class discussion, remind students of community norms around sharing ideas, listening to understand, stepping back to give others a chance, and being respectful when giving and receiving feedback.

Say, *Let's remember that we don't have any answers at the moment. We are just trying to see if the data helps us uncover any new ideas about the cups.*

Display (or project) class data. Display **slide G.** In small groups, give students 2-3 minutes to brainstorm different ways to sort the the class data.✱

Analyze the class data through an Initial Ideas Discussion. If you are displaying the data in Excel or another spreadsheet program, use the sorting option to display your first sorting suggestion to the class. If you are not using a spreadsheet program, ask students to take a moment to scan the data that can be compared by cup feature (e.g., lid versus no lid) and estimate, on average, if there is a difference. Prompt small groups to share 1-2 ways to sort the data. Tell students to look for patterns in the newly sorted data. Ask 1-2 small groups to share what they noticed with the class.

Say, *Let's think about how the data looks similar or different now that we've sorted it by 1 cup feature. Think about whether or not there is a pattern we can see now after sorting.*

After the first group shares their pattern, display **slide H**. Instruct students to find a new page in their science notebook and title it "Data Analysis: Cup Investigations". Prompt students to record the first shared pattern on this page. Toggle between **slide G** and **slide H** as the class works together on 1-2 patterns that are recorded in everyone's notebook.

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

Involve students in organizing the data in ways that help them identify trends across the investigations. The organization process may be overwhelming to students at first. Consider modeling for students how to organize the cups by 1 feature--for example, plastic versus metal--if you sense they need extra guidance. Importantly, focus students on reasoning about several possible outcomes; for example, by looking for ways to organize the data to help show different patterns or trends by cup feature.

✱ ATTENDING TO EQUITY

Emphasize to students that when they share their ideas, everyone's ideas matter. This is particularly important in moments when not everyone agrees that they saw the same patterns in the data or when there are uncertain findings. Sharing ideas with one another helps the class identify where there is common ground and where ideas differ. These differences can lead to productive investigations to resolve them. Encourage students who are uncertain or confused to speak up and ask questions of

Prompt small groups to further sort and analyze class data. Keep **slide H** displayed. For independent small-group analysis, tell the groups to record their own findings about patterns in their notebooks. Circulate among the groups, listening to their analyses. Prompt students to think about and prepare to share some of their findings, uncertainties, and questions with the whole class.

ASSESSMENT OPPORTUNITY	The data may be messy today. This is to be expected. The assessment in this moment should focus on whether students are identifying reasonable patterns and whether they see that other patterns can not be identified yet. Listen for students to identify clear patterns about parts of the systems, such as these: • No-lid conditions seem to warm up faster than those with lids. • Single-wall cups seem to warm up faster than double-wall cups. Students may be uncertain about patterns associated with these features: • material type • straw versus no straw • light versus more light (if light was included in their investigations)

Shift to a Building Understandings Discussion around patterns.✱ Show **slide G** again. Given time to sort and analyze data, students should now be able to identify patterns pointing to specific cup features that help keep a drink cold, and to identify inconclusive data. The focus of the discussion now shifts to what the evidence does and does not support. To get the conversation started, use the following prompts:

KEY IDEAS	**Purpose of this discussion:**
	• Generate an initial list of cup features that have evidence to support that they affect how well the system works.
	• Motivate the need to gather additional evidence on cup features that have inconclusive data.
	• Connect to initial questions that we posted to the DQB in lesson 1.
	
	Listen for these ideas:
	• Areas of agreement supported by evidence:
	    • Cups with double walls work better than cups with a single wall.
	    • Cups with a lid work better than cups without a lid.
	• Areas of disagreement due to inconclusive data:
	    • There is no clear pattern with the cup materials--sometimes metal works well and sometimes it doesn't.

Suggested prompt	Sample student response
Are there any cups that didn't work well at keeping something cold? How do we know?	*It looks like the single-wall metal cups didn't work well since the water temperature always went up the most in those.*
What patterns in the data helped us determine which cup features worked well, and which did not?	*When we sorted by lid or no lid, the temperature always seemed to go up more without a lid.* *I noticed that when we compared all the single-wall to double-wall cups, the double-wall cups always performed better.*

their classmates; their uncertainties and questions are a valuable part of the process too.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SYSTEMS AND SYSTEM MODELS

As the discussion unfolds, track where students are working in their systems using the initial class consensus model that is the backdrop of the DQB. This model includes the lid, walls, and inside or outside the cup. Help students see that they are gathering more evidence to help them make sense of the role of each part of the system, and that by looking at each part of the system they are already starting to answer, in part, some of their initial questions on the DQB.

Suggested prompt	Sample student response
What features did the cups that worked well have in common?	*All the cups that worked well had double walls.* *Cups with lids always seemed to work better than the same type of cup with no lid.*
What features did the cups that didn't work well have in common?	*Cups with a single wall always ended up with warmer water compared to cups with 2 walls.* *No matter what material the cup was, the water temperature always went up more in cups with no lid.*
Which cup features can we identify as critical for keeping the drink cold?	*It seems like having a lid mattered the most, but also that cups with double walls did better.* *Sometimes plastic cups did better than metal cups, but not always. I'm not sure this is as important.*
Did anyone identify cup features where there may be a pattern but you were uncertain?	*We noticed the double-wall metal did the best more than the plastic, but we couldn't tell if there was a pattern between all the plastic and all the metal ones.*
What questions have we already answered or started to answer from our Driving Question Board?	

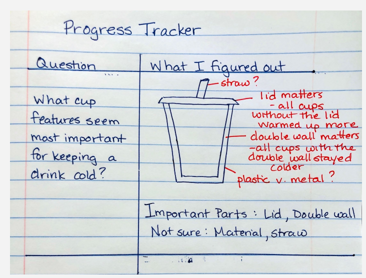
Summarize overall findings. Ask for volunteers to summarize which cup features seemed to show a clear pattern to help keep the drink cold. As students summarize, make connections to initial questions posted on the DQB that may be partially or completely answered by the data. Then, switch back to **slide H** and prompt students to write these overall findings in their notebook or highlight those patterns if they wrote them down in their small-group work.✱

6 · UPDATE INDIVIDUAL PROGRESS TRACKER

8 min

MATERIALS: science notebook

Set up the Progress Tracker for an individual reflection.✱ Explain to students that we tested some ideas and then figured out some new things after analyzing the data from our cup investigations. Remind students of how we used the Progress Tracker in the previous unit. Have students turn to this section in their notebooks, which should be 10 pages at the beginning of the section for the new unit. Use **slide I** to guide students to draw in the T-chart on the first page of this section and to complete the 2 columns. Remind students that the left column is to record the lesson question, and the right column is to record what they figured out.



Give students about 3-5 minutes to quietly update their Progress Tracker using words and drawings to show what they've learned so far about the parts of the cup system. Prompt students to use patterns from the evidence collected in the cup investigations.✱

✱ ATTENDING TO EQUITY

This is an opportunity for students to express their understanding and reasoning in their own way. Encourage students to express what they've learned using a mode that makes sense for them. The individual Progress Tracker is a space for students to be creative and to synthesize learning in their own words and drawings. It is not supposed to follow a prescriptive plan or structure and should be a low-stakes opportunity for students to make sense of

ASSESSMENT OPPORTUNITY	The individual Progress Tracker is a tool to help students reflect on their own learning in response to the question being investigated. Encourage students to use this space to share all the new information and new connections they have but also to note where they are still confused. Have students leave their science notebooks in the classroom and quickly scan their Progress Trackers to give you a sense of what students recorded as the key takeaways from the lesson and to see if they remark on areas of confusion, uncertainty, or lingering questions.

what they are learning without the worry and anxiety that comes with knowing their work will be graded.

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

Prompt students to use patterns from the data analysis process in their "What I figured out" column. Also, cue them to think about the parts of the system that they are more or less certain about and how those parts could relate to temperature change. Explicitly cuing students to thinking about patterns and systems may help them generate more focused explanations and/or models about the temperature change.

7 · ORDER THE CUPS BY PERFORMANCE

8 min

MATERIALS: Testing Cup Features cups

Summarize the process of reaching conclusions from class data. Briefly summarize everything students did during the lesson. Say, *Before we began this lesson, we started with some ideas about why the fancy cup worked so well. Then we designed some investigations to test those ideas. From those investigations we collected data, which we finally sorted and analyzed.*

Emphasize to students that sorting the data allows us to identify with greater certainty the cup features that play a larger role in keeping a drink cold.

Consider saying, *When we first looked at our data, it was hard to figure out what all the numbers meant. However, sorting the data in different ways allowed us to notice certain patterns. After sorting and analyzing our data, it now seems that certain cup features really do play a large role in keeping a drink cold.*

Elicit nominations for important features to help rank the cups. Display **slide J**. Remind students of the lesson question. Say, *What cup features seem most important for keeping the drink cold?*

Then ask the class to identify features that will help students rank the cups by performance. Say, *Which cup features are we more certain about? Which are we less certain about?*

Ask the class to order the cups from best to worst performer. As the class ranks the cup, place each one on a table top in order from best to worst performer. It's OK if students are uncertain about the cups in the middle. Students may want to simply use their data table to help them do this ranking.

If some data seems counterintuitive and problematic for students, you may consider asking students what should be done about this. These are some possible ideas:

- Repeat the test if you think the results will help determine an important cup feature.
- Discuss how to adjust the investigation to ensure greater certainty in upcoming lessons. (This helps students think more about planning investigations to get quality data.)

8 · NAVIGATION

2 min

MATERIALS: None

Wrap up the lesson. Show **slide K**. Students likely mentioned in Lesson 1 that some containers can keep substances inside both cold and hot. Remind students that some makers of cups claim that their cups can keep cold drinks cold *and* hot drinks hot too, and maybe some of the objects on the related phenomena poster do this too.

Say, *We've only been testing these cups with cold water. Do you think the cups that work well to keep things cold would also work well to keep things hot?* Elicit a few predictions from students. Then say, *Let's test this next and see if our best performers perform equally well with hot liquid inside*.

LESSON 3: How are the cup features that keep things cold the same or different for keeping things hot?

PREVIOUS LESSON *After the class tested several cup configurations, our data analysis showed that the 2 cup features most important for keeping a drink cold were a lid and double walls. We also found evidence suggesting that the cup's material plays a role, but we decided this data was inconclusive at the moment.*

THIS LESSON

INVESTIGATION

2 days

We look at the order of cups based on their ability to keep liquids cold. We investigate whether these same features are able to keep liquids hot. Based on our findings, we revise our explanation from Lesson 1 to explain how particular cup features help to keep liquids hot and/or cold. We ask additional questions about how cup features, such as the lid, work to maintain the temperature of hot and cold liquids inside the cups. We then design an experiment to investigate our questions and ideas about how the lid works.

NEXT LESSON *We will plan and carry out two investigations to determine (1) the effect of a lid on how much the temperature of a hot liquid in a cup will drop and (2) the effect of a lid on change in the mass of a hot liquid in the system. We will develop and use a particulate model of liquids and gases to explain the mass loss in an open system.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Develop and use a model to explain how the best-performing and worst-performing cup systems affect the temperature change of a substance inside a system.

Plan an investigation to investigate how the lid (a structural feature of the cup system) works to slow the temperature change (function) of a substance inside the system.

WHAT STUDENTS WILL FIGURE OUT

- Cups that can keep liquids cold are also able to keep liquids hot.
- Cups with lids are able to keep liquids hot and cold better than cups without lids.
- Cups with more walls or layers are able to keep liquids hot and cold better than cups with fewer walls or layers.

Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Display the ranked cups from the previous lesson. Have students turn and talk and then share with the whole group why we ordered the cups this way.	A	cups from lesson 2
2	25 min	**CONDUCT THE HOT WATER TEST** Have students test their cups' ability to keep water hot by taking temperature measurements for 15 minutes.	B-D	Testing Cup System Features data chart, Hot Water Test
3	15 min	**ANALYZE HOT WATER TEST DATA** Review cup investigation data and re-sort cups as needed based on the new data. Identify which cups stayed in the same place or changed position in the performance ranking.	E-F	Hot Water Test data chart
				End of day 1
4	12 min	**SHARE MODELS AND UPDATE PROGRESS TRACKER** Have students share their ideas about the best and worst performers and update their individual Progress Tracker with new ideas and questions.	G-H	colored pencils
5	18 min	**PLAN AN INVESTIGATION TO TEST THE LID** Students design an investigation to test how the lid on the cup system works to prevent liquids inside from warming up or cooling down.	I	*Investigation Plan:* ________________
6	15 min	**AGREE UPON PROCEDURES FOR OUR INVESTIGATION** Ask students to restate some of the variables that the class decided were important to keep constant in investigations. Discuss and make revisions to the independent and dependent variables too.	J	colored pencils, chart paper, markers
				End of day 2

Lesson 3 • Materials List

	per student	per group	per class
Hot Water Test materials	• 1 safety goggles	• labeled cup from Testing Cup System Features lab in Lesson 2 • 500-mL graduated cylinder or beaker • 1 thermometer • 1 timer or stopwatch • 1 oven mitt	• 2-4 electric kettles • water • 1 16-oz single-wall cup with lid • 1 16-oz double-wall cup with lid • 2 thermometers • 500-mL beaker
Lesson materials	• science notebook • colored pencils • *Investigation Plan:* ______________		• cups from lesson 2 • Testing Cup System Features data chart • Hot Water Test data chart • chart paper • markers

Materials preparation (25 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Modify the *Testing Cup System Features* data table from Lesson 2. Add 1 column to the far right for temperature change with hot water (there is no need to replicate the full data table). Display the table where students can see it and record their new data from this lesson's lab.

Cups from the *Testing Cup System Features* lab in Lesson 2 should be ordered from best-performing to worst-performing cup for keeping a liquid cold at the start of this lesson.

Day 1: Hot Water Test

- **Group size:** 3
- **Setup:** Heat water in electric kettles to 49-55°C, enough water so every group gets 800 mL of water (roughly 400 mL for each of their two cups). For each group of students, prepare a bin of these lab materials: 500-mL graduated cylinder or beaker, the group's labeled cup from *Testing Cup System Features* lab in Lesson 2, 1 thermometer, 1 stopwatch or timer, 1 pair of safety goggles per student, 1 oven mitt
- **Notes during the lab:** Turn on electric kettles about 15 minutes before you need the water to be ready for the lab.
- **Safety:** Make sure your water is not above 55°C. Most adults will suffer third-degree burns if exposed to 65°C water for two seconds. Burns will occur with a six-second exposure to 60°C water or with a thirty-second exposure to 55°C water. Students should wear safety goggles throughout this lab. Have students use an oven mitt when handling the cups or wait until the water has cooled before disposing of it down the sink. Warn students to be careful with glass thermometers, as any breakage may cause cuts and scrapes.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

Last lesson, we ranked cups based on their ability to keep liquids cold. In this lesson, we investigate whether these same features might be able to keep liquids hot. The intent is for students to pose their initial ideas about the mechanisms leading to temperature change and how features of the cup system contribute to minimizing these changes. It is important that students begin to think about the mechanisms by which each cup design works to keep things cold and keep things hot.

This lesson continues the process of students designing experiments to investigate how parts of the cup system work. Using the data from the *Testing Cup System Features* lab (Lesson 2) and *Hot Water Test* lab (this lesson), we highlight the important role that the lid plays in maintaining the temperature of a liquid inside the cup system--particularly because we observed more temperature changes when the cup did not have a lid than when it did have a lid. At the end of this lesson we design a more systematic investigation to see how the lid works. Subsequent lessons will explore the role of the cup wall and materials too.

Where We Are NOT Going

At this point in the unit, we are not designing the cup; rather, we are exploring existing design features of cups and how and why they work the way they do. This will help us understand what processes are taking place that change a substance's temperature and how cup features contribute to minimizing these changes. It is important to recognize that we do not expect students to have scientifically correct ideas at this point; rather, we are using these activities to surface students' ideas and motivate the need to investigate these ideas and their implications for the cup system.

LEARNING PLAN for LESSON 3

1 · NAVIGATION

5 min

MATERIALS: science notebook, cups from lesson 2

Navigation. Display **slide A** and have the actual ranked cups from the previous lesson visible to all students on a table. Ask students to turn to their elbow partners and talk for 1 minute about why they ordered their cups the way they did. Bring students back to the whole group and ask 4-6 students to share what they figured out in the previous lesson as well as their ideas for investigating whether the order would be the same if they put hot water in their cups.

Suggested prompts	Sample student responses
Last lesson, we ordered our cups in this way. What were we trying to figure out?	*We were trying to figure out which cups did the best job at keeping drinks cold and which were not as good.*
What did we figure out?	*We figured out that single-wall cups didn't work as well as double-wall cups.* *Cups without lids warmed up more than cups without lids.*
What do you think would happen if we switched to hot water? Do you think these trends would remain the same?	*We weren't really sure because some hot drinks are served in different kinds of cups from cold drinks.* *We aren't sure whether cups can keep things hot and cold.* *I think this could work because I have cups that advertise that they can keep drinks hot and cold for a long time.* *I think this could work because I have thermos/lunch container that I can keep hot soup in and keep a cold drink in.*
So how could we test our ideas?	*Pour hot water into each cup and measure the temperature for the same time as we did with the cold water.*

2 · CONDUCT THE HOT WATER TEST

25 min

MATERIALS: Hot Water Test, science notebook, Testing Cup System Features data chart

Discuss which testing parameters should be kept constant. Display **slide B**. Engage in a conversation about why it's important to set up a fair test and what students will need to keep constant in all of their tests. Say, *Each group is going to test the same cup they tested last time. Instead of cold water, you're going to put hot water into your cup. What are some things that we need to think about to ensure that we are conducting a fair test?*✱

Prompt students to briefly discuss with partners first and then to share with the class. Remind students to think back to the previous lab when they tested the cups with cold water. Student responses will vary, but these should be the minimum parameters agreed upon:

- Begin with water at the same temperature.
- Begin with the same amount of water.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

Throughout the *Hot Water Test*, focus students on getting more systematic in their investigations. It is OK if the students do not have a controlled experiment yet. On day 2 of this lesson, you will motivate

- Take temperature readings at the same time and for all tests (perhaps every 2-3 minutes).
- Be sure to run each test for the same duration (perhaps 12-15 minutes).

Direct students to find a new page in their science notebook and to title the page "Hot Water Test". Beneath the title, students should record what the class agreed should be kept constant. Use **slide C** to help your students set up their notebooks.

Discuss how to set up the data table. As a class, reach consensus on what the data table will look like (this may be similar to or different from the table on **slide C**, and either is OK). Make a quick sketch of the data table for the class, get verbal agreement from students that this table is satisfactory, and then ask students to draw the table into their notebooks. The data table will likely look like this:

Time (minutes)	Temperature (°C)
0 (starting temp)	
3	
6	
9	
12	
15	

Make predictions. Call students' attention to the *Testing Cup System Features* data chart on the wall. Point out the new column where they will add their hot water data. Ask students to make predictions about the outcomes for their hot water tests and how their findings might compare to the patterns observed from the cold water test. As students share their predictions, press them to justify their ideas. Say, *Do you think the best-performing cups will still outperform the worst performers after adding hot water? What patterns do you think we're going to see with the hot liquids? Why?*

Begin the *Hot Water Test*. Convene students into their previous lab groups. Display **slide D** with the investigation's instructions. Students should gather the appropriate materials from their lab bins to conduct the test at their tables.

While students work in their groups, conduct the same test with the two cups from lesson 1 (regular cup, which is a 16-oz single wall plastic cup with lid and the fancy cup, which is the 16-oz double-wall plastic cup).

SAFETY PRECAUTIONS

Go over safety precautions when working with hot liquids. Review why wearing safety goggles for the entire lab is required and how you expect students to obtain and handle the hot water throughout the lab. To ensure greater safety, you should pour the hot water into small cups for each group.

Students should record the temperatures every 2-3 minutes for up to 15 minutes (or at the intervals and time periods determined by the class). Students in the group can take turns taking temperature measurements, though they may want at least two of them in agreement each time they take a measurement. As students wait to record their measurements, they should make a sketch of their hot water cup system under their data table.✱

Stop investigation after 15 minutes. Remind students to clean up and return all materials. One group member should report their group's temperature change data on the class chart while the other members return to their seats.

the need for students to control their tests to get more reliable data on various cup features.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

As students collect data for the *Hot Water Test*, make explicit the connections between planning and carrying out investigations and all other practices. For example, today the students are carrying out an investigation to test their initial model ideas for cup systems containing hot water. They are gathering evidence to see if they need to revise their models based on whether cups that keep liquids cold can also keep liquids hot.

Sample Data

Cup	Cup material	Lid	Straw	Single or double wall?	Other change?	Temperature (°C) after 1 min	Temperature (°C) after 15 min	Temperature change
reg	plastic	yes	yes	single	no	69°C	59°C	-10°C
fancy	plastic	yes	yes	double	no	70°C	63°C	-7°C
1	metal	yes	no	double	no	70°C	68°C	-2°C
2	metal	no	no	single	no	69°C	57°C	-12°C
3	plastic	no	no	single	no	69°C	56°C	-13°C

3 · ANALYZE HOT WATER TEST DATA

15 min

MATERIALS: science notebook, Hot Water Test data chart

Analyze class *Hot Water Test* data. Display **slide E**. Ask students to work in their groups to look for patterns similar to what they did when they analyzed the cold water data. They should find a new page in their notebook opposite their *Hot Water Test* data and title the page, "Hot Water Data Analysis". Give groups 3-5 minutes to record what patterns they notice in the class data.

Facilitate an Initial Ideas Discussion about the hot water data. Ask students to discuss what patterns they noticed in the class data and what new questions arose after examining it. Spend about 5 minutes in this whole-group discussion.

KEY IDEAS

Purpose of this discussion: To identify patterns in cup features that keep the liquid inside the cup either cold or hot.

Listen for these ideas:

- The lid seems to help with both cold and hot liquids.
- The double wall seems to help keep liquids cold or hot.
- The double wall seems even more important than the lid.
- The metal double wall seems better than all the other cups.
- The thin plastic and metal seem not as good at keeping liquids cold or hot.
- We really can't tell if plastic or metal is better or worse than the other.

Suggested prompts	Sample student responses	Follow-up questions
What patterns did you notice about the cups' ability to keep water hot?	*Thick metal cups kept the water warmer than the thin metal cups.* *Cups with lids were able to keep water hot more than cups without lids.*	*What do you think can explain this observed pattern?*
Why do you think these cups performed better than the other cups?	*The heat was able to leave the thinner cup easier because we could feel it warming up. The thicker-walled cup kept the heat in better because we could feel it wasn't as hot.* *The lids kept the heat in the cups.*	

Suggested prompts	Sample student responses	Follow-up questions
How did this pattern compare to what we observed with the cups that kept water cold?	*The pattern was (mostly) similar.* *The cups that tended to keep drinks hot are also the cups that keep drinks cold.* *The water cooled off faster when there was no lid.* *The water changed temperature, but it was faster than with the cold water.*	*Why do you think these patterns were similar?* *Why do you think there were these differences?*
What cup features were important for keeping water cold and hot?	*Having a lid seems to be important. Cups with lids performed much better at keeping liquids hot than cups without lids.* *Cups with more walls seem to keep water warmer than cups with fewer walls.*	*How do you think these features can keep things both hot and cold?* *Were there particular cup features that were better at keeping water hot than keeping water cold?* *Were there particular cup features that were better at keeping water cold better than keeping water hot?* *Why do you think the lid was so important for keeping things hot (and cold)?*

Construct an individual explanation about the best and worst performers. Display **slide F**. With the remaining class time, direct students to their notebooks for individual work time. Below where students wrote their analysis, direct students to model, using words and diagrams, the best-performing and worst-performing cups (e.g., a double-wall metal or plastic cup with a lid compared to a single-wall metal or plastic cup with no lid). Students should explain how each cup system can keep liquids both hot and cold or cannot keep liquids hot and cold.

Allow students to take their notebooks home if they want to finish their models.

ASSESSMENT OPPORTUNITY	In these models, see how students' model ideas do and do not change with different starting temperatures of the liquid inside the cup. For example, if the cup begins with a hot liquid inside, do students use a different mechanism to explain how it cools down compared to the mechanism students use for how a cold drink warms up? It is not important for students' models to "look nice" or have details that are unrelated to the goal of explaining how the cup features work.

End of day 1

4 · SHARE MODELS AND UPDATE PROGRESS TRACKER

12 min

MATERIALS: science notebook, colored pencils

Share best-performing versus worst-performing cup models. Have students gather in groups of two or three. Display **slide G**. Give each group about 6 minutes to work together to share their models of the best and worst performers, which allows roughly 1 minute per group member to share and another couple minutes to think about similarities and differences. Students should consider the parts of the model that are supported by evidence and those that they are less certain about and need more evidence or information.

Update Progress Tracker. Transition students to individual reflection. Display **slide H**. Ask students to find the pages in their science notebook reserved for the Progress Tracker. They should have already recorded their thinking from Lesson 2. Prompt students to draw a line below what they wrote and drew for Lesson 2. Then ask students to record the Lesson 3 question "How are the cup features that keep things cold the same or different for keeping things hot?"

Give students 6 minutes to update their Progress Tracker with words and pictures that indicate what they have learned so far about the lesson question. As students work, circulate around the room to probe student thinking as needed.

5 · PLAN AN INVESTIGATION TO TEST THE LID

18 min

MATERIALS: science notebook, *Investigation Plan:* _______________

Investigate the lid as an important cup feature.✱ Problematize the need to systematically investigate how structural differences in the cup systems contribute to helping liquids stay hot and cold. It is likely that students will have already identified the lid and number of walls as important cup features. If it has not yet been mentioned, suggest investigating the lid's role first, but let students know that investigations of the walls and materials will happen as well.

Display **slide I**. Say, *Based on the hot and cold cup tests, we've identified certain cups with features that we think are important for keeping liquids hot or cold. For example, we saw how cups with lids were better able to keep liquids hot and cold than cups without lids.* Engage in a discussion about the existing evidence and students' ideas for investigating the lid's role in keeping liquids hot or cold and how it works.

Suggested prompts	Sample student responses
What evidence do we already have to support the importance of the lid in helping to keep liquids hot or cold?	*When we tested cups without lids compared to cups with lids, the hot water did not stay hot as long, and the cold water did not stay cold as long.*
What evidence could we collect to help us understand whether cups with lids are better able to keep things hot or cold?	*In cups without lids, the hot water would cool down faster than in cups with lids.* *In cups with hot water, the final water temperature would be cooler after a period of time in cups that had no lids compared to cups with lids.* *In cups without lids, the cold water would warm up faster than in cups with lids.* *In cups with cold water, the final water temperature would be warmer after a period of time in cups that had no lids compared to cups with lids.*
What are some things that we need to keep in mind when designing our investigations?	*We need to change only one part of the cup system at a time to see how that part affects the cup's ability to keep liquids hot or cold.* *We need to test the cup feature with both hot and cold liquids.*

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

The purpose of this activity is to engage students in planning the procedures to systematically investigate features of the cups, starting with the lid. Students have confirmed what they suspected about the lid: that it is important to maintaining the temperature of the liquid inside the cup. Now students define the strategies and/or methods that should be used for collecting observations or data to figure out how the lid helps maintain the temperature.

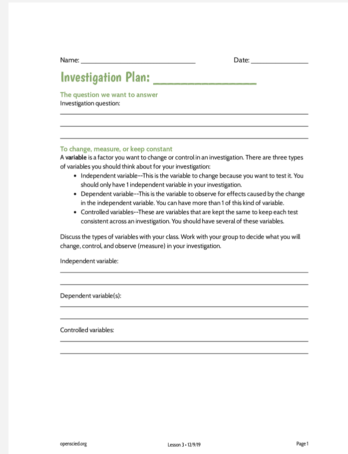
Emphasize the iterative nature of investigations and connections to other practices (e.g., how conducting some initial investigations and doing some initial analysis of data leads to new questions and new investigations). Lessons 2 and 3 provide opportunities for students to engage in investigations to test cups and to answer initial questions from the DQB. However, these investigations are loosely controlled and will generate a need for them to focus more systematically on cup features at a time that seem important.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Use this opportunity to reinforce students' development of asking close- versus open-ended questions. This is also an

Suggested prompts	Sample student responses
What are some things that we need to keep constant in our investigations?	*We need to use the same amount of water.* *The intervals for taking temperature readings have to be the same.* *We need to have the same starting temperature for all the hot water tests or all the cold water tests.* *The cups should be made of the same type of material.*

Plan an investigation about the lid's role. Pass out 1 copy of *Investigation Plan:______________* to each student.


Name: ______________ Date: ________

Investigation Plan: ______________

The question we want to answer

Investigation question:

To change, measure, or keep constant

A **variable** is a factor you want to change or control in an investigation. There are three types of variables you should think about for your investigation:

- Independent variable--This is the variable to change because you want to test it. You should only have 1 independent variable in your investigation.
- Dependent variable--This is the variable to observe for effects caused by the change in the independent variable. You can have more than 1 of this kind of variable.
- Controlled variables--These are variables that are kept the same to keep each test consistent across an investigation. You should have several of these variables.

Discuss the types of variables with your class. Work with your group to decide what you will change, control, and observe (measure) in your investigation.

Independent variable:

Dependent variable(s):

Controlled variables:

openscied.org Lesson 3 • 12/9/19 Page 1

Work on the investigation question together. Prompt students to fill in "lid" in the title of their handout since that is the variable we want to investigate. Then ask students to suggest the investigation question based on questions initially asked about the lid posted on the DQB. For example, the class may want to use the question, "Does the lid affect how quickly the drink warms up?" Point out that this question is close-ended because it can be answered with a yes or no. Encourage the class to turn it into an open-ended question such as, "How or how much does a lid affect what happens to the liquid in the cup?" If you want to push students even further, ask your students to turn the open-ended question into a testable question (e.g., "If we test cups with and without a lid, is there a temperature change difference?").✱

Develop vocabulary for variables. Say, *We've been talking about things we need to change in our investigation and things we need to keep the same. These are called variables. Variables are things about a system that we can change. Changing a variable can change the outcome of what happens in the system. Sometimes we want to intentionally change a variable in our system to test what happens when we change it. But when we do that, we also need to make sure the other variables in the system are kept constant.*✱

Ask students, *Why would it be important to keep track of what's changing and what we are keeping constant, or the same, in an investigation?*

Listen for student ideas like these:

- so we know what's really causing it to happen
- so we can compare to other groups
- so it's a fair test
- because we won't know if the thing we change matters if we change other things at the same time

ADDITIONAL GUIDANCE

The handout, *Investigation Plan:______________*, is a generic template that you can use to scaffold students' work as they plan and carry out investigations. This first use of the handout will focus on testing the role of the lid on temperature. In Lesson 4, students will carry out this investigation with the dependent variable of temperature; then they will change their dependent variable to mass and reflect on how this changes their procedures.

The move from Lesson 3 to Lesson 4 is important. In Lessons 2 and 3, students test various cup features they are interested in to satisfy their initial curiosities and to gather some initial data. Starting in Lesson 4, students will systematically investigate the same cup feature at the same time, following more systematic investigation plans and will learn how to pool their data.

opportunity for you to model for your students or coach students through the process of turning an open-ended question into a testable question.

✱ ATTENDING TO EQUITY

The term *variable* is similar across many European languages and some African languages. Asian languages use a few distinct terms for *variable*. Once you add the words "independent", "dependent", and "controlled" to the term *variable*, the meanings may be more difficult for students to decipher, particularly for emergent multilingual students. Keep in mind that these will be new terms for all your students, and that emergent multilingual students are likely building an understanding of these terms in multiple languages simultaneously. Developing this scientific vocabulary is critical, as the words are applicable to many of your students' science experiences going forward and will become relevant in their mathematics classes too. Students need to hear these words used in context often and to be given the opportunity to practice using them. Students may also need to spend time relating the new words to existing vocabulary (e.g., *independent variable* = changed, different; *dependent variable* = measured, output, outcome; *controlled variable* = same, identical).

Discuss the words i*ndependent variable*, *dependent variable*, and *controlled variables* in the context of the investigations in Lesson 2 and the first day of this lesson. Have students use the definitions on their handout to practice identifying these variables in those prior experiments. Do not add the new words to the word wall just yet. Wait until students have more understanding of what each word means so that it becomes a "word we earn" later in the unit.

Develop an investigation plan for the lid. Have students form small groups of three. Have students use the prompts on the handout to guide them through the planning process. Circulate among the groups as they work.

6 · AGREE UPON PROCEDURES FOR OUR INVESTIGATION

15 min

MATERIALS: science notebook, colored pencils, chart paper, markers

Facilitate whole-group agreement on the variables and procedures. After students have had time to brainstorm in small groups, reconvene the class to decide on the investigation procedures. Explain that we want to be able to compare our data and pool it together, so we will all need to follow the same procedures. Ask students to use a different colored pencil or ink to add notes to their handout about what is agreed upon by the class. This will be important for assessment.

Put up chart paper and write the investigation question on it to start a class poster. Direct students to the *To change, measure, or keep constant* section of their handout.

Prompt students to summarize the one thing we are changing between the cups that we think is going to affect the temperature. Students should say something like, "We are having a lid on one cup and no lid on another." Remind students that this is a variable that we are purposefully changing and that whenever we identify the variable that we are going to purposefully change, it is called the independent variable. Write the selected independent variable on the class poster.Ask students what effect we want to measure in both cup systems. Students should say that we want to measure the change in temperature. Remind students that whenever we identify the variable we want to measure the outcome of, it is called the dependent variable. Write the selected dependent variable on the class poster. You may want to indicate here that students will be starting the new investigation with hot water in the cups since the lid was an even more important factor with hot water in the previous investigation.

Follow up by asking all groups for ideas about how to measure the temperature of the liquid inside the cup with the lid on it, without taking off the lid. Students will suggest sticking the thermometer through the straw hole. Confirm that this is a good idea and then suggest that after they take the initial temperature measurement, they should remove the thermometer from the cup until they are ready to take another measurement. Say, *Let's make sure to add that to our procedures when we get there*.

ADDITIONAL GUIDANCE	Keep the class-generated procedures in public view for students to see. This set of procedures will be used again on day 1 of Lesson 4 as students carry out the lab investigating the lid's effect on temperature change. The class will then modify these procedures by changing the dependent variable from temperature change to mass change.

Review variables to keep constant. Present **slide J.** Use this prompt to have students think more carefully about all the things they need to control in their investigation.

Suggested prompts	Sample student responses
Besides using the same amount of water, what else did we want to keep constant in an investigation comparing a cup with no lid to a cup with a lid?	*amount of water in the cup, starting temperature of water, type of material the cup is made of, number of walls in the cup, how long we are going to test the cups*

Write the selected controlled variables on the class poster. Prompt students to add to their controlled variables list in their notebook if they missed any of the class agreed-upon variables.

Generate a class set of procedures. Direct students to the *Procedures* part of the handout. Ask one group to share their first step in the investigation and then see if other groups have a similar step. As groups share each step, make sure the class agrees the step makes sense and that nothing important is being skipped over. Students can decide to measure temperature for 10 minutes or 15 minutes. Adjust your data charts accordingly.

As the class agrees on steps, remind students to either (1) use a different color to make corrections to their original procedures, or (2) if their original procedures are very different from the class procedures, to simply write the class procedures in the right-hand column next to their original procedures. Record the agreed-upon procedures on the class poster as they are determined.

Have students attach their investigation plan to their science notebook.

Once finished, say, *Looks like we have a plan of how we want to test the lid. Let's try this test tomorrow and see what we find out.*

ASSESSMENT OPPORTUNITY	Have students leave their notebooks in the classroom. Students will have written their original investigation plans in one color and their corrections and additions in a different color. Use the two colors to compare how similar or different students' original plans were to the class agreed-upon plans. If the class' investigation procedures were very different from the student's original set, they wrote the class set alongside their original procedures. Look for these features in their original drafts: • lid identified as independent variable • temperature identified as dependent variable • at least 3 controlled variables identified, including amount of water, number of walls, and material of the cup--may also identify starting temperature of water • a carefully planned investigation showing specific steps that may or may not match the class agreed-upon plan

Additional Lesson 3 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.** Students are working toward this standard. Students work collaboratively to generate investigation plans, planning how to carry out an experiment and take measurements. They work on these plans in small groups and revise the plans based on class consensus.

LESSON 4: How does a lid affect what happens to the liquid in the cup?

PREVIOUS LESSON *We figured out that cups that were able to keep liquids cold were also able to keep liquids hot. We found that several features, such as the lid, were important for maintaining the temperature of the liquid inside. We revised our explanations and asked more questions about how the cup features worked. We identified the lid as a feature to investigate next.*

THIS LESSON

INVESTIGATION

3 days

We plan and carry out two investigations to determine (1) the effect of a lid on how much the temperature of a hot liquid in a cup will drop and (2) the effect of a lid on changes in the mass of a hot liquid in the system. We apply concepts of probability to calculate the mathematical mean for two different cup systems to compare the temperature drop and mass change in each condition. We develop and use a particulate model of liquids and gases to explain the mass loss in an open system.

NEXT LESSON *We are still wondering about how and why water droplets form on the outside of a cup of cold water. We will investigate our ideas about where this water comes from and use mass measurements and observational data as evidence to construct an explanation.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Plan and carry out investigations to determine the effect of a lid on temperature change and mass change in systems that are more open and less open.

Analyze and interpret data by applying concepts of probability to calculate the mathematical mean to compare the temperature change and mass change across conditions (patterns) and use these measures to make claims about the effect of the lid.

Develop a model to describe why mass is lost in some conditions but not others (open systems versus less-open systems), using a particle model of matter for liquids and gases.

WHAT STUDENTS WILL FIGURE OUT

- A cup with a lid helps to maintain the temperature of a hot liquid inside it longer than a cup without a lid.
- The lid also slows down matter loss from the system.
- Matter has mass and takes up space. Liquids and gases are made of particles of matter. Particles in a gas have a lot of space between them but those in liquids do not.
- The smallest particle of water is a molecule, and it is much smaller than we can see. Molecules of water in liquid form go into gas form over time (evaporation).
- An open system has enough space between the solid parts of the system for particles of matter to get in or out. A closed system is one in which no matter can enter or exit.
- The hot liquid still cools down even when we prevent most matter from leaving the cup system by using a lid.

Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**SET UP NOTEBOOKS FOR CUP LID LAB 1** Set up science notebooks to make predictive models during the investigation, set up a class data table to pool results across groups, and review lab safety and cleanup procedures.	A-B	*Investigation Plan:*_______________, class data table for temperature change
2	13 min	**CARRY OUT CUP LID LAB 1** Monitor students as they carry out their procedures and collect their data for how a lid versus no lid affects the temperature change of a hot liquid in a cup. As they wait for their final temperature measurement, students complete their predictive models.	B	Cup Lid Lab 1
3	10 min	**POOL AND ANALYZE THE CLASS DATA** Pool the groups' data and (re)introduce how to calculate the mean of a data set. Have students calculate the average temperature change in the cups with lids versus no lids and make claims based on their calculations.	C-D	calculator, class data table for temperature change, calculating mean anchor chart, markers
4	12 min	**DISCUSS NEXT STEPS, MODIFY PROCEDURES, AND MAKE PREDICTIONS** Facilitate a discussion about whether any matter may be getting into or out of the cup systems we previously tested. As a class, modify the procedures from *Cup Lid Lab 1* to test for whether the mass of the systems will change.	E-F	note cards, tape, class poster of variables and procedures made for Cup Lid Lab 1, 1 16-oz single-wall plastic cup, 1 digital scale (accurate to +/- 0.1 g)
				End of day 1
5	5 min	**MAKE PREDICTIONS AND REVIEW SAFETY FOR CUP LID LAB 2** Have students make predictions about whether the mass of the two cup systems would change over time and why.	G	*Procedure: Measuring Changes in Mass in the Cups*, calculator, class data table for mass change
6	10 min	**CARRY OUT CUP LID LAB 2** Monitor students as they carry out the lab and collect their data for mass change in two cup systems with hot liquid in them.		calculator, Cup Lid Lab 2
7	8 min	**POOL AND ANALYZE THE CLASS DATA AND MAKE CLAIMS** Pool all the groups' data and calculate means for each condition (lid versus no lid) to make claims based on the calculations.	H	calculator, calculating mean anchor chart, class data table for mass change, markers
8	7 min	**MAKE SENSE OF MASS LOSS DATA** Facilitate a Building Understandings Discussion focused on making sense of matter leaving the cup system as a way of explaining the mass loss.	H	whiteboard or chart paper, markers
9	10 min	**DEVELOP MODELS AND SHARE PREDICTIONS** Have students develop a model to explain why the cup system without a lid lost mass over time. Then have students predict what would happen if an open cup were left outside for a longer time.	I	*Initial Model of Mass Loss in the Cup with No Lid*, 1 16-oz single-wall plastic cup of water with no lid
				End of day 2

Part	Duration	Summary	Slide	Materials
10	8 min	**COMPARE THE AMOUNT OF WATER IN THE CUPS OVER TIME** Share two videos (one is time-lapse and one is slow-motion) of evaporation with students for analysis. Facilitate a Building Understandings Discussion about mass loss due to water entering the air.	J	*Initial Model of Mass Loss in the Cup with No Lid*, slow-motion evaporation video, time-lapse evaporation video
11	15 min	**MODEL DROPPING WATER LEVELS AND MASS CHANGE OVER TIME** Help students work in partners to use manipulatives (e.g., chips) to model evaporation in open systems (i.e., cups with no lids) and less open systems (i.e., cups with lids).	K	*Manipulative Mat for a Model of Matter at the Surface of the Liquid*, bag of 19 blue chips, bag of 4 yellow chips, chart paper, markers, 15 blue circular magnets, 4 yellow circular magnets, whiteboard
12	12 min	**UPDATE THE CLASS PROGRESS TRACKER** Facilitate a Consensus Discussion to develop a class Progress Tracker that students add to their science notebook.	L	*Progress Tracker* or *Progress Tracker 2*, chart paper, markers
13	10 min	**USING OUR MODEL IDEAS TO EXPLAIN AND PREDICT** Monitor students as they work individually to construct an explanation for the lidded versus unlidded cup results on *Explanations and Predictions of Lids and Covers*.	M	*Explanations and Predictions of Lids and Covers*, chart paper, markers

End of day 3

Lesson 4 • Materials List

	per student	per group	per class
Cup Lid Lab 1 materials	• 1 safety goggles	• 2 note cards • tape • marker • 500-mL graduated cylinder or beaker • 2 16-oz single-wall plastic cups • 1 clear plastic lid • 2 thermometers • timer	• Hot water (49-55°C) • enough for 800 mL (400 mL in each cup) per group of students • class data table for temperature change
Cup Lid Lab 2 materials	• 1 safety goggles	• 2 note cards • tape • marker • 500-mL graduated cylinder or beaker • 2 16-oz single-wall plastic cups • 1 clear plastic lid • 1 digital scale (accurate to +/- 0.1 g)	• Hot water (49-55°C) • enough for 800 mL (400 mL in each cup) per group of students • class data table for mass change
Lesson materials	• science notebook • *Investigation Plan:_______________* • calculator • *Procedure: Measuring Changes in Mass in the Cups* • *Initial Model of Mass Loss in the Cup with No Lid* • *Progress Tracker* or *Progress Tracker 2* • *Explanations and Predictions of Lids and Covers*	• calculator • *Manipulative Mat for a Model of Matter at the Surface of the Liquid* • bag of 19 blue chips • bag of 4 yellow chips	• class data table for temperature change • calculating mean anchor chart • markers • note cards • tape • class poster of variables and procedures made for Cup Lid Lab 1 • 1 16-oz single-wall plastic cup • 1 digital scale (accurate to +/- 0.1 g) • class data table for mass change • whiteboard or chart paper • 1 16-oz single-wall plastic cup of water with no lid • slow-motion evaporation video • time-lapse evaporation video • chart paper • 15 blue circular magnets • 4 yellow circular magnets • whiteboard

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Students need access to the handout *Investigation Plan:_______________* from Lesson 3 containing their agreed-upon procedures for investigating the lid as an independent variable.

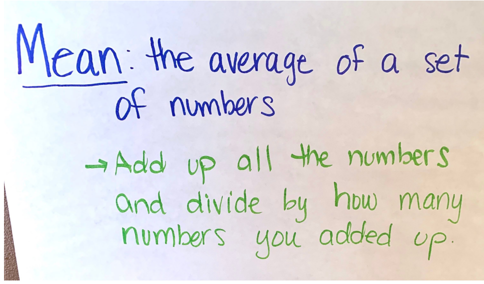
You only need to make 1 copy of *Manipulative Mat for a Model of Matter at the Surface of the Liquid* per 2 students.

For every 2 students in your largest class, make a bag of 19 blue chips and a separate bag of 4 yellow chips. You will reuse these across all your classes. If chips are unavailable, substitute another round object, such as paper dots, beads, or coins. You will need two different kinds (e.g., pennies and nickels, blue and yellow beads).

Make a class data table on chart paper (see image below) for pooling data across groups for both temperature change and mass change. This chart can be reused from class to class if you have students post their data on it with note cards and tape.

Test these videos of evaporation ahead of time (one is time-lapse and one is slow-motion):
- https://youtu.be/Q4P6N0ZrF2o
- https://youtu.be/npkBC4GYodg

Make an anchor chart describing how to calculate a mean. Students will refer to this chart in your classroom from this lesson forward.



Calculating a mean of a data set is a target idea in 6th-grade CCMS. Talk to your grade's math teacher to find out when students will learn how to calculate the mean of a numerical data set in math class this year. If they have worked on this already, ask the math teacher for an example data set they worked with and any suggested modification to your anchor chart for calculating a mean. If students haven't yet worked through any examples in their math classes, then the pooled temperature data in this lesson will be an example you save to refer to in future lessons in concert with this anchor chart. Also ask the math teacher if students have worked with using negative numbers to represent quantities in the real world. This will inform your decision about how to represent temperature changes in the pooled class data table.

Day 1: ***Cup Lid Lab 1***
- **Group size:** 3
- **Setup**: Heat water in electric kettles to 49-55°C, enough water so that every group of students gets 800 mL (400 mL in each of their 2 cups). For every group of students, prepare a bin containing these lab materials: 500-mL graduated cylinder or beaker, 2 16-oz single-wall plastic cups, 1 clear plastic lid, 2 thermometers
- **Safety:** Make sure your water is not above 55°C. Most adults will suffer third-degree burns if exposed to 65°C water for two seconds. Burns will occur with a six-second exposure to 60°C water or a thirty-second exposure to 55°C. Students should wear safety goggles throughout this lab.

Day 2: ***Cup Lid Lab 2***
- **Group size**: 3
- **Setup**: Heat water in electric kettles to 49-55°C, enough water so that every group of students gets 800 mL (400 mL in each of their 2 cups). For every group of students, prepare a bin containing these lab materials: 500-mL graduated cylinder or beaker, 2 16-oz single-wall plastic cups, 1 clear plastic lid, 1 digital scale (accurate to +/- 0.1 g).
- **Safety:** Make sure your water is not above 55°C. Most adults will suffer third-degree burns if exposed to 65°C water for two seconds. Burns will occur with a six-second exposure to 60°C water or a thirty-second exposure to 55°C. Students should wear safety goggles throughout this lab.

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

In NGSS in 5th grade, students develop a particulate model of matter to account for things that air can do, and they measure and graph the amount of weight of systems as evidence for the amount of matter being conserved in different types of changes (phase changes, dissolving, and mixing that forms new substances). It is implicit in this work that students might also develop a particulate model of matter to explain why the amount of matter doesn't change when something melts, freezes, or dissolves. In such a model, they also need to work with the idea that solids and liquids are made of particles of matter too small to see, which can break apart and move around and pass through the space between them.

This lesson builds from these ideas about the particulate model to account for mass changes in the cups as water evaporates into the air and then escapes the cup system. It also uses these ideas to account for why there is no mass change in the airtight container.

In the lesson, students re-establish that matter has mass. They also work with the idea that liquids and gases are made of particles of matter and that particles in a gas have a lot of space between them but particles in a liquid do not. They show that particles of liquid water go into the air over time (evaporation), which results in loss of mass from the system when that gas can escape the container. The word *molecule* is introduced as a way to refer to the smallest particle of certain substances, such as water.

Where We Are NOT Going

In this lesson, students do not develop the idea that particles in a gas are always moving; they only develop the idea that the evaporated water particles must have moved from the liquid into the air and out of the cup. They also do not develop the idea that particles in a liquid or solid are always moving. These ideas will be developed in later lessons and will be key pieces of the puzzle in explaining the unit's anchoring phenomenon through both matter and energy perspectives.

In Lesson 6 students learn that solids are made of particles too. That idea is not introduced in this lesson.

Different types of materials (e.g., water versus other gases in the air) are represented with different colors to distinguish the type of particles. No attempt is made in this unit to refer to the different types of gases in the air. This idea will be developed in OpenSciEd unit 6.3, and then reused in multiple units in 7th grade.

This unit does not make the distinction that molecules are made of smaller particles (e.g., atoms), as this idea is not needed to explain any of the phenomena in this unit. This idea will be developed in OpenSciEd unit 7.1, as students will develop a need to explain what is happening in chemical reactions.

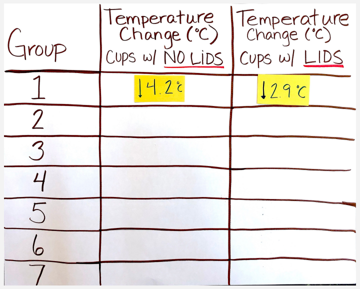
LEARNING PLAN for LESSON 4

1 · SET UP NOTEBOOKS FOR CUP LID LAB 1

10 min

MATERIALS: science notebook, *Investigation Plan:_______________*, class data table for temperature change

Build a class data table ahead of time. Before class starts, make a class data table on chart paper like the one shown here, with one row for each group. The cells should be large enough to fit a note card (attached with tape). You will reuse this chart across all classes.



Establish how and where to record the data. Display **slide A**. Have all students turn to a new page of their science notebook, title it, and draw a data table to record their temperature measurements for today's first investigation. Note that the data table only needs to record temperature change.

Tell students that at the end of the lab you will ask each group to send one person to share their group's calculations of the temperature change in both cup systems. Demonstrate how this person will report the two results by writing each one on a note card and posting them on the class data table. Emphasize the need to write the values in marker big enough for all of us to see from our seats.

ALTERNATE ACTIVITY

Decide if you want students to write the temperature change as a negative number if it drops and a positive number if it goes up. If you do, explain this now and show examples of both.

This decision should be informed by what your math teacher said about your students' status in regard to working with negative numbers.

If students have not yet worked with negative numbers, you could have them indicate whether the temperature change was an increase or a decrease by using an arrow (pointing either up or down) as shown in the image above. If you do this, then when it is time to calculate an average temperature change you will need to explain what the arrows mean in terms of summing all the values. At that point, explain that an up-arrow means we need to add this number to our sum and a down-arrow means we need to subtract this number from our sum.

Orient students to their planned procedure. Direct students to their investigation plans from Lesson 3 where they generated a class agreed-upon procedure for the lab, on the handout *Investigation Plan:_______________*. Review these procedures as needed. Tell students you want them to put a check mark next to each step as it is completed.✱

Prepare students to create predictive models. Say, *We are going to draw predictive models in our notebooks during the lab as you wait for 10 minutes between taking your initial temperatures and your final temperatures.* Display **slide B**. Have students add a place to model the two cup systems below the data table in their notebook. Students should not draw the systems until they have recorded their initial temperature measurements and are waiting to take their final temperature measurements. Emphasize that these will be predictive models, so students should show what is the same and different between the systems, as well as what they predict the final outcome will be in both cups and why.

✱ ATTENDING TO EQUITY

Encouraging students to keep a record in their procedure by checkmarking each step they complete can help them develop a transferable approach to tracking their progress on any technical task in multistep procedure form. This can be particularly helpful for emergent multilingual students. You may want to emphasize that (1) following the steps carefully is more important than getting to the end of the procedure and (2) you want students to practice following a procedure and trust that as a whole class, we will be able to generate the data needed to analyze our results even if their group doesn't get to the last step. Reuse this approach in future labs when students have a multistep procedure to follow.

SAFETY PRECAUTIONS

Go over safety precautions for working with hot liquids. Review (1) why wearing safety goggles for the entire lab is required and (2) how you expect students to obtain and handle the hot water throughout the lab.

Review behavior expectations and norms for working in small groups and any additional logistics for how to get materials, return and/or recycle materials, and clean up. Answer any remaining questions students have.

2 · CARRY OUT CUP LID LAB 1

13 min

MATERIALS: Cup Lid Lab 1, science notebook

Monitor lab procedures and model creation. Check on student progress in setting up the two conditions and starting the experiment. The designated students in each group should pour hot water into their 2 cups, put a lid on 1 cup, insert the thermometers, read and record the initial temperatures, and set the timer for 10 minutes.

When groups have done this, redirect all students to **slide B** to remind them that they should now be working on their predictive models. Remind them to draw what they think is happening with and without the lid specifically. Say, *What is the lid doing and why? And what's happening in the cup system when the lid's not there?*

If you have a separate area for lab, students can return to their desks (and remove their goggles) to complete their predictive models before returning to the lab area 3-4 minutes before the lab time is over to get their final results. Students should take the final temperature reading after 10 minutes or at the class agreed-upon time in their procedures.

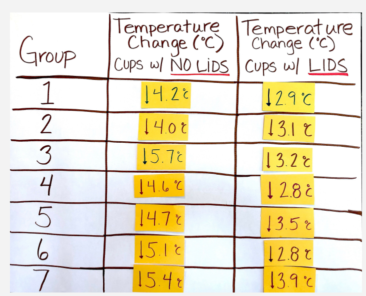
In the last 2 minutes of this block of time, cue students to calculate their temperature change for both cups and to post their temperature change data to the class data table.

3 · POOL AND ANALYZE THE CLASS DATA

10 min

MATERIALS: calculator, science notebook, class data table for temperature change, calculating mean anchor chart, markers

Review the pooled class data. Direct students to look for interesting patterns in the whole-class data set for a minute on their own.



Group	Temperature Change (°C) Cups w/ NO LIDS	Temperature Change (°C) Cups w/ LIDS
1	↓4.2°C	↓2.9°C
2	↓4.0°C	↓3.1°C
3	↓5.7°C	↓3.2°C
4	↓4.6°C	↓2.8°C
5	↓4.7°C	↓3.5°C
6	↓5.1°C	↓2.8°C
7	↓5.4°C	↓3.9°C

Connect to prior experiences with averages or mathematical means. Show **slide C**. Read the first bubble and say, *After you discuss this with a elbow partner, decide if your answer is yes or no, and then talk about the question that applies in the in the bubbles below.* Listen to students' discussions to determine their answer to the first question.

Bring students together to discuss their answers to the slide's questions as a class.

If the answer to the first question is yes, the discussion will progress as follows:

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

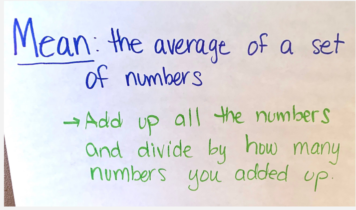
The focus of this work is to ask students to apply the concept of a mean to analyze and characterize data. Ask students to think about why looking at the average temperature change of the pooled data could be more useful compared to looking at a single data point, as they did in Lesson 3.

Suggested prompt	Sample student response
Why might it be easier to compare the average temperature change from the systems with lids to the average from systems without lids, rather than try to compare all of the data at once?	*It would be easier to compare just two numbers.*
If we calculate an average or a mean, what does it tell us?	*Where the center of the data tends to be.*
How do you calculate an average in a set of data?	*You add up all the values and divide by the number of values you have.*

If the answer to the first question is no, the discussion will need to be framed as follows:

Suggested prompts	Sample student responses	Follow-up questions
How have you heard the word average used outside of math class? How might you use it in a sentence to describe something?	*If something is average, then it isn't the best or the most. If something is above average, then it's better than most.* *An average day is just a day that is like almost every other, nothing out of the ordinary.* *It means like normal or common.*	*Outside of math or science, we use the word average to describe something that isn't out of the ordinary. That is one of its meanings when we use it in math and science too. But we can also calculate a numerical value called the average of a data set from a set of numbers like those we have for the temperature changes in the cups with lids. Another word for that kind of average is a mean.*

Introduce how to calculate an average. Whether or not students have worked with means in math class yet, you should now introduce the anchor chart for calculating a mean.



Ask a student volunteer to read through what the chart says. Explain that students will need to use calculators to figure out the means for their two data sets. Have students take out their calculators.

Calculate average temperature changes for both conditions. Work together to calculate the sum of the values for the temperature changes from the cups with lids first. Then ask students to count off how many values there are and tell them to divide the sum by that number. Have a student report out the mean while you write the number under the class data table's first column ("Cups with lids") and label it "Average temperature decrease for cups with lids".✱

Explain that we can do the same calculation for the temperature change values from the cups without lids. Ask students to work with a elbow partner to do this. Have a student report out the result while you write this number under the data table's second column ("Cups with no lids") and label it "Average temperature decrease for cups with no lids".

Consider claims supported by the data. Say, *These average temperature changes represent what we think would be typical if we ran even more trials under the same conditions. Let's use these average temperature changes to make some claims.* Present **slide D**. Have students read the claims silently and pick one they think the data supports. After a minute ask for volunteers to share which claim they picked and why.

4 · DISCUSS NEXT STEPS, MODIFY PROCEDURES, AND MAKE PREDICTIONS

12 min

MATERIALS: note cards, tape, class poster of variables and procedures made for Cup Lid Lab 1, 1 16-oz single-wall plastic cup, 1 digital scale (accurate to +/- 0.1 g)

Motivate questions around changes to the mass of the system. Say, *Our lesson question is about how a lid affects the liquid in a cup. We've seen that it affects the temperature of the liquid in the cup, but is that the only thing it affects about the liquid?* Present **slide E**. Have students read the questions and discuss them with a elbow partner for 2 minutes.

Bring students back together and encourage them to share their ideas.

Suggested prompt	Sample student response
Do you think anything was getting into or out of either of the two systems we tested today?	*Steam could be getting out of the cup with no lid.* *Water is evaporating out of the cup with no lid.* *Water is getting out of the lid through the opening where the straw goes.* *It seems like a lid with the straw hole taped up should keep anything from getting in or out.*
How could weighing each of these systems at the start and end of an experiment like today's first lab help us figure that out?	*If water is leaving the cup, then the weight should go down.* *If nothing is getting in or out of the cup, then its weight shouldn't change.*

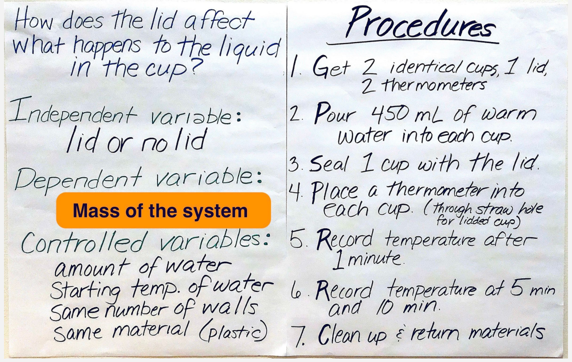
Say, *It sounds like if we retried what we did today, but also weighed the systems before and after the investigation, it would help us find out if any matter is leaving or entering the systems. Let's do a brief demonstration of how to use a digital scale to measure the mass of the system. Then you can use what you know to make a new investigation procedure we'll follow tomorrow.*

ADDITIONAL GUIDANCE

You will introduce the idea that the scale can detect and calculate the amount of mass in an object based on how much matter is on resting on the scale. You are not introducing any distinction between mass versus weight in this unit. That discussion will be introduced in OpenSciEd unit 6.3.

Demonstrate how to use a digital scale. Gather students around the front table. Show them how to turn on and tare (zero) the scale. Place a cup on it to demonstrate how to weigh an object. Emphasize that the scale is a delicate device and has a limited range of what it can weigh, so they should only put the cups with water in them on the scale and not heavier objects. Explain that the scale uses the weight it detects to calculate the mass of all the matter in the system and reports that amount in grams. Show how to change the scale so that it reports grams.

Ask students what should happen to the system's mass measurement if the system loses or gains liquid during the minutes we are waiting before measuring it again. Listen for students to say that the mass will go down or go up.



✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

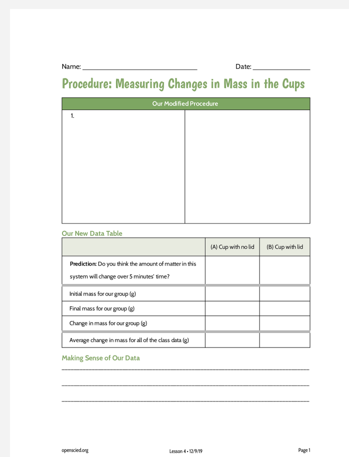
The purpose of this activity is to again engage students in planning the procedure to systematically investigate features of the cups, again starting with the lid. Students use the procedure they previously developed for testing the lid's effect on temperature change as mentor text to modify parts of the investigation plan so that it is now targeted at determining how the lid affects changes in mass.

Identify the variable that will change. Direct students' attention to their procedures from the previous lab and look through those to determine which variables will be different in this new experiment (the independent variable, the dependent variable, or any of the control variables). Students should say the dependent variable will be different this time--we will measure the mass of the system instead of the temperature. On the class poster outlining the variables and procedures for *Cup Lid Lab 1*, indicate this change by covering the dependent variable of "temperature" with a strip of colored paper that has "mass of the system" written on it.

Discuss why other variables wouldn't change. Review the interrelationship of independent, dependent, and control variables.

Suggested prompt	Sample student response
Why would we want to keep the same independent variable as before in this new experiment?	*We still want to see what the effect of lid versus no lid is.*
We have a new dependent variable, which is the mass of the system. How could investigating the relationship between these two things help us answer our original question "How does a lid affect what happens to the liquid in the cup?"	*It will help us find out if having a lid or not affects the amount of liquid in the cup.*
Why would it be important to keep track of what we are changing and what we are keeping constant, or the same, in an investigation?	*So we can compare our results to other groups' results.* *So it's a fair test.* *Because we won't know if the thing we change matters if we change other things at the same time.*

Modify the procedure. Point out that much of the procedure your students developed for looking at temperature changes in the two cup systems over time might be reusable to look at mass changes in those cup systems over time. But add that they will probably need to modify a couple of steps, and after they decide on those steps they will need to make a new data table to record their new measurements and calculations.



Name: ______________ Date: ______________

Procedure: Measuring Changes in Mass in the Cups

Our Modified Procedure	
1.	

Our New Data Table

	(A) Cup with no lid	(B) Cup with lid
Prediction: Do you think the amount of matter in this system will change over 5 minutes' time?		
Initial mass for our group (g)		
Final mass for our group (g)		
Change in mass for our group (g)		
Average change in mass for all of the class data (g)		

Making Sense of Our Data

openscied.org Lesson 4 • 12/9/19 Page 1

Pass out a copy of *Procedure: Measuring Changes in Mass in the Cups* to each student. Show **slide F**. Tell students to work in their previous groups to decide which steps of the old procedure should be modified for this new investigation and which ones should remain the same. Then have students write their group's whole series of procedure steps for the new experiment on this handout.✱

As groups are working, you can remove the note cards from the pooled class data table to get it ready for the next class.

Have each group bundle the group members' handouts together with a paperclip and turn them in so you can see each student's copy of the new procedure. You can look through these sets to provide feedback on the investigation plans before starting the lab on day 2.

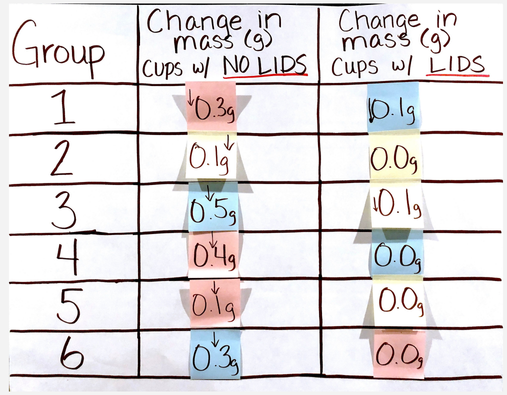
End of day 1

5 · MAKE PREDICTIONS AND REVIEW SAFETY FOR CUP LID LAB 2

5 min

MATERIALS: science notebook, *Procedure: Measuring Changes in Mass in the Cups*, calculator, class data table for mass change

Build a class data table ahead of time. Before class starts, make a new class data table on chart paper for the results of the mass investigation with both conditions, lid and no lid. Include enough rows for all the groups, and you can reuse the chart across your classes if students post results using note cards attached with tape.



Pass back the students' copies of *Procedure: Measuring Changes in Mass in the Cups* with feedback on them. Show **slide G**. Have students record their predictions on the handout, attach it to their science notebook, and share predictions with a elbow partner.

Review how and where to record the data. Tell groups to assign a different person than last time to be responsible for recording their group's mass change calculations on note cards and posting them on the class data table. Point out that there is a row in the handout's data table for students to record the averages that we will calculate once we have everyone's data.

Tell students that we will have around 10 minutes total for the lab, which might only give them 5-7 minutes between the time they record their initial mass measurement and the time you will signal them to record their final mass measurement (2 minutes before the end of the lab). Remind students to take their calculators with them. Answer any remaining questions students have.

SAFETY PRECAUTIONS

Have students summarize the behavior expectations and norms for working in small groups that they used the last time. Have students restate the safety precautions for working with hot liquids and why wearing safety goggles for the entire lab is required.

6 · CARRY OUT CUP LID LAB 2

10 min

MATERIALS: Cup Lid Lab 2, science notebook, calculator

Monitor lab procedures. Check on students' progress in setting up their two system conditions and recording their initial mass measurements. Groups may only have about 5 minutes between when they are done recording their initial measurement and when you give the signal for recording the final measurement approximately 2 minutes before this block of time is up.

Remind students to record their mass changes on note cards and post them in their group's row on the class data table.

ADDITIONAL GUIDANCE

Five minutes will be enough for students to see approximately 0.5 g of mass loss in the cup with no lid. In that same amount of time, some groups may start to detect a 0.1-g mass loss in the cup with the lid (due to gaps in the straw hole and where the lid meets the sides of the cup). Many groups will detect no mass loss in the cups with lids in that period of time, and that is fine too.

7 · POOL AND ANALYZE THE CLASS DATA AND MAKE CLAIMS

8 min

MATERIALS: calculator, science notebook, calculating mean anchor chart, class data table for mass change, markers

Calculate averages and make claims. Remind any groups who have not yet posted their results to do so. Show **slide H**. Instruct students in their small groups to work together to calculate the average mass change for each condition. Each student could calculate the average for the condition they collected data for and then share with the group, so everyone can record it in the fourth row of their data table.

Students should also discuss the questions on **slide H** with their small group and record their answers in the *Making Sense* section of their handout in their notebook.

8 · MAKE SENSE OF MASS LOSS DATA

7 min

MATERIALS: science notebook, whiteboard or chart paper, markers

Lead a Building Understandings Discussion about the mass data. Focus students on trying to understand and explain the pooled mass change data.

KEY IDEAS

Purpose of this discussion: Establish which system(s) lost the most matter, where that matter came from, and where it went to.

Listen for these ideas:

- At least one type of system (*A*) and possibly also the other (*B*) lost matter.
- We know this because matter has mass and the mass went down.
- The matter loss was probably because some water left the system.
- The water must have gone into the air.
- If mass went down in the cup with a lid, then some of the water that went into the air inside that cup might have gotten out the straw hole or out the edge of the cup where it meets the lid, because it might not be airtight or leak-proof.

Suggested prompt	Sample student response
Which of the type of systems lost the most matter--A or B? Why?	*A, because there was no lid to stop the matter from getting out of the cup.*
Where did the matter that was lost come from to start with?	*Probably from the water.* *It was evaporating.* *I could see it steaming.*
Where does that matter go?	*Into the air.* *Out of the cup.*
Do you think little pieces of matter, like those that make up gases, can get out of system B? Where would it be able to get out?	*Yes, through the opening for the straw.* *Maybe where the edge of the lid meets the cup walls.*

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

Students will use the idea that matter in physical processes, where the particles in the system might be rearranged, but do not disappear. We will use this idea throughout the rest of the unist in OpenSciEd. This is the point at which we introduce the idea that particles of matter have mass and that if some leave or enter a system (an open system) then the mass would change, but if they don't because the system is closed, the mass should not change.

Say, *So we see that these systems were not completely closed. There were openings in both cups where matter could get out. In* A *it was the top of the whole cup, in* B *it was the straw hole and at the edges of the lid. When matter can get in and out through openings in a system, scientists call that system an* ***open system****, even if those openings are really small. When no matter can get into or out of a system, scientists refer to that system as a* ***closed system****.*

Write these phrases on the board or chart paper:

- Open system--Matter can get in and out of it through openings in the system.
- Closed system--No matter can get in or out of the system.✱

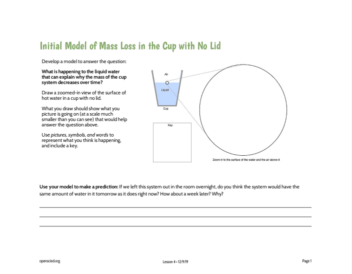
Say, *I heard some of you saying the water was evaporating or going into the air. But what does that mean? What is going on with the matter in the system when something like that is happening? What do you picture is going on at the surface of the water, where it meets the air above it, that would explain this? I want you to try to represent what you picture is going on.*

9 · DEVELOP MODELS AND SHARE PREDICTIONS

10 min

MATERIALS: science notebook, *Initial Model of Mass Loss in the Cup with No Lid*, 1 16-oz single-wall plastic cup of water with no lid

Develop Individual Models. Show **Slide I.** Pass out a copy of the handout *Initial Model of Mass Loss in the Cup with No Lid* to each student. Read the directions together. Point out that below the space to develop their model, there is a prediction question that you want them to answer too.



Initial Model of Mass Loss in the Cup with No Lid

Develop a model to answer the question:

What is happening to the liquid water that can explain why the mass of the cup system decreases over time?

Draw a zoomed-in view of the surface of hot water in a cup with no lid.

What you draw should show what you picture is going on (at a scale much smaller than you can see) that would help answer the question above.

Use *pictures, symbols, and words* to represent what you think is happening, and include a key.

Use your model to make a prediction: If we left this system out in the room overnight, do you think the system would have the same amount of water in it tomorrow as it does right now? How about a week later? Why?

opensciedorg Lesson 4 • 12/9/19 Page 1

Allow about 5 minutes for students to individually work on this.

With about 3 minutes remaining, pause students and hold up a cup of water from system *A* (no lid). Ask students to share out their responses to the prediction question on their handout. Accept all responses.

Say, *I have a time-lapse video of a container of water with no lid that was left out in conditions like our room, which we can analyze next time to see if our predictions are correct.*

Collect the completed handout as an exit ticket.

Take the note cards off the class data table to use the table with the next class.

ASSESSMENT OPPORTUNITY

In these models, you will be able to see if students apply particulate models of matter to explain this process. In NGSS, in 5th grade students should have developed a particulate model of matter for liquids and gases and used it to explain phenomena such as the gradual disappearance of liquid water in an open system (evaporation). This modeling exercise will serve as useful pre-assessment for you to see student fluency in using this idea to explain this phenomenon of mass change.

End of day 2

10 · COMPARE THE AMOUNT OF WATER IN THE CUPS OVER TIME

8 min

MATERIALS: science notebook, *Initial Model of Mass Loss in the Cup with No Lid*, slow-motion evaporation video, time-lapse evaporation video

Review predictions from last time. Show **slide J**. Read the text to remind students what we were making predictions about last time. Have students turn and talk about the question on the slide as you pass back their initial models on the handout *Initial Model of Mass Loss in the Cup with No Lid* you collected from them last time.

Have students attach the handout you are passing back to a new page in their science notebook.

Introduce the context of the first video and show it. Explain to the class you are going to show them a time-lapse video that was shot over 66 days, of a container of room-temperature water with no lid on it, so we can analyze it to determine whether our predictions were correct. Show https://youtu.be/Q4P6NOZrF2o .

Introduce the context of the second video and show it. Explain that, unlike the last video of liquid water at room temperature, the next video is of a cup with hotter water in it, shot in slow motion over just a few seconds. Show https://youtu.be/npkBC4GYodg .

Lead a Building Understandings Discussion about the videos. Ask students to share ideas about what is happening to the water, particularly where it is going and why we can't see the water leaving the container in the first video.

KEY IDEAS

Purpose of this discussion: Establish that this process (evaporation) happens to liquid water exposed to air, and that it is a relatively slow process in which small bits of water are leaving the liquid and going into the air.

Listen for these ideas:

- Water is going into the air.
- We know this because the height of the water in the container is decreasing over time.
- The water that goes into the air is doing so at a relatively slow rate.
- The water that goes into the air is leaving in really small pieces.
    - In one case (the first video), those pieces are too small for us to see).
    - In the other case (the second video), we can see something going into the air, and so the pieces must be bigger than they were in the first video.

Suggested prompt	Sample student response
What can we say about what is happening to water at its surface to explain where some of the matter in the liquid water is going?	*It is going into the air.*
Which system seemed like this was happening at a faster rate, the one with the room-temperature water or the one with the hotter water?	*The one with the warmer water in it.*
Why can't we see the water leaving the container of water at room temperature?	*It must be happening too slowly and with pieces too small to see when they go into the air.*

11 · MODEL DROPPING WATER LEVELS AND MASS CHANGE OVER TIME

15 min

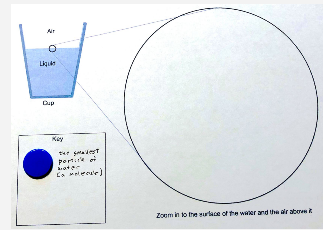
MATERIALS: *Manipulative Mat for a Model of Matter at the Surface of the Liquid*, bag of 19 blue chips, bag of 4 yellow chips, chart paper, markers, 15 blue circular magnets, 4 yellow circular magnets, whiteboard

Introduce manipulatives. Summarize that it seems important for us to develop a model of this process, since it seems to involve the movement of matter out of the cup system and is influenced by the temperature of the liquid, but it is happening at a scale that is too small for us to see.

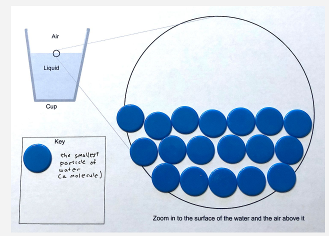
Say, *I saw in your models from yesterday that many of you were showing water going into the air. Each of you represented it in your own way, so let's take time to develop a common way we can all represent this idea of little pieces of water moving into the air over time.*

Present **slide K**. Pass out a copy of the handout *Manipulative Mat for a Model of Matter at the Surface of the Liquid* and a bag of 19 blue chips to each pair student. Explain that we are going to develop a model together to show what we think is happening to the water that explains why the mass of the system decreases and why the level of the water drops over time.

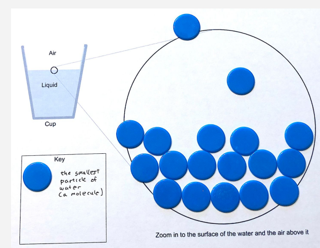
Then say, First let's establish a way to think about really small pieces of water that are too small to see. When we talk about really small pieces of matter, particularly when they are too small to see, we often refer to them as particles. And if we are talking about the very smallest piece of a substance like water, we sometimes refer to it as a molecule, which is what we can call these particles of water too. Let's have a blue chip represent a single smallest piece, or molecule, of water. Have pairs of students take 1 blue chip out of the bag and place it in the key. Have them label this chip as the smallest particle of water (a water molecule).



Then remind students that we are trying to show what is happening to all the water in the container, and we are zooming in on the surface of the water, like we did yesterday. Propose that we use the remaining chips in the bag to represent the water in the liquid. Have students lay out those chips the way you lay out the blue magnets on the board.



Ask students how they could use these manipulatives to show why the mass of the system and the level of the water starts slowly dropping over time. How would you show where the matter is going? Give students a couple of minutes to work with their chips to show this. Examples of what students might show are included here.



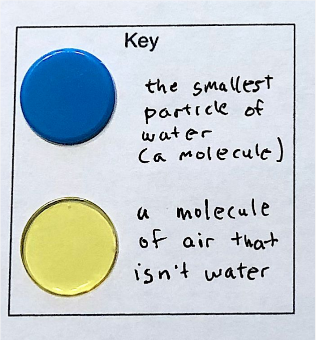
ALTERNATE ACTIVITY	You can adjust the level of guidance in this activity based on whether or not most of your students showed particles in their models you collected from them on *Initial Model of Mass Loss in the Cup with No Lid*. If students need more guidance, or if most students didn't use particles in these initial models, it is recommended you demonstrate these steps using the blue and yellow magnets on the whiteboard while having students concurrently recreate your demonstration with their own chips on their handout.

Have students cover their chips with one of their notebooks.

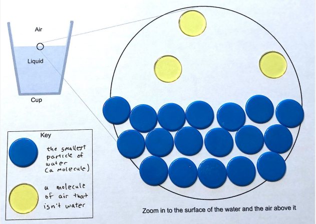
Say, *This process where water slowly changes from a liquid to a gas and single molecules of water leave the surface to go into the air one at a time is called evaporation*. Put this word on the word wall at this time.

Then say, *These blue chips are helping us represent water going into the air as individual molecules, but we really aren't representing the air. Air is also matter and is made of particles, but those particles--just like those that make up any gas--are spaced more widely apart than in a liquid. This is one reason we can't see the gas particles that make up the air.*

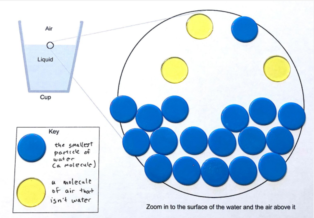
Pass out a bag of yellow chips to each group of students and have them update their key with a yellow chip so it looks something like this.



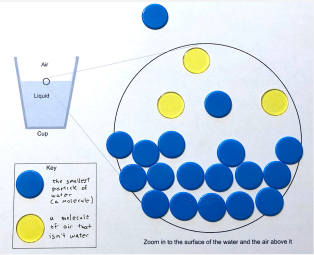
Ask students to use the remaining chips to model the gas particles in the air above the water.



Ask students how they could use these manipulatives again to show why the mass of the system and the level of water starts slowly dropping over time. How would you show where the matter is going? Give students a couple of minutes to work with their chips to show this. Examples of what students might show are included here.



Have students put their chips away in the bag and prepare to meet as a group to update the Progress Tracker.



12 · UPDATE THE CLASS PROGRESS TRACKER

12 min

MATERIALS: *Progress Tracker* or *Progress Tracker 2*, chart paper, markers

Choose a norm to work on in class. Show **slide L** and read the text aloud. Give students a minute to look through the class norms as you pass out a class Progress Tracker sheet (*Progress Tracker* or *Progress Tracker 2*) to each student. Have students add this sheet to the Progress Tracker section of their science notebook.

ADDITIONAL GUIDANCE

Progress Tracker is a version of the class Progress Tracker that fills most of an 8.5-×-11 piece of paper. This version is ideal for use in a spiral notebook or binder that uses 8.5-×-11 pages, but it can also be folded in half and taped onto a page in a composition notebook. Alternatively, *Unknown material with identifier: l4.ho5* is a scaled-down version of the Progress Tracker that prints with two on one page, so it can be cut in half and taped onto a composition notebook page without folding. This version is easier to see in a composition notebook but will also limit students' writing space.

Lead a Consensus Discussion. Start with having students recall the lesson question and the sources of data we explored to make progress on it.

Ask students to look back at our first investigation related to the lid and temperature change and tell you what question we were trying to answer in that investigation. This should be at the top of their sheet that identified the variables for that experiment. Students should say, "How does a lid affect what happens to the liquid in the cup?"

Write this question on chart paper and instruct students to write it in their Progress Tracker.

Then ask students what sources of data we used to investigate this question. Students should recall the two different investigations they did. They may need a reminder that the time-lapse and slow-motion videos of water in a container were also data sources. Have students add these sources of evidence to their Progress Tracker:

- Two labs:
    - effect of lid versus no lid on temperature change in a cup
    - effect of lid versus no lid on mass change in a cup
- Two videos:
    - Time-lapse video of room-temperature water in a container
    - Slow-motion video of air above hot liquid in a cup

Shift to co-developing a list of key ideas that we figured out from our work with these data sources and the models we created to explain the phenomenon. It is likely that students won't have time to record all the key ideas from this discussion yet. That is fine. If time permits, have them record a few and tell them that you will return to these in a couple lessons and add the rest to their model tracker. Make a record of these on chart paper and save it. You will need to present this record for Lesson 6.

KEY IDEAS

Purpose of this discussion: Summarize the findings we figured out from the labs. Establish ideas about matter and particles in the system to use in all future models of this system and related phenomena.

Listen for these ideas:

- A cup with a lid on it causes a hot liquid in it to drop in temperature less than in a cup without a lid. The lid also slows down matter loss from the system.
- Matter has mass and takes up space.
- Gases, and liquids are made of particles that are too small to see with an unaided eye; these particles are often called molecules.
- Particles in a gas have a lot of space between them but those in liquids do not.
- Particles of water in liquid form go into the air over time (evaporation).
- An open system has spaces for particles of matter to get in or out. A closed system is one in which no matter can enter or exit.

Some potential prompts to help co-construct these ideas together are summarized here:

Suggested prompt	Sample student response
What did we figure out about how a lid affects the temperature of a liquid in a cup?	*A cup with a lid causes a hot liquid in it to drop in temperature less than in a cup without a lid.*
What did we figure out about how a lid affects the amount of liquid in a cup over time?	*The lid also slows down matter loss from the system.*
How did we know that we were losing water from the system? What did we measure?	*We measured the mass of the system.*
What did we see happening in the videos to the level of the water that told us there was less of it in the container over time?	*We saw the water level dropping.*
Do others agree that seeing the amount of liquid going down or seeing the mass measurement decrease were both ways to prove that matter was leaving those systems?	*Yes.*

Say, *This idea that we can tell how much matter is in a system, based on the space it takes up or how much mass is there, is based on an important scientific principle, which is that matter has mass and takes up space. We should add this principle to "What we figured out" in our Progress Tracker.*

At this point the list of "What we figured out" should look like this:

- A cup with a lid causes a hot liquid in it to drop in temperature less than in a cup without a lid.
- The lid also slows down matter loss from the system.
- Matter has mass and takes up space.

Have students add these things to their Progress Tracker before going on, but tell them to leave more than half the remaining space in it to add some other key ideas. Then return to developing those other key ideas together.

Suggested prompt	Sample student response
Why did we use blue chips to model the liquid in the cup? What did we say those chips represented?	*They represented particles of water.* *One chip represented a molecule of water.*
Can we see a single molecule of water with our own eyes? If no, why?	*No. They are very small.*
Why did we use yellow chips to model the air above the cup? What did we say those chips represented?	*They represented other particles of the air.*
What was different about the spacing between the particles in the liquid water versus the air above it?	*The particles in the air are very spread apart, and those in the liquid are close together.*

Say, *This is something that is true for all liquid and gases. The molecules in a gas have a lot of space between them, but those in liquids are close together.*

ADDITIONAL GUIDANCE

If a student suggests that solids are also made of particles that are close together or asks if they are, ask other students to weigh in. If there is general agreement around this idea, add solids to the list. If not, add it as a question to the Driving Question Board.

If the idea of solids being made of particles isn't suggested from students here, it will be introduced in Lesson 6.

At this point you should also have these sorts of things added to the list of "What we figured out":

- Liquids and gases are made of particles of matter. Particles in a gas have a lot of space between them but those in liquids do not.
- The smallest particle of water is a molecule, and it is much smaller than we can see.

Have students add these to their Progress Tracker before going on, telling them to leave at least a third of the remaining space in it to add some other key ideas. Then return to developing the last of the key ideas for this lesson together.

Suggested prompt	Sample student response
So what is happening over time to some of the particles of water that are in liquid form? Where are they going?	*They are going into the air.*
What do others think? Do you agree with this idea?	*We agree.*
When the molecules go into the air, they are now in gas form. Why can't we see these molecules when they are spread far apart in a gas?	*They are too small to see as single molecules.*
Let's think back to our cup with no lid. Would we consider that an open system or a closed system? Could matter get in and out of the system or was it completely blocked from doing so?	*It was an open system. Matter could get in and out.*
What about the cup with a lid? Was there any way that matter could have gotten in or out in gas form?	*The hole in the lid. Maybe the edge of where the lid meets the cup walls.*

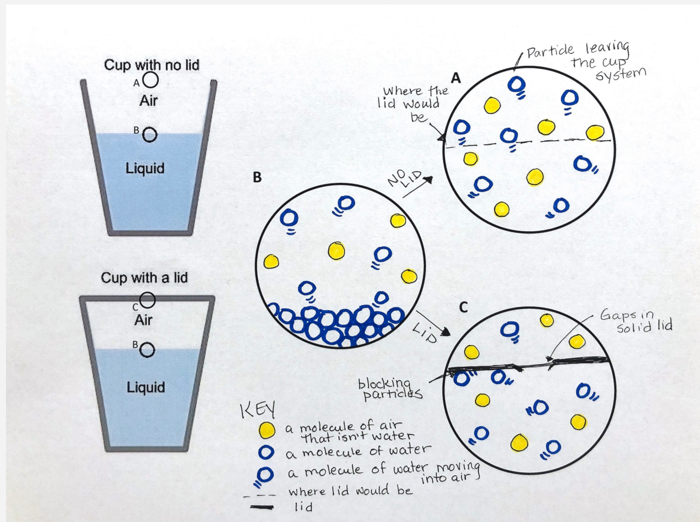
Say, *These ideas about little bits of matter either going out of the system, or being prevented from going out of the system, seem important to include too. Let's jot these down.*

At this point you should also have these sorts of things added to the list of "What we figured out":

- Particles of water in liquid form go into the air over time (evaporation).
- An open system has enough space between the solid parts of the system for particles of matter to get in or out. A closed system is one in which no particles of matter can enter or exit.

Emphasize that students can and should reference these ideas throughout our work in this unit to try to explain and predict related phenomena we will explore.

While students are mostly working toward a list of agreed-upon ideas, they could also represent these ideas visually as shown below.



13 · USING OUR MODEL IDEAS TO EXPLAIN AND PREDICT

10 min

MATERIALS: *Explanations and Predictions of Lids and Covers*, chart paper, markers

Introduce the phenomena. Project **slide M**.

Read the text, emphasizing that you will be looking for how they apply the ideas we developed together just now in our Progress Trackers to their responses to questions 1, 2, and 4 in the next handout. Pass out a copy of the handout *Explanations and Predictions of Lids and Covers* to each student. Tell students that they can look back at their Progress Trackers as they answer these questions, but these are to be individual responses. Collect this handout at the end of the period.

ASSESSMENT OPPORTUNITY	Look for the use of one or more key science ideas from the Progress Tracker in students' responses to question 1 in the handout, related to particles of matter.

Additional Lesson 4 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.** Students follow a multistep procedure in days 1 and 2 of this lesson. Asking students to keep a record of each step they complete by putting a checkmark near that step can help them develop a transferable approach to tracking their progress on other technical tasks that are in multistep procedure form in other contexts.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	**CCSS.MATH.Content.6.NS.C.5: Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, debits/credits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation.** **CCSS.MATH.Content.6.SP.A.3: Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.** In this lesson's three investigations, students measure, calculate, and represent drops in temperature and mass in the cup systems as negative numbers, increases in temperature and mass as positive numbers, and no change as 0 in each situation. Students pool their data to calculate class mean.

LESSON 5: Where does the water on the outside of the cold cup system come from?

PREVIOUS LESSON *We planned and carried out two investigations to determine (1) the effect of a lid on how much the temperature of a hot liquid in a cup will drop and (2) the effect of a lid on change in the mass of a hot liquid in the system. We developed and used a particulate model of liquids and gases to explain the mass loss in an open system.*

THIS LESSON

INVESTIGATION

1 day

We construct an investigation to support or refute the claim that the formation of water droplets (condensation) on the outside of a cup of cold water comes from water leaking through the cup walls. We measure the mass of a cup of cold water before and after condensation forms on the outside. We also observe condensation on the outside of a cup of cold water that has been dyed using food coloring. We use our observations and data to construct an argument to refute the claim that water droplets on the outside of the cup come from inside the cup system.

NEXT LESSON *We will use a model to show why water molecules cannot leave a cup at some points in the cup system but can at other points. We will complete an individual assessment that includes making predictions about the performance of a cup with a new lid design, developing a plan for collecting data to measure its performance and developing a model to explain a set of results.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Collect and analyze different forms of data to identify patterns across our data sources that serve as evidence that condensation that forms on the outside surface of a cold cup system comes from the air outside the system.

Construct an argument to support the claim that water forming on the outside surface of a cold cup system comes from the air outside the system and is not leaving the system through the walls.

WHAT STUDENTS WILL FIGURE OUT

- The water droplets that form on the outside of a cup of cold water come from the air outside the cup, not from the inside of the cup.
- Water droplets often condense on a cold surface when humid air comes in contact with the surface.
- Liquids do not move through solids.
- Matter does not enter or leave a closed system; therefore, the mass of a closed system does not change.

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review important science ideas figured out in previous lessons and motivate the need for students to explore water droplets forming on the outside of a cup of cold water.	A	ice-cold water, 1 16-oz single-wall plastic cup (no lid)
2	5 min	**PLAN THE WATER DROPLET INVESTIGATION** Elicit ideas from students about testing cups to determine the origin of the water droplets that form on the outside of a cold cup system.	B	
3	20 min	**CONDUCT THE WATER DROPLET INVESTIGATION** Gather students in a Scientists Circle to conduct the investigation. Students record observations and data for both parts of this investigation.	C-E	*Water Droplet Investigation* handout, Water Droplet Investigation
4	10 min	**DISCUSS OBSERVATIONS AND DATA IN A SCIENTISTS CIRCLE** Remain in a Scientists Circle to share students' analysis and conclusions from the data and connect to related experiences.	E-F	chart paper, markers
5	5 min	**COLD LEMONADE ON A HOT DAY!** Distribute the assessment *Cold Lemonade on a Hot Day!* to evaluate students' understanding of how water droplets form on the outside of a cold container system.	G	*Cold Lemonade on a Hot Day!*

End of day 1

Lesson 5 • Materials List

	per student	per group	per class
Water Droplet Investigation materials			• pitcher of ice-cold water • 2 16-oz single-wall plastic cups • 2 clear plastic lids • 2 16-oz single-wall metal cups • 2 lids for metal cups • tape • 2 digital scales (accurate to 0.1 g) • timer • 12-16 drops of food coloring • 1 spoon • white paper towels or tissues
Lesson materials	• *Water Droplet Investigation* handout • science notebook • *Cold Lemonade on a Hot Day!*		• ice-cold water • 1 16-oz single-wall plastic cup (no lid) • chart paper • markers

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare a class data chart on chart paper, or the whiteboard, ahead of time for Part A of the Water Droplet Investigation.

Day 1: Water Droplet Investigation Parts A and B

- **Group size:** Whole group
- **Setup:** Chill 2 pitchers of water to 6°C. Gather 2 16-oz single-wall plastic cups, 2 clear plastic lids, 2 16-oz single-wall metal cups, 2 lids for metal cups, tape, 2 digital scales (accurate to 0.1 g), timer, 12-16 drops of food coloring, 1 spoon, and white paper towels or tissues.
- **Notes for during the lab:** Students will need their science notebooks and a pen or pencil to record data. The digital scales are very sensitive, so students should wait approximately 10 seconds after the cups are placed on the scales (i.e., until the mass reading no longer fluctuates) before taking mass measurements.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 1, students observed that water droplets formed on the outside of the regular cup but not as much on the outside of the fancy cup. Lesson 2 confirmed that condensation occurs on some cups but not on others. Students shared a few possible explanations at that time. After focusing on the function of the lid with respect to evaporation in Lessons 3 and 4, students now turn their attention to whether matter can move through the walls of the system. In this lesson, students plan and conduct an investigation to figure out where the water droplets forming on the outside of some cups come from. They collect and use data from their investigation to determine that the condensation on the outside of a closed cup system comes from the air outside the cup system. To do this, students determine that the mass of the closed system increases due to the mass of water droplets forming on the outside surface of the system. Students use additional data from a second investigation involving dyed water, as well as personal experiences involving condensation, to further support their claims. The main take-aways from the lesson include that (1) condensation comes from the air outside of a system and (2) condensation happens when air comes in contact with a relatively cold surface.

Note that if your students live in an arid climate or your classroom has low humidity, and if your students did not make observations of condensation in Lesson 1, then this lesson is unnecessary at this point in the course. It does not add explanatory power to students' models for thermal energy transfer and is better left to investigate in the next unit.

Where We Are NOT Going

Students are not expected to understand the mechanisms for how condensation occurs. Do not spend time now elaborating on the process of condensation, as it will be further discussed in the next unit on water cycling and weather. If students remain curious, use their curiosity to motivate their future investigations in that unit. As students transition to the next unit, it may be useful to highlight condensation-related questions that were added to the Driving Question Board in Lesson 1, especially those not answered, as a motivation for further investigation.

LEARNING PLAN for LESSON 5

1 · NAVIGATION

5 min

MATERIALS: ice-cold water, 1 16-oz single-wall plastic cup (no lid)

Revisit our previous investigation with a closed system. Ask 3-4 students to summarize for the class what we were trying to figure out when we put lids on the cups to create a closed system in the previous lesson.

Suggested prompt	Sample student response
What were we trying to figure out in the last class?	*We wanted to see if a completely closed system would stay colder than one without a lid.* *We wanted to see if you have a more opened straw hole on the top of the lid, or no lid at all, how a cold drink warmed up faster or how a hot drink cooled down.*
Is our cup system closed when we put a lid on it?	*Not completely. You have to screw on the lid really tightly to close it.* *Our cup with a lid still lost a little mass, but the completely closed one didn't.*
How was this different for our hot drink compared to the cold drink?	*The hot drink had more mass loss and cooled down a lot quicker without the lid.*

Motivate the need to look closer at the water droplets forming on the cold drink. Pour ice-cold water into a clear plastic cup. Then say, *Not a lot of particles (or water molecules) are escaping from the top of this cold cup system, but we've noticed that water droplets formed on the outside of some of the cups in our investigations. We weren't sure where that water came from, but we've had a few ideas.*✱

Display **slide A**. Use the prompt on the slide to facilitate a turn and talk among students to think about where the water droplets might have come from. Have them share their ideas with a partner for 1 minute. Elicit ideas from a few students and point out similarities you notice among their ideas.

Listen for these student ideas:

- The water droplets came from inside the cup because water particles can go through the cup.
- The water droplets came from outside the cup because water particles cannot go through the cup.

After ideas are shared, say, *We have a couple of ideas about where the water droplets that form on the outside of a cold cup system come from, but now we need to figure out how to test our ideas.*

ALTERNATE ACTIVITY

This lesson is motivated by students' observations of condensation on some of the cups containing cold water. If you live in an arid climate or your classroom has low humidity, and if your students did not make observations of condensation, then this lesson is unnecessary. Students will delve deeply into condensation in the next unit on water cycling and weather. This lesson is intended to satisfy students' curiosity about the water collecting on the outside of cups but not to present a full explanation. Key take-aways from this lesson should include that (1) the water on the outside of the cup is coming from the air, not leaking through the walls, and (2) the water is collecting on a cold surface.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

This lesson makes an important instructional move that is part of the bigger storyline. Across Lessons 4-6, students will establish that even in closed systems where matter is not moving in or out of the system, something else causes the substance inside to change temperature over time, which hopefully will lead students to think about the transfer of energy as the cause of a substance warming up or cooling down. This lesson contributes to this storyline by helping students establish that matter is not leaving through the cup walls and that the cup system is (mostly) closed.

ADDITIONAL GUIDANCE	The term *condensation* may have already been introduced and used by your students. Use the language that your students bring to the lesson. It is not critical that students name this phenomenon as condensation in this lesson, but certainly use that word if students want to describe it that way. If students are using the word, ask them to explain what they mean by it and consider adding it to the word wall at the end of the lesson as a "word we earned". Students' definitions for condensation may be limited to the conditions under which it happens and less focused on the process. That is OK at this point as students can revisit the term in the next unit to add to their understanding of it as a process of phase change.

2 · PLAN THE WATER DROPLET INVESTIGATION

5 min

MATERIALS: None

Brainstorm ways to test the water droplet source. Display **slide B**, and say, *Given what we did when we tested whether water particles were leaving through the lid, what are some things we could do to test whether particles are coming from inside or outside the cup?*✱

Have students brainstorm in partners or small groups. Then elicit 3-4 ideas from students for testing the source of the water.

Suggested prompts	Sample student responses	Follow-up questions
How might we test our ideas?	*We could measure the mass of the cup like we did when we tested the lid.*	*What do we think the mass measurement would show if the water was coming from the inside?* *What would the mass measurement show if the water was coming from the outside?*
What are some other ways to test our ideas?	*We could mark the water line and see if it goes down.*	*Would the lid need to be completely sealed too?*
What are some important things we need to consider as we plan and conduct our investigation?	*We need to make sure no water goes out the top of the lid.* *We need to look at all the cups that had condensation.*	*Do you think this could be different for different types of cups?*

ALTERNATE ACTIVITY	Both *Part A* and *Part B* of this investigation can be conducted in small groups rather than as a demonstration. If small-group investigation is preferred, more materials and instructional time should be allotted in your planning.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

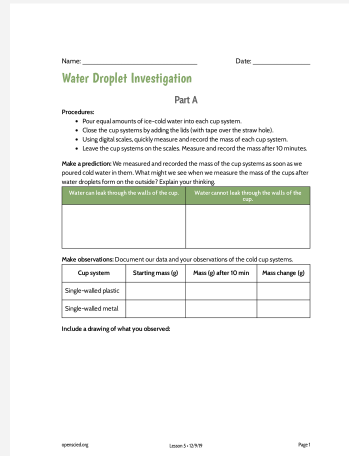
Students will conduct an investigation to collect evidence for where the water droplets that form on the outside of the cup come from. In this lesson, there is less emphasis on co-constructing the investigation plan with students. However, you can invite students to suggest ways to investigate potential sources of water before sharing the investigation plan. Students will evaluate the investigation plan you provide, make suggestions, and justify potential revisions. If the suggested changes are reasonable, you can decide to make any changes deemed necessary.

3 · CONDUCT THE WATER DROPLET INVESTIGATION

20 min

MATERIALS: Water Droplet Investigation, *Water Droplet Investigation* handout, science notebook

Have students review the *Water Droplet Investigation* plan. Gather students in a Scientists Circle for the remainder of class. They should bring chairs and their science notebooks. Pass out the handout *Water Droplet Investigation* to each student. Ask students to read through the procedures for *Part A*. Ask students if these procedures make sense and are similar to what they would want to test given the previous discussion. Elicit any suggested changes that may be reasonable to add at this time.


Name: ____________ Date: ____________

Water Droplet Investigation

Part A

Procedures:

- Pour equal amounts of ice-cold water into each cup system.
- Close the cup systems by adding the lids (with tape over the straw hole).
- Using digital scales, quickly measure and record the mass of each cup system.
- Leave the cup systems on the scales. Measure and record the mass after 10 minutes.

Make a prediction: We measured and recorded the mass of the cup systems as soon as we poured cold water in them. What might we see when we measure the mass of the cups after water droplets form on the outside? Explain your thinking.

Water can leak through the walls of the cup.	Water cannot leak through the walls of the cup.

Make observations: Document our data and your observations of the cold cup systems.

Cup system	Starting mass (g)	Mass (g) after 10 min	Mass change (g)
Single-walled plastic			
Single-walled metal			

Include a drawing of what you observed:

openscied.org Lesson 5 • 12/9/19 Page 1

Start *Part A* of the investigation. Display **slide C**. Turn on the digital scales and tare both scales until they read 0.0 g. Cover the straw hole in 1 plastic cup lid and 1 metal cup lid with tape. Select four students to come to the table. Have two pour ice-cold water into each cup system (1 plastic, 1 metal) and quickly close them by putting on the lids. Then place each cup on a digital scale. Have the other two students read and document the starting mass on the class data table, which you have prepared already. Other students can record the starting mass on the handout too. Set a timer for 10 minutes so that the class can measure and record the mass of both cup systems again.

ADDITIONAL GUIDANCE

Below are sample data collected in a 22.2°C room with 51% humidity using a digital scale sensitive to 0.01 g. Do not share this sample data with students. You can observe differences with a scale with 0.1-g sensitivity. You may need to remove the cups from the scale and then turn the scales back on and tare again before you get your final mass reading. Be careful not to disturb the condensation when you do this.

Cup system	Starting mass (g)	Mass (g) after 10 min	Mass change (g)
Single-wall plastic	395.93	396.22	+0.29 g
Single-wall metal	485.31	485.81	+0.50 g

Note: You may want to use the small plastic dish that comes with your digital scales to collect any condensation water that may run off the sides of the cup. If you use this dish, make sure to include it in your mass measurements before and after the 10 minutes.

Record predictions on *Part A*. Say, *We measured the mass of the cup systems as soon as we poured cold water in them. So what might we see when we measure the mass after water droplets form on the outside of the cups?* Ask students to first record predictions on their own in their handout, along with the reasoning to support their predictions. Elicit a few responses from students.

Suggested prompt	Sample student response
We measured the mass of the cup systems as soon as we poured cold water in them. So what might we see when we measure the mass after water droplets form on the outside?	*The mass will stay the same if the water droplets come from inside the cup.* *The mass will increase if the water droplets do not come from inside the cup.*

Give students a few minutes to document their predictions and observations for *Part A* of the investigation. While they work, set up the materials for *Part B* of the investigation. Students will revisit the observation and analysis questions for *Part A* after 10 minutes, but in the meantime, proceed to *Part B* of the investigation.

Start *Part B* of the investigation. Direct students to **slide D** and say, *Now let's get started on* Part B *while we wait for our timer.* Select a new set of four students to come to the table and have two of them pour ice-cold water into each cup system (1 plastic, 1 metal). Add 6-8 drops of food coloring to each cup and stir with the spoon. Ask the other two students to place a piece of tape on each remaining lid to close the straw hole and then place the lids on the cup systems.

Ask students, *Since we have added food coloring to the cold water in each cup system, what might you expect to see when water droplets form on the outside?* Instruct students to individually record their predictions on *Part B* along with the reasoning to support their predictions. Then elicit a few responses from students.

Suggested prompt	Sample student response
Since we have added food coloring to the cold water in each cup system, what might you expect to see when water droplets form on the outside? Explain your thinking.	*We might see colored water droplets on the outside if the colored water inside the cups is the source of the water droplets.* *We might see clear water droplets if the water is not coming from inside the cups.* *We might not see any water droplets forming on the outside of the cups. Maybe the food coloring will prevent the water from leaking through the cup.*

Return to the *Part A* setup. If students would like to, let them come forward and observe both investigation setups. When the timer goes off, select two students to come to the table and read and record the mass of both cup systems on the digital scales. Remind the class to record the data in their data table. Give students a few more minutes to complete their observations and drawing for *Part A*.

Return to the *Part B* setup. Ask another volunteer or two to come to the table. Have them wipe the outside of each cup with a white paper towel or tissue and hold up the tissue for their classmates to make observations. Give students a few more minutes to complete their observations and drawing for *Part B*.

Give students time to work on the analysis and conclusions questions for both parts. Have them stay in their Scientists Circle but work in small groups of three to respond to the questions. Display **slide E** as necessary to guide their work.

4 · DISCUSS OBSERVATIONS AND DATA IN A SCIENTISTS CIRCLE

10 min

MATERIALS: science notebook, chart paper, markers

Facilitate a Building Understandings Discussion about the observations and data. Keep the lab setups visible for the students to reference during the discussion. This will also allow students to visually observe condensation continuing to occur.✱

KEY IDEAS

Purpose: This discussion is to build on what students already know about condensation and to establish some patterns in those experiences of condensation.

Listen for students to share these ideas:
- connect the phenomenon to cold surfaces
- connect the phenomenon to humidity in the air
- connect the phenomenon to where air meets solids
- establish that the water on the outside of the cup is coming from the air and not from inside the cup

Connect to related experiences to augment the discussion. Display **slide F**. Say, *Before we discuss what we observed, think about some instances when you have seen water droplets form on surfaces. Where else have you seen this phenomenon happen?* Elicit responses from students.

Suggested prompt	Sample student response
Where have you seen this phenomenon happen?	*Water droplets form on the mirror in my bathroom whenever I take a hot shower.* *This happens on our car's windows when it's cold outside and we've been in the car for a few minutes.* *Sometimes it happens on my glasses when I go outside from an air-conditioned building and it's hot and humid outside.*
What conditions were present when this happened?	*It's usually on glass or a smooth surface.* *When it's cold outside.* *When it's humid in the air.*

Summarize patterns across these experiences on chart paper. Work with students to identify patterns that emerge from the experiences that students shared, and record these patterns on a sheet of chart paper. Examples of patterns include these:
- Water droplets usually form on surfaces when there is humidity in the air.
- Water droplets usually form on surfaces that are cold (the mirror, the car windows, and the eyeglasses).
- Water droplets form when air touches a solid.

Tell students to keep these ideas in mind as we discuss the investigation.✱

Return to **slide E** and say, *Let's talk about* Part A *of our investigation.* Use the prompts to guide this discussion.

✱ STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

The purpose of this discussion is to (1) share claims and reasoning based on evidence from the *Water Droplet Investigation*, (2) connect to related experiences involving condensation, (3) critique and build on each other's conclusions, and (4) arrive at a tentative conclusion about where the water forming on the outside of the cup comes from (i.e., the air outside the cup).

✱ ATTENDING TO EQUITY

Expanding to students' related experiences will make the conclusions drawn from these investigations more meaningful to students and will broaden their explanations beyond the cups that were tested. Leverage students' prior experiences with condensation as a valuable source of observational data alongside the classroom-collected data to support or refute claims. The reliability of the evidence increases if more than one student shares the same or similar experiences.

Suggested prompt	Sample student response
What did you observe in Part A ?	*After a few minutes, water droplets formed on the outside of the cup systems. The mass went up.*
What did the mass data seem to indicate?	*It shows that the water droplets come from somewhere other than the cup because the mass went up.* *If the water droplets had come from inside the cup, the mass would have stayed the same.*

Turn the discussion to the analysis and conclusion questions for *Part B*. Focus students on thinking about what they observed in Part B and how the data on both parts of the investigation can be used to draw conclusions.

Suggested prompt	Sample student response
What did you observe?	*After a few minutes, we could see water droplets forming on the outside of each cup. The water droplets were clear and not colored like the water inside the cup.*
What conclusions can you draw based on what you saw?	*The water droplets did not come from inside the cup, because the water inside the cup is colored. If the water droplets had come from inside the cup, they would have been colored.*

If students think that the phenomenon of clear water in the droplets is due to particle size, have students examine the empty and cleaned plastic cups to see if the food coloring was trapped in the plastic of the cups.

Relate the *Water Droplet Investigation* to students' prior experiences again. Focus students on the class chart where you recorded a list of conditions in which water droplets form. Ask students if what they observed in *Part A* and *Part B* meets those same conditions or whether these additional things need to be added to the list:

- Water droplets usually form on surfaces when there is humidity in the air.
- Water droplets usually form on surfaces that are cold (the mirror, the car windows, and the eyeglasses).
- Water droplets form when air touches a solid.

Conclude the discussion by asking students some additional questions.

Suggested prompt	Sample student response
Based on our investigation, where did the water droplets on the outside of the cup systems come from?	*The water droplets must have come from the air outside the cup systems.*
Do we have any evidence to support that the water leaked through the cup walls?	*No, because the data did not support our predictions if water was leaking through the walls.*

ALTERNATE ACTIVITY	If students observed the formation of water droplets on the underside of the lid in a closed cup system containing a hot liquid in prior lessons, now is the best opportunity to revisit this observation. With the completion of this lesson's investigation, students are ready to understand how water droplets form on the underside of the lid in a closed hot cup system, as the warm, humid air inside the cup meets the cool surface of the lid.

5 · COLD LEMONADE ON A HOT DAY!

5 min

MATERIALS: *Cold Lemonade on a Hot Day!*

Assess understanding of the water droplet phenomenon. Have students return to their seats from the Scientists Circle. Show **slide G**. Tell students to read the slide while you pass out the assessment *Cold Lemonade on a Hot Day!*. Preview the directions and answer any questions students might have. Give them time to complete the assessment before they leave class.

ASSESSMENT OPPORTUNITY

There are several ways to interpret the student data from this assessment. Below are a few patterns you may see:

- Pattern 1: Agreement with Regina and explanation (in words and a diagram) that the water collecting on the outside comes from the air, supported by the evidence from the *Water Droplet Investigation* and related experiences. These students should be considered as meeting the lesson-level performance expectation.
- Pattern 2: Agreement with Regina and explanation (in words and a diagram) that the water collecting on the outside comes from the air, without drawing on support from evidence or experiences. These students should be considered as meeting the lesson-level performance expectation with respect to the DCI and CCC. These students may struggle with how to use evidence in their explanations. Consider practicing with these students how to write an explanation that draws on evidence and/or show students examples of explanations written using evidence.
- Pattern 3: Agreement with Michael and explanation that the clear water that forms the ice inside the pitcher of lemonade could be leaking through the walls. This indicates that these students have not yet mastered the DCI and CCC performance expectations but are using some evidence, foregrounding the food coloring evidence over other sources. See suggested activity below.
- Pattern 4: Agreement with Sarah and explanation that the water on the outside comes from the water inside the cup (and that maybe the food coloring particles are too large to get through). This kind of response indicates that these students have not mastered the DCI and CCC performance expectations and are not using evidence from the investigations to support their explanation. See suggested activity below.

If students choose Michael or Sarah as the claim they most agree with, consider conducting a follow-up investigation. Chill an empty plastic or metal cup overnight and then make observations of the empty cup the following day. Remove the cup from the cooler and place it into the classroom air. Watch and observe that water continues to collect on the surfaces of the chilled cup even when there is no water inside the cup.

Start thinking about next steps. Say, *It seems like we've figured out that most matter cannot escape the cup system because it can't go through the walls and it mostly can't go through the lid. Do we think if we could test a completely sealed-off container where no matter could escape, that the liquid would still warm up or cool down over time? Why or why not?* Elicit a few initial ideas from students, and collect students' assessments before they leave class.

Lesson-Specific Teacher Materials

Lesson 5 Assessment Scoring Guidance

Sarah and Michael were visiting their friend, Regina. They were in Regina's backyard, enjoying some ice-cold lemonade. They noticed that there were droplets on the outside of the pitcher of lemonade. The 3 friends made the following claims:

A. **Sarah** said, "Those droplets must be lemonade leaking from inside the pitcher."
B. **Regina** said, "The droplets on the outside of the pitcher are water. They came from the air outside the pitcher."
C. **Michael** said, "I agree that the droplets on the outside of the pitcher are water, but the water comes from the melting ice cubes inside the pitcher."

Based on what you have figured out from our investigation, pick the claim that you most agree with. Use words and pictures to explain why you agree with it, and support your thinking with evidence from our investigation. Use reasoning to explain why each piece of evidence supports the claim.

+1's in red below indicate the important ideas to look for in student responses. They do not indicate a preferred scoring scheme. You can choose how to score or grade the assessment.

+1 select Regina's claim

+1 explain that air is made of particles or that water particles are in the air

+1 explain that water cannot pass through the walls of the cup because of the structure of the solid particles

+1 explain that the mass of the system doesn't change, so the matter on the outside of the cup must come from outside the cup.

If students select the correct claim (Regina) but do not support it with evidence, consider practicing with them how to write an explanation that draws on evidence and/or showing students examples of explanations written using evidence.

If students choose an incorrect claim (Michael or Sarah), and the data from the current investigations is not convincing to them, consider conducting a follow-up investigation. Chill an empty plastic or metal cup overnight and then make observations of the empty cup the following day. Remove the cup from the cooler and place it into the classroom air. Watch and observe that water continues to collect on the surfaces of the chilled cup even when there is no water inside the cup.

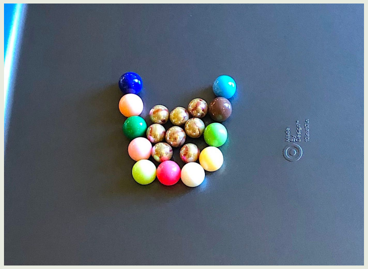
LESSON 6: How can we explain the effect of a lid on what happens to the liquid in the cup over time?

PREVIOUS LESSON *We used data from our investigation as evidence to argue that the formation of water droplets (condensation) on the outside of a cup of cold water comes from the air around the cup and not from inside the cup.*

THIS LESSON

PUTTING PIECES TOGETHER

2 days



We use a model to show why water molecules cannot leave a cup at some points in the cup system but can at other points. We complete an individual assessment that includes making predictions about whether a cup with a new lid design will keep a drink cooler than a cup with an old lid design, developing a plan for collecting data to see if the amount of liquid changed in either cup over time and developing a model to explain why one cup system would lose more mass than another.

NEXT LESSON *We will consider what we've learned about the interactions occurring within the closed cup system and determine other possible explanations for a temperature change in the liquid inside. We will use models to represent our ideas, and we will determine ways to test our ideas.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Develop and use a particle model of matter for solids, liquids, and gases to show how structural differences in a cup system allow water molecules to leave the system at some points in the system but not at others.

Plan an investigation and in the design, identify the controls, the tools needed to gather the data, and how much data are needed to support a claim about how much liquid (matter) leaves two different cup systems over 30 days.

WHAT STUDENTS WILL FIGURE OUT

- Liquids, gases, and solids are made of particles of matter.
- Particles in a gas have a lot of space between them, but particles in liquids and solids do not.
- Liquids and gases are made of particles that can move around freely, but solids are made of particles that cannot.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Connect to what we figured out in prior lessons and the manipulative we used to represent particles of liquids and solids in a previous activity.	A-C	
2	10 min	**MAP THE ELEMENTS OF THE OLD AND NEW MODELS** Introduce students to the particulate nature of solids and the manipulatives we can use to represent particles in solids, liquids, and gases.	D	*Analogy Map for Chips and Marbles*, Marble Manipulatives Introduction
3	10 min	**USE THE MARBLE MODEL TO SHOW CHANGES IN MASS** Use manipulatives, which include glass marbles, magnetic marbles, and a baking tray, to show how liquid particles can move, evaporate, and leave an open system but cannot leave a closed system.	F	Marble Manipulatives Activity
4	20 min	**USE DIAGRAMS OF PARTICLES TO EXPLAIN MATTER MOVEMENT IN THE CUP SYSTEM** Introduce and use diagrammatic representations of particles in the cup system to explain how liquid particles can move, evaporate, and leave an open system but cannot leave a closed system.	G	*Particle Representations for Matter in the Cup System*, whiteboard, markers
				End of day 1
5	20 min	**UPDATE CLASS PROGRESS TRACKER** Facilitate a Consensus Discussion to help students update their class Progress Trackers in a Scientists Circle.	H	*Progress Tracker* or *Progress Tracker 2*, chart paper of key ideas from Lesson 4, chart paper, markers
6	20 min	**EXPLAINING THE EFFECT OF DIFFERENT LID DESIGNS** Monitor students as they work individually to plan a hypothetical investigation and construct an explanation for the performance of different lid designs.	I	*Explaining the Effect of Different Lid Designs*
7	5 min	**NAVIGATION** Orient students to the results from an airtight system, to foreground a hard-to-explain outcome--the temperature of a liquid in a container can change even if no matter enters or exits the system.	J	sample container with airtight lid
				End of day 2

Lesson 6 • Materials List

	per student	per group	per class
Marble Manipulatives Introduction materials			• 30 glass marbles in a clear plastic cup • 30 magnetic marbles attached to the inside and outside of a cutaway cup edge
Marble Manipulatives Activity materials		• steel baking tray • 30 magnetic marbles with flat bottoms • 30 glass marbles in a clear plastic cup	
Lesson materials	• science notebook • *Analogy Map for Chips and Marbles* • *Particle Representations for Matter in the Cup System* • *Progress Tracker* or *Progress Tracker 2* • *Explaining the Effect of Different Lid Designs*		• whiteboard • markers • chart paper of key ideas from Lesson 4 • chart paper • sample container with airtight lid

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Decide the Progress Tracker you want to use. You only need to make 1 copy of *Progress Tracker 2* per 2 students or make 1 copy of *Progress Tracker* for each student.

Before making copies of *Explaining the Effect of Different Lid Designs*, determine whether you want to include Question 6 in the assessment. Question 6 targets one part of one element of the practice of analyzing and interpreting data that students have worked with in Lessons 3 and 4. If students haven't had additional practice calculating a mean and explaining how a mean is determined in their math classes by this point in the year, you may want to remove this question from the assessment.

Day 1: Marble Manipulatives Introduction

- **Group size:** Whole class
- **Setup:** Fill a clear plastic cup with 30 glass marbles. Cut a second plastic cup in half lengthwise. Attach a line of magnetic marbles on the inside and outside of the cup along the cutaway edge on one of the cup halves (as shown on **slide E**).

Day 1: Marble Manipulatives Activity

- **Group size:** 3
- **Setup:** Prepare the following for each group: a steel baking tray with a plastic cup of 30 glass marbles on it and 30 magnetic marbles attached to it.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

In NGSS in 5th grade, students develop a particulate model of matter to account for things that air can do, and they measure and graph the weight of systems as evidence for the amount of matter being conserved in different types of changes (phase changes, dissolving, and mixing that forms new substances). It is implicit in this work that students might also develop a particulate model of matter to explain why the amount of matter doesn't change when something melts, freezes, or dissolves. In such a model, they also need to work with the idea that solids and liquids are made of particles of matter too small to see, which can break apart and move around and pass through the space between them.

In this lesson we are establishing that matter isn't leaving certain systems across the solid boundaries of the system, because those solids are also made of particles and the spaces between their particles are not big enough for liquid or gas particles to fit through. But in non-airtight systems like the lidded cup, gas particles could still escape through the gap between the cup's lid and wall if that space is larger than a particle of water vapor.

Students correlate the increased matter loss with the increased temperature change of the liquid in the cup in this lesson. But by the end of the lesson, they also determine that matter loss alone cannot account for all the temperature changes in the system, because such temperature changes occur in airtight containers too.

Where We Are NOT Going

Students do not develop the idea in this lesson that particles in solids are vibrating back and forth in place. This will be developed in later lessons. For now, they work with the idea that particles in solids cannot move around freely like they can in liquids and gases.

Different types of materials (e.g., water versus other gases in the air) are represented diagrammatically with different colors to distinguish the type of particles. No attempt is made in this unit to refer to the different types of gases in the air. This idea will be developed in OpenSciEd unit 6.3 and then reused in multiple units in 7th grade.

This unit does not make the distinction that molecules are made of smaller particles (e.g., atoms), as this idea is not needed to explain any of the phenomena in this unit. This idea will be developed in OpenSciEd unit 7.1, as students will develop a need to explain what is happening in chemical reactions.

No attempt is made in this lesson or unit to explain how evaporative cooling contributes to why hot liquids cool down quicker in an open versus closed container.

LEARNING PLAN for LESSON 6

1 · NAVIGATION

5 min

MATERIALS: science notebook

Connect to prior lessons. Show **slide A**. Say, *Think back to the last few investigations when we put cold and hot liquids in a cup with a lid and a cup without a lid. What did measuring the mass of each of these systems help us figure out?* Give students a couple of minutes to review these ideas.

Recall prior manipulatives. Show **slide B**. Discuss the question on the slide as a whole class.

Suggested prompt	Sample student response
What did we show and explain last time we used plastic chips of different colors to represent the smallest pieces of water and air?	*The liquid water is made of lots of smaller pieces of water (molecules) loosely packed together.* *Air is made of small pieces of matter (particles) very loosely packed together.* *Individual molecules of water go into the air over time (evaporation).*

Problematize the prior model's missing element. Remind students that when we used the chips, we only showed the liquid and gas being made of particles. Say, *This was a limitation in the model.*✱ *We were only showing what was happening where the surface of the water met the air above it. We showed water molecules leaving the liquid and going into the air at that spot. We weren't trying to show what was happening to particles of matter at other places in the system. Let's think about that now.*

Show **slide C**. Read the questions on the slide. Discuss these questions as a whole class. Anticipated students responses are that water molecules won't leave the cup where there is solid material unless there is a big enough gap or hole in it for them to get out.

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Motivate an explicit conversation about the limitations of the prior model with the chips to consider how modifying the model to use marbles can help us account for a different aspect of the phenomenon.

2 · MAP THE ELEMENTS OF THE OLD AND NEW MODELS

10 min

MATERIALS: Marble Manipulatives Introduction, science notebook, *Analogy Map for Chips and Marbles*

Introduce modeling solids. Say, *If we try and zoom in to these points to picture how the cup and the matter in and around it are interacting, we need to model the structure of the solid too. Liquids have particles that can move around freely. This is why we can stir and pour a liquid. When we freeze a liquid, like cooling liquid water enough to turn it into ice, what happens to the water molecules of the water? Can those water molecules that make up the ice still move around freely?* Students should say no.

Say, *This difference is true of the particles in all solids compared to the particles in all liquids. The particles of matter that make up solids stay in a relatively fixed position. Let's use these ideas to try to show what is happening in the cup system, to explain why we lose mass in a cup without a lid but why a lid prevents this mass loss.*

Problematize working in two dimensions. Say, *When we used the chips to represent water and air particles, we moved those flat discs around a flat paper diagram of the cup. But we know that the cup, the liquid in it, and the air above it aren't flat. They are three dimensional. If we want to show a more three-dimensional representation of the particles, a better representation might be something like a sphere.*

Hold up a marble as an example. Say, *Let's try using objects shaped like these to represent the molecules that make up liquids like water, solids like the plastic cup, and gases, like the air. And let's think about how each object is like the thing it is representing in the real world.*✱

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Have students map the new model's manipulative (marbles) to the prior model's manipulative (plastic chips) and to the real-world object (particles) to help them make connections between the different ways we can represent particles and how the two different models are useful but also limited in the ability to accurately represent the real-world object.

Pass out *Analogy Map for Chips and Marbles* to each student. Have students add the handout to a new page in their science notebooks.

Map the prior manipulatives. Project **slide D**. Ask students what the blue plastic chip and yellow plastic chip represented in the model activity in Lesson 4. Students should say that the blue chip represented a molecule of water and the yellow chip represented a molecule of other gases in the air.

Have students fill in the corresponding cells in the third column of their table to represent these ideas:

Manipulative in a previous activity . . .	***manipulative in this activity . . .***	***is like this thing in the cup system . . .***	***because . . .***
A blue plastic chip		A molecule of a water (in liquid or gas form)	
A yellow plastic chip		A molecule of other gases in the air	

Say, *We were able to move the chips around, like moving blue chips out of the cup to show water molecules moving into the air. This feature of the model is similar to how molecules of liquids and gases behave in the real world. Liquid molecules can move freely past other liquid molecules. They can go into the air when a liquid evaporates or boils. And when they are in gas form they can continue to move through the space they are in. This is something all gas molecules can do. Let's add this idea to our table.*

Have students fill in the corresponding cells in the fourth column of their table:

Manipulative in a previous activity . . .	***manipulative in this activity . . .***	***is like this thing in the cup system. . .***	***because . . .***
A blue plastic chip		A molecule of a water (in liquid or gas form)	It can move around freely.
A yellow plastic chip		A molecule of other gases in the air	It can move around freely.

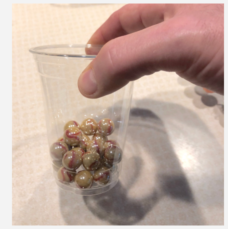
Map the new manipulatives. Say, *In this next activity we will again use manipulatives to represent molecules. But this time we will use marbles to represent the particles of the liquid.*

Fill up a clear plastic cup with 30 glass marbles. Hold it up to demonstrate what this looks like. Ask students if these marbles will be able to move around freely. They should say yes.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

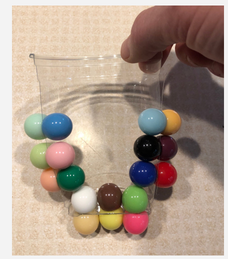
Emphasize to students that some phenomena are too small to observe directly but can be modeled at the macroscopic scale. Make it explicit to students that we are modeling particles at a scale much smaller than the marbles being used in this activity.

Say, *Obviously the scale of the particles in this model is way off.✱ Molecules are millionths of a millimeter big, far too small to see with our unaided eyes. So even though we are making the molecules in our model big enough to manipulate, we should keep in mind that in reality molecules are so small that there are many millions of them in a drop of water.*



Say, *But, notice that the marbles behave like molecules of liquid in the real world in some ways. They settle to the bottom of the cup, just like a liquid does. I can tip the cup a bit, and they move to that side of the cup. That sort of behavior makes them more useful for representing particles in a liquid, but less useful for representing particles in a gas. In a gas the particles are widely spread apart, and they don't settle to the bottom of a container like a liquid. Because of this limitation, we won't include a manipulative to represent the particles that make up the rest of the air in the cup. But we will introduce a new manipulative to represent the particles that make up the solid material in our system--the walls, bottom, and lid of the plastic cup.*

Show **slide E**. Read the text on the slide aloud. Hold up a similar physical setup of a clear plastic cup with magnetic marbles double-layered on the cutaway edge. Discuss the question on the slide as a class.



Suggested prompt	Sample student response
How does this model help you visualize why water molecules can move freely between other water molecules but can't go through the particles the wall is made of?	*The particles of the solid are stuck together.* *The particles of the solid wall are really close together.* *There is not enough room/space between the particles in the solid for the water molecules to be able to get through.*

Show **slide D** again. Have students fill in the corresponding cells in their table to represent these ideas:

Manipulative in a previous activity . . .	***manipulative in this activity . . .***	***is like this thing in the cup system. . .***	***because . . .***
A blue plastic chip	A glass marble	A molecule of a water (in liquid or gas form)	It can move around freely.
A yellow plastic chip	(we won't include any)	A molecule of other gases in the air	It can move around freely.
(we didn't include any)	A plastic marble with a magnet on it	A molecule of a solid (like the plastic cup)	It doesn't move around freely.

3 · USE THE MARBLE MODEL TO SHOW CHANGES IN MASS

10 min

MATERIALS: Marble Manipulatives Activity, science notebook

Review the modeling task. Show **slide F** and arrange students in groups of 3. Review the directions on the slide for the manipulative activity using marbles, and tell students to follow the directions as they work in their groups. Ask students if they have any questions.✱

Circulate among the groups to monitor student activity and discussion. Collect the materials before moving on to the next activity and have students return to their regular seats.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

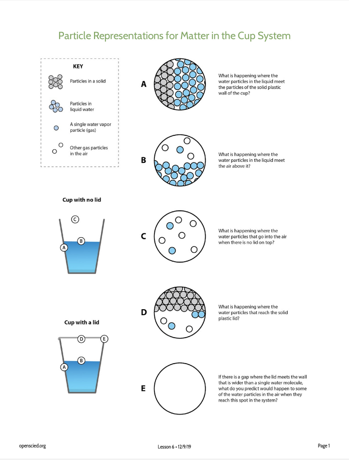
Focus students on using the marbles to simulate matter flow into or out of the cup system. Use the CCC as a lens to help students focus on making connections between the cups with and without lids and the models that students are building using the marbles.

4 · USE DIAGRAMS OF PARTICLES TO EXPLAIN MATTER MOVEMENT IN THE CUP SYSTEM

20 min

MATERIALS: science notebook, *Particle Representations for Matter in the Cup System*, whiteboard, markers

Introduce a diagrammatic representation of particles. Say, *When we try to show in future models how the particles in the cup system are interacting, we won't always have manipulatives like chips or marbles to work with. Often we will need to represent our thinking on paper. One way to do this is to draw the particles that make up solids, liquids, and gases as circles. Let's work through an example of this together.*



Pass out a copy of *Particle Representations for Matter in the Cup System* to each student, with the page folded over so students can see only the key on the left side. Direct them to that left side of the handout first. Show **slide G**. Give students a couple of minutes to discuss the questions on the slide with an elbow partner. If time permits, have a few partner pairs share out what they discussed.

Have students unfold the handout and secure it on a blank left page in their science notebook. After doing this, have them add arrows and/or letters to the right page of their science notebook, to indicate where they will record their answers to the five questions on the handout (*A*-*E*).

Orient students to zoomed-in circle *A*. Have students point to circle *A* in either cup diagram on the bottom left side of their handout with one hand, and point with the other hand to the zoomed-in view of *A* at the top right side of the page. In that zoomed-in view, have students point to the particles that represent the water molecules that can move around freely. Then have them point to the particles that represent the molecules of the solid that cannot. As a class, discuss the question next to this zoomed-in view of *A*.

Suggested prompt	Sample student response
What is happening at A where the water particles in the liquid meet the particles of the solid plastic wall of the cup? Why don't they leave the cup at this location?	*No water particles can fit through the spaces between the particles in the solid.* *And the solid particles don't move out of the way to let the water particles through.*

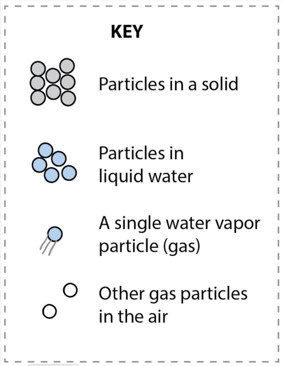
On the whiteboard, write a couple-sentence summary of student responses to this question. Have students write this summary as the answer to the first question for *A* in their science notebook.

Orient students to parts *B* and *C* of the model. Use the same pointing technique as for part *A* of the model to orient students to parts *B* and *C* of the model. Student responses to the questions for *B* and *C* should converge on the ideas listed in the sample student responses below. On the whiteboard, write a couple-sentence summary of student responses to each question. Have students write these summaries of the answers for *B and C* in their science notebook.

Suggested prompt	Sample student response
What is happening at B where the water particles in the liquid meet the air above it?	*Some water particles leave the surface of the liquid and become a gas and go into the air (evaporation).*
What is happening at C to the water particles that go into the air when there is no lid on top?	*The water particles that go into the air can leave the cup system when there is no lid.*

Introduce a need and a way to represent particle movement. Say, *You were suggesting that the particles in the liquid can move around and the particles of water that go into the air can too. We modeled that with chips and marbles. But with drawn diagrams, we can't move those circles on the paper, so we don't have a way to show motion. If we want to show that particles go from the liquid into the air, we need to represent their movement from one place to another. One way we could do that is by adding something like this to our drawing of the particles that are moving.*

Add three "motion lines" to a particle (or another representation chosen to represent movement).



Ask students which way it looks like this particle is moving. Students should say up and to the right. Say, *Sometimes you might be trying to show a particle of water going one way versus another, so you can adjust this "motion tail" to show the path it is traveling along.*

Have students add this representation to their handout's particle key for a single water vapor particle (gas), and have them add additional text to the key to say "moving through the air". An example is shown here.

Say, *At some point we might want to try to show that the particles of the liquid or air move around too. But for now let's just stick with thinking about the water that goes into the air as vapor and whether it leaves the cup or does not.*

Update the zoom-in views for *B* and *C* to show movement. Have students add motion tails to the water vapor particles moving through the air in the zoom-in views for *B* and *C*. Give students a minute to do this before introducing the next small-group task.

Assign groups to complete parts *D* and *E*. Emphasize that part *E* doesn't have a molecular model yet, and they will need to draw one to illustrate their thinking using the representations we have been using in *A* through *C*.

Monitor student discussions and written responses. Look for student responses that converge on the following ideas:

- For *D*: What is happening to the water particles that reach the solid plastic lid?
    - The water particles that go into the air run into the lid and then can't get out (they either bounce off it or collect on the inside of its surface).
- For *E*: If there is a gap where the lid meets the wall that is wider than a single water molecule, what do you predict would happen to some of the water particles in the air when they reach this spot in the system?

Some water particles in the air could escape the system (or enter it).

End of day 1

5 · UPDATE CLASS PROGRESS TRACKER

20 min

MATERIALS: science notebook, *Progress Tracker* or *Progress Tracker 2*, chart paper of key ideas from Lesson 4, chart paper, markers

Prepare for a class Progress Tracker update. Show **slide H**. Pass out a class Progress Tracker sheet (*Progress Tracker* or *Progress Tracker 2*) to each student. Have students add this sheet to the Progress Tracker section of their science notebook and record the lesson question in their Progress Tracker: "How does a lid affect what happens to the liquid in the cup?"

Facilitate a Consensus Discussion.✱ Have students bring their notebooks and chairs to meet in a Scientists Circle. Start with reviewing the record of key ideas you recorded on chart paper for the class in Lesson 4, which should include these:

- A cup with a lid causes a hot liquid in it to drop in temperature less than in a cup without a lid. The lid also slows down matter loss from the system.
- Matter has mass and takes up space.
- Liquids and gases are made of particles of matter.
- Particles in a gas have a lot of space between them, but those in liquids do not.
- Molecules of water in liquid form go into the air over time (evaporation).
- An open system has spaces where particles of matter can get in or out. A closed system is one in which no matter can enter or exit.

Review some of these ideas and identify new ideas to add about the particles that make up solids.

KEY IDEAS

Purpose of the discussion: Update the list of key ideas from the end of Lesson 4 to include new ideas about particles that make up solids.

Listen for the new ideas underlined here:

- Liquids, gases, and solids are made of particles of matter.
- Particles in a gas have a lot of space between them, but those in liquids and solids do not.
- Liquids and gases are made of particles that can move around freely, but solids are made of particles that cannot.

Suggested prompt	Sample student response
What evidence did we collect to be able to say that a cup with a lid causes a hot liquid in it to drop in temperature less than in a cup without a lid? And that the lid also slows down matter loss from the system?	*We all measured temperature changes and mass changes in cups of hot water with a lid and without. We found that the lidded cup dropped temperature less and lost less (or no) mass.*
Besides liquids and gases, what is the other type of matter we have started to model with particles?	*A solid.* *The solid wall and lid of the plastic cup.*
How do the spacing between particles and the way that particles can move in liquids and gases compare to the spacing and movement of particles in solids?	*Particles in a gas have a lot of space between them, but particles in liquids and solids do not.* *The particles in liquids and gases can move around freely , but the particles in solids cannot.*

Add new key ideas to the list. The non-underlined portion of the following text is from Lesson 4, and the underlined portion is the new ideas from this lesson:

✱ ATTENDING TO EQUITY

The key ideas shared in the teacher guide are suggestions for important ideas that the model could include. It is important, however, to appropriate the words and ideas that your students use and agree upon during this discussion. Your class's list of key ideas could be articulated differently and may include other ideas not listed here. Actively look for different ways that students share and represent their ideas as an opportunity to communicate to your students that different ways of representing our thinking are valuable.

- A cup with a lid causes a hot liquid in it to drop in temperature less than in a cup without a lid. The lid also slows down matter loss from the system.
- Matter has mass and takes up space.
- Liquids, gases, <u>and solids</u> are made of particles of matter. Particles in a gas have a lot of space between them, but those in liquids <u>and solids</u> do not.
- Particles in a gas have a lot of space between them, but those in liquids <u>and solids</u> do not.
- Particles of water in liquid form go into the air over time (evaporation).
- An open system has spaces where particles of matter can get in or out. A closed system is one in which no matter can enter or exit.
- <u>Liquids and gases are made of particles that can move around freely, but solids are made of particles that cannot.</u>

Have students add these underlined additions (and any other parts of the list they didn't record from the end of Lesson 4) to *What we figured out* on their class Progress Tracker sheets.

6 · EXPLAINING THE EFFECT OF DIFFERENT LID DESIGNS

20 min

MATERIALS: *Explaining the Effect of Different Lid Designs*

Introduce the assessment. Pass out the handout *Explaining the Effect of Different Lid Designs* to each student and show **slide I**. Read the scenario on the slide. Say, *Explaining how to test the performance of these two different lid designs and predicting the results of those investigations is your chance to demonstrate what you have figured out so far. This is an independent summative assessment. You can use anything in your science notebook or on the chart papers in our classroom to help you answer the questions on the handout.*

ASSESSMENT OPPORTUNITY

Question 2 on this assessment is designed to assess student progress in independently planning an investigation in which they identify controls, what tools are needed to gather data, and how much data are needed to support a claim about how much liquid (matter) leaves different cup systems.

Questions 3 and 4 on this assessment are designed to assess student progress in developing and using particulate models to account for how structural differences in different cup systems would cause different amounts of matter loss through evaporation.

Question 6 targets one part of one element of the practice of analyzing and interpreting data that students have worked with in Lessons 3 and 4. If students haven't had additional practice calculating a mean and explaining how to determine a mean in their math classes by this point in the year, you may want to remove this question from the assessment.

Use *Rubric for Model in Lesson 6 Assessment* to evaluate students' use of different elements of DCIs, CCCs, and practices in their responses.

7 · NAVIGATION

5 min

MATERIALS: sample container with airtight lid

Present results from an airtight system. Show **slide J**. Say, *There are some containers that are airtight, like this one.* Hold up a sample container with an airtight lid. Read the text at the top of the slide. Give students a moment to study the data in the data table. Read the question on the slide. Emphasize how strange this is, that even when no matter leaves the system, hot stuff inside still cools down and cool stuff inside still warms up. Have students discuss the question on the slide with an elbow partner.

Bring students back together, emphasizing that this is something you want to discuss more in the next lesson, so we can see what other ideas the class has for what might be going on to cause these changes in the liquid inside a closed system.

ALTERNATE ACTIVITY	If students are skeptical of there being no mass loss in the airtight container resulted presented in **slide J,** conduct an overnight closed system investigation. Use an airtight sealed container with cold water in it. Measure the initial temperature of the liquid and the mass of the system. Repeat these measurements the next day to determine any temperature change and/or mass change. The mass of the system should not change, but the temperature of the liquid will rise.

Lesson-Specific Teacher Materials

Lesson 6 Assessment Scoring Guide

+1's in red below indicate the important ideas to look for in student responses. They do not indicate a preferred scoring scheme. You can choose how to score or grade the assessment.

A beverage company wants to stop using plastic straws, so the company designs a new lid. The new lid has a much bigger hole than the old lid.

Alex, a scientist at the company, is wondering how this might affect what happens with the liquid inside the cup.

OLD LID

NEW LID

1) First, Alex does an experiment in which she fills 2 cups with cold liquid at the same temperature: 1 cup with the old lid and 1 cup with the new lid. She finds that the liquid in one cup warmed up more than the liquid in the other cup after 10 minutes. Which cup do you think warmed up more? Why?

+1 The cup with the new lid will warm up more.
+1 The new lid creates a more open system, which lets more stuff in or out of the cup system (matter, heat, cold, etc. ...)

2) Now, Alex wants to do a second experiment to see how the amount of liquid changes in the same 2 cups (1 with the old lid, 1 with the new lid) over time. She decides to leave them out for a month. She designs the following procedure:

- Fill each plastic cup with liquid and put the lid on the cup.
- Draw a line where the liquid level is on each cup.
- At the end of 30 days, weigh the 2 cups to see if there is a difference in mass between them.

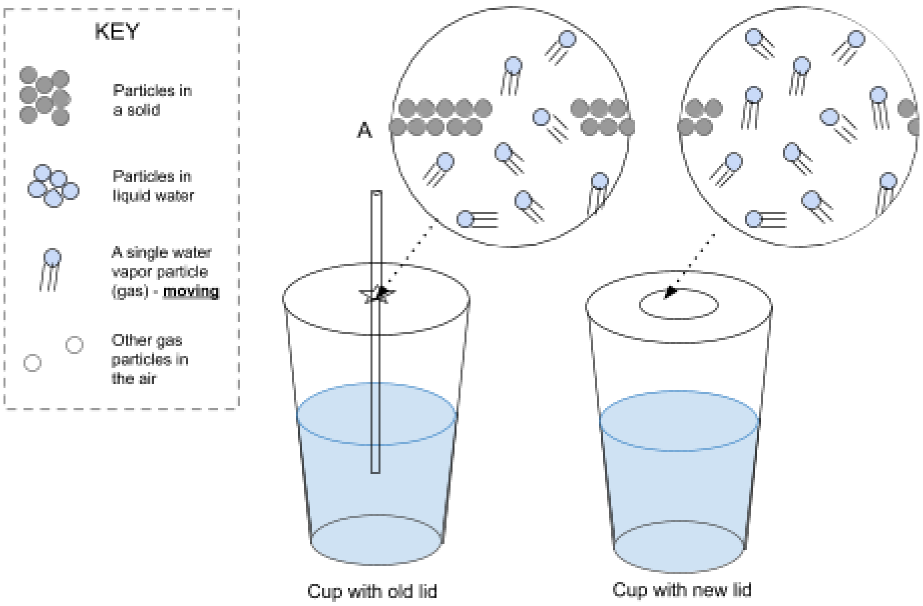
Fill out the table below to help Alex improve her investigation to produce more reliable results.

Question	Your Response
If Alex wants to use the mass of the liquid as her dependent variable, what other steps should she take to get the data she would need?	+1 Weigh the cups at the beginning of the experiment (day 1). +1 Calculate the difference between the weight at the beginning and the weight at the end of 30 days. +1 Have 3 cups of each type. +1 Calculate the average weight change, averaging the 3 cups for each cup type.
If Alex wants to use the liquid level as her dependent variable, what other steps should she take to get the data she would need?	+1 Draw a line where the liquid level is at day 30. +1 Calculate the difference between the liquid level lines from day 1 and day 30. +1 Have 3 cups of each type to measure. +1 Calculate the average liquid level change, averaging the 3 cups for each cup type.

To compare the 2 cups, what should Alex keep constant in her investigation?	+1 the type of liquid used +1 the size of the cups +1 the amount of liquid in each cup to start

3) Alex finds that one cup lost more liquid than the other. Add particle diagrams for the zoomed-in views at lid locations A and B to help explain how that could happen.

Possible Student Response below. Use *Rubric for Model in Lesson 6 Assessment* to assess.



4) How do your diagrams help explain how one cup could lose more liquid than the other?

- Use *Rubric for Model in Lesson 6 Assessment* to assess.

5) Think back to Question 1. Does your model help explain why one cup warmed up more than the other cup after 10 minutes? Why or why not?

Don't score this question but it will be helpful in figuring out what students are thinking as you move forward into the next lesson.

6) Alex repeats the Question 1 experiment 4 times. Each time, she records how much the liquid in the cup that warmed up the most changed temperature after 10 minutes. Here are her results:

Temperature change in °C	Trial 1	Trial 2	Trial 3	Trial 4
	2.4	2.6	2.7	2.3

Based on these data, what is the average temperature change for the liquid in the cup? ___2.5__ °C
+1 for answer in the blank space above: 2.5

How did you calculate this?
+1 They added the different results from each trial and divided the sum by the number of trials.

Name: ______________________________ Date: _______________

Lesson 6: Rubric

Rubric for Model in Lesson 6 Assessment

Components The model clearly represents or describes the system components and includes:	Category			Feedback
	Missing	Developing	Mastered	
• **water particles** in the air on the inside and outside of the lid of the cup				
• **system boundaries** in the form of particles that make up the solid material of the lid				
• **water particles moving** through the air				
Interactions between Components The model clearly represents or describes the following:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• solid particles with spacing between them (that is less than the width of the diameter of a water particle) to represent the edge of the lid near the opening *(pattern/structure)*				
• a gap in the solid particles to represent the opening or the start of the opening *(pattern/structure)*				
• more water particles leaving the system with the large opening *(cause/effect)*				
• some water particles moving through the air and colliding with the solid structures or being prevented from passing through the solid structures *(pattern/structure)*				

LESSON 7: If matter cannot enter or exit a closed system, how does a liquid in the system change temperature?

PREVIOUS LESSON *We used a model to show why water molecules cannot leave a cup at some points in the cup system but can at other points. We completed an individual assessment that included making predictions about the performance of a cup with a new lid design, developing a plan for collecting data to measure its performance and developing a model to explain a set of results.*

THIS LESSON

PROBLEMATIZING

1 day

We consider what we know about the components (or structures) of the closed cup system, how they function, and how they interact with one another and with other objects and substances outside of the cup system to determine what else might a temperature change in the liquid inside. We develop models to represent our ideas about interactions between energy (light, heat, or cold) and the closed cup system. We use these models to explain the temperature change, and we determine ways to test our ideas to figure out how energy interacts with the closed cup system.

NEXT LESSON *We will investigate whether light warms up water inside cups and how the cup surface affects this warming. We will shine light on various cups and measure temperature changes in the water inside. We will measure the amount of light that transmits through and reflects off the cup surfaces to test our ideas. We will also measure temperature changes of water in cups in the dark.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Develop two models to show relationships among the parts of the mostly closed cup system and how light and heat or cold (i.e., mechanisms) cause the liquid inside to warm up or cool down (effect).

WHAT STUDENTS WILL FIGURE OUT

- Since most of the matter does not enter or leave the cup system with a lid, light and heat or cold may interact with the system to cause a temperature change in the liquid inside.

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION AND DQB** Gather students together to take stock of what they have figured out and still need to figure out about the cup system.	A	Driving Question Board, chart paper, markers
2	10 min	**BRAINSTORM OTHER POSSIBLE CAUSES OF THE TEMPERATURE CHANGE** Brainstorm ideas for what might be causing the temperature change in the liquid inside the closed cup system.	B	chart paper, markers
3	28 min	**USING MODELS TO REPRESENT OUR THINKING** Guide students to construct models that represent how they think light and heat or cold interact with a closed cup system to change the temperature of the liquid inside.	C-D	chart paper, markers
4	2 min	**NAVIGATION** Summarize for students that they should investigate their ideas regarding both of these mechanisms, beginning with light because they have more background ideas with respect to light.		

End of day 1

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials	• science notebook		• Driving Question Board • chart paper • markers

Materials preparation (10 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

In the first lesson set (lessons 1-6), students investigated a variety of cup systems to determine the effectiveness of each in maintaining the temperature of either a hot or a cold liquid inside the systems. Students figured out that certain structural features helped some cup systems perform better than others. For example, cup systems with walls of more than one layer outperformed those with a single layer, and those with a lid (closed systems) outperformed those without a lid (open systems). Students also determined that matter can't enter or leave a closed system (conservation of matter); however, the temperature of the liquid inside the closed cup system still changes. In this lesson, students use the problematizing routine to determine other possible mechanisms that might cause temperature change in the liquid inside the closed cup system. Ideas are shared and documented. Students work together to determine possible ways to investigate how light interacts with different closed cup systems and if light is causing the temperature change in the liquid inside. As we move further into the second lesson set (Lessons 7-14), students will investigate the role of energy in the cup system and use models to represent the effects of energy on the parts of the system at the particle level.

Where We Are NOT Going

Students have investigated certain structural features of a variety of cup systems, and they have noticed that some materials seem to work better than others; however, this has not been a major focus of students' investigations up to this point. Investigations have focused on building an understanding of the cup system's components and the significance of a closed system in terms of matter. This next lesson set (Lessons 7-14) includes investigations that give students opportunities to build their understanding of the effects of energy at the particle level on the different types of matter that are interacting within and across the cup system. It is not until lesson set 3 (Lessons 15-18) that students focus on the properties or characteristics of the different materials that seem to work better than others, such as corrugated cardboard, styrofoam, and insulated double-walled cups.

LEARNING PLAN for LESSON 7

1 · NAVIGATION AND DQB

5 min

MATERIALS: Driving Question Board, chart paper, markers

Prompt student to answer questions from the DQB. Display **slide A** and say, *Up to this point in our unit, we have figured out a few things that are important to understanding how the cup system works.* Ask students to read the slide and take a moment to quietly think about each question.

Then prompt students to turn to a elbow partner and discuss the questions. Tell them to be prepared to share their thinking with the whole group. After a few minutes of partner-talk, call on a few students to share their ideas. Document students' responses to the last question on a sheet of chart paper under the title "What do we still need to figure out?"

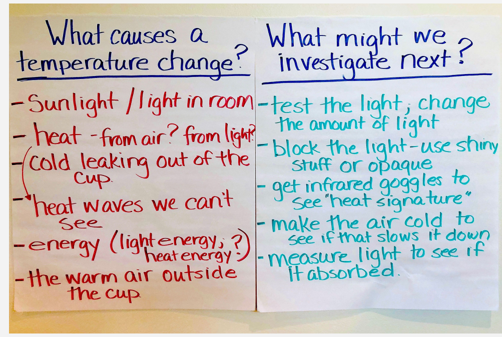
Suggested prompt	Sample student response
What have we figured out about closed cup systems?	*We figured out that matter cannot enter or leave a closed cup system. The cup system is almost closed, but not completely closed.*
What questions can we now answer on our DQB?	*Answers will vary, but will include questions about the lid and how open the cup system is around the lid and straw area.*
How did we figure out answers to these questions?	*We measured the mass of the mostly closed cup systems before and after water droplets formed on the outside of the cup. The mass of each cup system went up, which meant that the droplets on the outside of the cup did not come from the inside.* *We saw that the droplets on the outside of the cup systems were clear, even when the water on the inside was dyed with food coloring.* *We investigated hot liquids in open and closed cup systems, and saw that hot liquids cannot leave closed systems, even though evaporation still happens inside. We checked this by measuring the mass of open and closed cup systems and an airtight container.*
What do we still need to figure out?	*The temperature of the liquid inside the completely closed cup system still changes, even though matter does not enter or leave the system. So, we still need to figure out how that happens.*

ALTERNATE ACTIVITY

If you chose to conduct the alternate activity suggested at the end of Lesson 6 (*Overnight Closed System Investigation*), students can begin this lesson by checking the setup from that investigation. They should record observations and data in their science notebooks and calculate the changes that occurred in the temperature of the liquid in each closed cup system. (Students may also want to use the digital scales to verify that the mass of each system has not changed.) After analyzing the data, students can work together to construct a claim supported by evidence. You should expect students to claim something similar to: "The temperature of the liquid inside a closed cup system changes even when no matter can get in or out of the system." From this point, you can begin brainstorming ideas for other possible causes in this lesson.

MATERIALS: chart paper, markers

Brainstorm ideas in small groups. Display **slide B**. Direct students' attention to the questions on the slide and ask, *What else could be causing the temperature of the liquid inside the closed cup system to change? Can anything else go into, out of, or through the cup walls and/or the lid?*✱ Tell students to gather in groups of three with students sitting near them. Give students 1-2 minutes to brainstorm ideas with their small groups. Encourage students to think "outside the box," especially when considering that nothing made of matter can enter or leave the closed system. Tell them to be prepared to share their thinking with the whole group.



Narrow the list of ideas to investigate. After students brainstorm in small groups, facilitate a discussion to surface ideas of possible causes for the temperature change in the liquid inside the closed cup system. If necessary, help students narrow their ideas to one or two possible causes that they can investigate. Document their ideas for next steps on a second sheet of chart paper under the title "What might we investigate next?"

Suggested prompt	Sample student response
What have we determined is not leaving or entering the system?	*Matter cannot enter or leave the system. It can change state and change temperature, but it stays inside the system.*
What did we decide could be happening that does not include matter flowing into or out of the system? That is, what else might be interacting with the system, even though it is closed?	*Somehow, the temperature is changing. If matter is not going in or out, maybe energy is involved. Maybe energy is entering or leaving the system.*
Are there parts of the system that we need to include that we didn't include before?	*We need to investigate the idea that energy is entering or leaving the system.* *It might be light, or heat, or cold causing the change in the temperature of the liquid inside.* *We might also need to think more about the parts of the cup and the role they play in the change in temperature of the liquid inside.*
What would make the most sense to investigate next?	*It might make sense to investigate how light affects different cup systems, since we already know some things about light..* *It might make the most sense to investigate heat, since temperature is a measure of the "hotness" or "coldness" of things.*

Summarize the discussion. Now that students have some ideas regarding mechanisms that might be causing the temperature change in the liquid inside the closed cup system, summarize the discussion by saying, *Some of us think heat or cold is something we should investigate as the cause for the change in temperature of the liquid. Others think we need to investigate light. It sounds like we are interested in energy. Let's think about how we could represent our thinking about energy going into or leaving the cup system using models.*

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

Use this moment as an opportunity to focus students on systems modeling as a way of tracing inputs and outputs of the cup system. The purpose of lesson set 1 (Lessons 1-6) was to establish that the warming and cooling temperatures of liquid inside the cup system were not primarily a result of matter entering or exiting the system, and therefore something else must be entering or exiting the system.

3 · USING MODELS TO REPRESENT OUR THINKING

28 min

MATERIALS: science notebook, chart paper, markers

Get students set up to model mechanisms of temperature change. Tell students, *Based on our thinking, we need to figure out if light and heat or cold are interacting with some or all of the components of the closed cup system, and if these interactions are causing the temperature change in the liquid inside. We've been focused on matter, but now we want to look at energy. Often, scientists use models to represent their thinking, even if they do not have a complete understanding of how a system works. I think we need to do the same and represent our thinking using models. This will help us figure out which ideas we should test and how to test them.*✱

Ask students to open their science notebooks to the next available page, then show **slide C**. Describe to students how to set up their notebooks.

Prepare to model light interactions with the closed cup system. Give students a minute or two to prepare their science notebooks, then move to **slide D**. Say, *We have decided that we need to think about light and heat or cold as mechanisms that may cause a temperature change in the liquid inside the closed cup system. So, let's think about what we know about light and heat or cold and what our models need to include to represent our ideas.* Animate the left text box on **slide D**, then use the questions below to help students think about how they could model light interacting with the closed cup system and how those interactions might affect the temperature of the liquid inside.

Suggested prompt	Sample student response
How does light interact with different materials, such as clear plastic and metal?	*Light transmits through transparent materials, like the clear plastic that some cups are made of.* *Light reflects off of smooth surfaces, like mirrors and smooth metals.* *Light may be absorbed by the water or the cup.*
How might light shining on the closed cup system cause the liquid inside to change in temperature?	*When light interacts with matter, it heats up the matter that it comes into contact with.* *Light energy transmits through the clear plastic cup and might be heating up the water inside the cup when it does this.* *Light reflects off of the metal, and some of the light is absorbed by the metal. The absorbed light could cause the metal to warm up, which might cause the water to warm up too.*
How might you represent your thinking using a model?	*I can use arrows to show how light interacts with cups made of different things.* *I can use arrows to show where light is reflected or transmitted, and I can use words to describe how the light that is absorbed heats up the material that absorbs it.* *I can use color (or words) to show that the liquid inside the closed cup system is warming up or cooling down.*

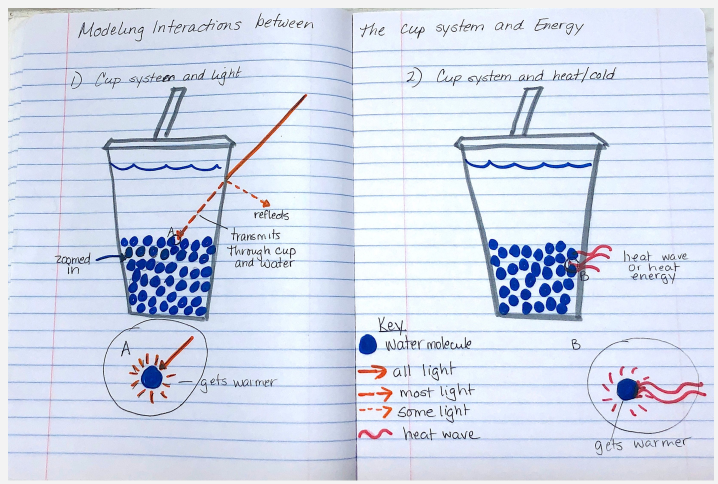
✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

As students prepare to model energy interactions with the closed cup system, set the expectation that their models should reflect their current understanding of light and heat or cold. Since students are just now beginning their study of heat, their models of the interactions between heat and the cup system may lack details. On the other hand, students do have prior classroom knowledge about how light interacts with materials. This will probably lead to models that have more detail, and students may find it easier to represent light interactions because they can access their prior knowledge. These outcomes are to be expected. Encourage students to represent in their models what they know *and* what they do not yet fully understand but think could be happening.

Prepare to model heat interactions with the closed cup system. After students have shared their thinking about light, animate the right text box on **slide D**, then use the questions below to help students work through the same process as they think about heat or cold interacting with the closed cup system and then share their thinking. It might be helpful to connect students' own experiences with heat to help them think about how heat might be interacting with the components of the cup system and the liquid inside.✱

Suggested prompt	Sample student response
How does heat move? Does cold move too?	*We don't know as much about heat. We do know that objects can warm up and cool down, but we are not sure how heat (or cold) moves.*
How might heat (or cold) cause the liquid inside the closed cup system to change in temperature? Do you have any similar experiences that might help you model this idea?	*We know from our own experiences that when something cold touches something warm, the cold object warms up. For example, when we place our cold hands under warm water, our hands warm up. When we place an ice cube on a hot sidewalk, it warms up and melts. The same thing might happen if cold liquid inside the cup comes into contact with a warmer cup.*
How might you represent your thinking using a model?	*I can use words to describe my ideas as I draw a model of the cup system.* *I can use color (or words) to show that the liquid inside the closed cup system is warming up or cooling down.*

Construct models of light and heat interactions with the closed cup system. Show **slide E** and say, *In your notebooks, construct two models--one for light and one for heat or cold. Your models should show how you think each of these interacts with the closed cup system and how those interactions could cause the temperature of the liquid inside the system to change.*



Have students work independently in their notebooks. After 10 minutes, some students may not yet be finished, but this is a good time to share an additional requirement for the models. Animate **slide E** and tell students, *As you finish your models, you will need to make a claim to accompany each model. Your claim should answer the question: "How do you think ________ causes the temperature of the liquid inside a closed cup system to change?" Make sure your claim is then supported by evidence and your reasoning for how this happens.*

Note that students may draw "heat waves" as shown in the example model. While this representation is inaccurate, it reflects students' current understanding of heat. From Lesson 8 to 14, one important goal is to refine students' understanding of heat as the transfer of energy at the particle scale, therefore a new understanding of heat will necessitate a new representation.

Give students the remaining time in this section to complete their models and write their claims.

ASSESSMENT OPPORTUNITY	This is a good opportunity for formative assessment of student understanding based on an examination of students' models and claims. When analyzing students' work, keep in mind that students bring more prior knowledge about light than heat, and their models should reflect this. Their models of light interactions with the closed cup system should be much more detailed and should include references to the concepts learned in the previous unit, *Light and Matter*. Likewise, their claims should include evidence gathered during this unit. In contrast, students' models and claims in regards to heat energy or cold will more likely include references to their personal experiences. In either case, students' work should give you information about what they do and don't yet understand, which should guide your instructional decisions in the next few lessons. Keep in mind that formative assessment is not about giving grades but rather giving students feedback on their work in a timely manner, whether as written comments in their notebooks or as verbal feedback. It could include pointing out strengths you observe in their work, such as good connections made by referencing prior learning or experiences, or the skillful construction of a claim supported by evidence and reasoning. Feedback can also include suggestions for improving areas of weakness, but that should not be the only focus.

4 · NAVIGATION

2 min

MATERIALS: None

Preview the next investigation. Tell students, *Next, let's explore both of our ideas, starting with light because we seem to have a better understanding of how light interacts with different materials, and we have some prior knowledge in how to investigate light interactions.*

Additional Lesson 7 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.W.6.1.a: Introduce claim(s) and organize the reasons and evidence clearly.** In this unit's second lesson set (Lessons 7-14), students begin to develop their argumentation skills. This lesson introduces students to making claims based on initial models for mechanisms that may cause warming of the liquid inside the cup. These mechanisms will be more or less supported by evidence and reasoning based on students' prior knowledge. Students' claims for how light could warm the drink inside the closed cup system should be more clearly articulated and supported by evidence compared to students' claims about heat or cold.

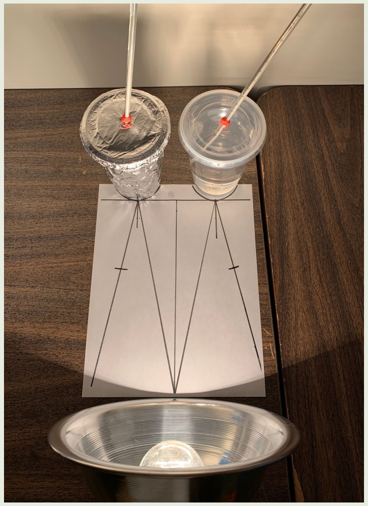
LESSON 8: How does a cup's surface affect how light warms up a liquid inside the cup?

PREVIOUS LESSON *We considered what we've learned about the interactions occurring within the closed cup system to determine other possible explanations for a temperature change in the liquid inside. We developed models that represent how light, heat, or cold (i.e., energy) might be interacting with the system to cause the temperature change, and we determined ways to test our ideas.*

THIS LESSON

INVESTIGATION

2 days



We carry out an investigation to test the interaction between light and the cup surface in warming up the cold water inside the cups. We shine light on cups with walls of different materials and colors and measure the amount of incoming, reflected, and transmitted light, and we also place some cups in a completely dark condition. We figure out that the water in all the cups warms up, even cups in the dark condition, but it warms up more in the cups in the light conditions. We wonder about additional mechanisms by which the water inside the cups warms up.

NEXT LESSON *We will carry out an investigation to test whether heat or cold moves into or out of a cup system. We will gather temperature data inside and outside the system to see if the temperature goes up on one side when it goes down on the other side. We will analyze the data to assess the movement of heat or cold through the cup wall and the transfer of energy between the inside and the outside of the cup system.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Develop and use models to describe how light transmission through, reflection off, and absorption by cup walls causes changes in the temperature (effect) of water inside the cup.

WHAT STUDENTS WILL FIGURE OUT

- Light can transfer energy into a system.
- When light that shines on a surface is not reflected or transmitted, it is absorbed, which warms the matter it shines on.
- Temperature changes in the water can still occur even if light does not transmit through the cup wall and even if there's no light.

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Prompt students to revisit their ideas from Lesson 7 about how light affects the temperature of water inside a clear plastic cup and how to test their ideas through investigation.	A-B	
2	35 min	**LIGHT AND TEMPERATURE INVESTIGATION** Monitor students as they conduct an investigation of how light warms up water differently in cups with different surfaces. Place a set of cups in the dark as well. Demonstrate how to take light readings. Collect and record temperature and light measurements.	C-J	calculator, note cards and tape, markers (optional), class Temperature Change table, markers, Light and Temperature Investigation
				End of day 1
3	3 min	**NAVIGATION** Remind students about the purpose of the investigation and the controls used to answer those questions.	K	class Temperature Change table
4	22 min	**ANALYZE DATA FROM LIGHT AND TEMPERATURE INVESTIGATION** Facilitate a Building Understandings Discussion to conclude students' analysis and interpretation of data from the light and temperature investigation.	L-P	calculator, class Temperature Change table, whiteboard and chart paper, markers
5	15 min	**DEVELOP MODELS TO EXPLAIN TEMPERATURE CHANGE** Guide students as they draw models to explain how light warmed up water differently in clear versus opaque cups.	Q	*Explaining Temperature Changes in Each Cup*
6	5 min	**UPDATE PROGRESS TRACKER AND NAVIGATION** Have students add an entry to their Progress Tracker. Motivate the next lesson to explore students' ideas about heat and cold.	R	
				End of day 2

Lesson 8 • Materials List

	per student	per group	per class
Light and Temperature Investigation materials	• *Investigating Light's Effect on Warming Up Water*	• Group A's: 1 lamp with 100-W light bulb 1 *Light Measurement Template* 2 thermometers 1 500-mL beaker 1 16-oz clear plastic cup and lid 1 16-oz foil-wrapped cup and lid timer (optional) • Group B's: 1 lamp with 100-W light bulb 1 *Light Measurement Template* 2 thermometers 1 500-mL beaker 1 16-oz white-painted cup and lid 1 16-oz black-painted cup and lid timer (optional) • Dark Group: 4 thermometers 1 500-mL beaker 1 16-oz clear plastic cup and lid 1 16-oz foil-wrapped cup and lid 1 16-oz white-painted cup and lid 1 16-oz black-painted cup and lid access to a dark cabinet or box timer (optional)	• 4 2-L pitchers of cold water chilled to 6°C (800 mL per Groups A and B and 1200 mL for Dark Groups) • 1 16-oz clear plastic cup and lid • 1 16-oz foil-covered cup and lid • 1 16-oz white-painted cup and lid • 1 16-oz black-painted cup • 2 lamps with 100 W light-bulbs • 1 light meter • 2 *Light Measurement Template*
Lesson materials	• science notebook • calculator • *Explaining Temperature Changes in Each Cup*	• note cards and tape • markers (optional)	• class Temperature Change table • markers • whiteboard and chart paper

Materials preparation (60 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Ahead of time, make a class *Temperature Change* table on chart paper for pooling data across groups. This table can be reused from class to class if students post their data on it with note cards and tape.

Analyze and interpret the class data from day 1 in preparation for the discussion in day 2. See relevant guidance between days 1 and 2 for more information.

Day 1: Light and Temperature Investigation

- **Group Size:** 3
- **Setup:** Chill pitchers of water in the refrigerator overnight to 6°C. You will need approximately 800 mL per Groups A and B and 1600 mL for the Dark Group. Use the directions in *How to Make the Test Cups for the Light and Temperature Investigation* to create the cups for the investigation. Make 1 copy of the handout *Investigating Light's Effect on Warming Up Water* for each student. Make 1 copy of the *Light Measurement Template* for each Group A and Group B (but not the Dark Group). Prepare lab bins for the groups with these investigation materials:
    - Group A's: 1 lamp with 100-W light bulbs, 1 *Light Measurement Template*, 2 thermometers, 1 500-mL beaker, 1 16-oz clear plastic cup and lid, 1 16-oz foil-wrapped cup and lid, timer (optional)
    - Group B's: 1 lamp with 100-W light bulbs, 1 *Light Measurement Template*, 2 thermometers, 1 500-mL beaker, 1 16-oz white-painted cup and lid, 1 16-oz black-painted cup, timer (optional)
    - Dark Group: 4 thermometers, 1 500-mL beaker, 1 16-oz clear plastic cup and lid, 1 16-oz foil-wrapped cup and lid, 1 16-oz white-painted cup, 1 16-oz black-painted cup, access to a dark cabinet or box, timer (optional)

Day 1: Class Light Measurement

- **Group Size:** Whole class

- **Setup:** Using the *Light Measurement Template*, set up 2 lamps and 2 light meters with one set of the 4 test cups and lids (clear plastic, black-painted, white-painted, and foil-covered) to demonstrate light measurements at the front of the classroom.
- **Notes for during the lab:** Darken the room as much as possible by closing shades and turning off floor lamps. Some light from windows is OK. You can leave the classroom lights on until it is time to collect data. Monitor students to make certain they are recording the light measurements appropriately.
- **Storage:** Remove batteries from light meters for long-term storage.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students used models to consider how light could explain how liquids warmed up inside cups, and they devised ways to test those ideas. Students referred to light as a source of energy that could be transferring into the cup. In this lesson, students carry out an investigation to test light's role in warming up cold water and observe how various cup surfaces affect this process. Students shine lights on the test cups and measure the amounts of incoming, reflected, and transmitted light. Students also place cups in the dark as a comparison.

Students figure out that when a cup surface transmits light, the water inside warms up more than when the surface reflects light. Students also think about light that is absorbed by the surface of the cup and by the water inside, and they make conclusions about the role of light absorption in causing the water to warm up. Additionally, students observe that the water warms up even in cups in dark conditions. Thus, students realize that light is only part of the explanation and create the need to figure out additional mechanisms beyond light absorption by which the water can warm up. We consider what else might be moving through the cup walls that could lead to temperature changes.

As much as possible, try to reference changes in the water's temperature as "warming up" (or "cooling down") rather than "heating up." Encourage students to think about energy entering the cup systems. "Heating up" involves the word "heat," which we want to reserve for describing the *amount* of heat that is moving from one place to another and resulting in a temperature change (Lessons 9 and 14).

Where We Are NOT Going

Students will collect evidence in this investigation to associate the absorption of light with an object's temperature. However, we are not yet explaining the mechanism by which this occurs or what leads to these changes beyond the absorption of light as an energy transfer at the macroscale. In Lesson 15 students will revisit the absorption of light at the particle scale to explain mechanistically how energy transferred from light leads to an increase in kinetic energy of particles.

In addition, it is not necessary for students to use the term *radiation* for this type of energy transfer, as this will be articulated after students have constructed their models of energy transfer through conduction later in the unit (Lesson 15). Students may refer to the light as giving energy to the water inside the cup. It is OK for students to use the term *energy* in a loose way. Students will talk more explicitly about the relationship between changes in temperature, particle motion, and kinetic energy in Lessons 11-12.

LEARNING PLAN for LESSON 8

1 · NAVIGATION

10 min

MATERIALS: science notebook

Review our ideas about the role of light. Display **slide A**. Ask 2 students to summarize the ideas that were raised in the last class about how light could affect the temperature of the water inside a clear plastic cup. After students share, emphasize that we are trying to figure out how water inside the cup warms up without matter entering or leaving the cup system. In the previous lesson we settled on the idea that energy from light and heat or cold could change the temperature of the water.

Motivate the need to investigate different cup surfaces. To broaden our understanding of this phenomenon, have students consider how their model for explaining the role of light might apply to cups composed of various materials and surfaces that transmit different amounts of light through the cup wall. Display **slide B**. Say, *So we've been thinking about these clear plastic cups and we know that light passes through their walls. When we discussed your models, some of you mentioned blocking the light, so that got me thinking about using cups that could reflect some or all of the light. These types of cups are common, like the cups you can buy for a birthday party. There are other types of plastic cups that are solid colors* (hold up/point to an opaque cup). *We've also thought about metal cups.*✱

Say, *Do you think light would affect water in an opaque cup in the same way as in the clear plastic cup? What do you think would be similar or different?* Ask students to turn to a elbow partner for 2 minutes to discuss their ideas. Encourage students to use the light models they created for the clear plastic cup as the basis for developing their ideas.✱

Elicit students' predictions. Bring the class together and poll students' ideas about how the water temperature in an opaque cup would compare to the water temperature in a clear plastic cup if they were left in the light for the same amount of time. Say, *Do you think light might affect the water's temperature differently in the different cups, or not?* Have students raise their hand to indicate which statement they agree with: say, *Raise your hand if you think that the water in the opaque cup would be warmer than the water in the clear plastic cup ... cooler than the water in the clear plastic cup ... the same as the water in the clear plastic cup.*

Prompt 1-2 students to share their reasoning for each choice. Example prompts are included below.

Suggested prompt	Sample student response
For those who thought that the water in the opaque cup would be a different temperature than the water in the clear plastic cup, why do you think so?	*I think the water in the opaque cup will be cooler because light can't transmit through the cup. If light can't get through, it won't warm it up.* *I think the water in the opaque cup will be warmer because it absorbs the light and warms up the water like an oven.*
For those who thought that the water in the opaque cup would be the same temperature as the water in the clear plastic cup, why do you think so?	*The same amount of light is going to hit the cup and then warm up the water.*

Ask, *Do you think that the cup's color would affect the water's temperature? Why or why not?* Example responses and follow-up questions are listed below.

✱ ATTENDING TO EQUITY

After describing the types of cups and predicting the amount of light that would transmit through their walls, refer to these objects as *transparent* and *opaque* and have students practice using these words throughout this lesson. These terms should already be on your word wall as words earned in the light and matter unit, but continued practice applying them in new context will benefit students' vocabulary development, particularly for emergent multilingual learners.

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Throughout this conversation, encourage students to look at their science notebooks and use their models for light's interaction with the clear plastic cup as a starting point to generate predictions about how the interaction would change if the cup's material (a variable in the system) were to change.

Suggested prompts	Sample student responses	Follow-up questions
How do you think the color of the cup's surface might affect the water's temperature?	*The water in lighter-colored cups will be cooler than water in darker-colored cups because some of the light reflects off the cup. So less light will get to the cup.* *The water in darker-colored cups will be warmer than water in lighter-colored cups because the darker surface absorbs more light and warms up the water.* *The water in the darker-colored cups will likely be cooler because the surface blocks more light from entering the water.*	*What does it mean for some light to be absorbed?* *What evidence do you have from your previous experiences that the cup's color might affect the water's temperature?*

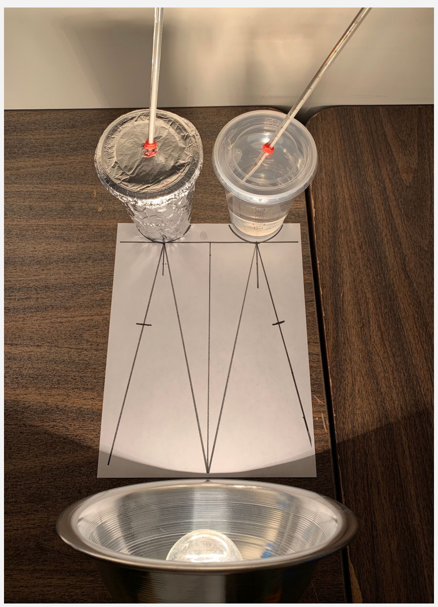
Explain that in the next part of the lesson, we are going to conduct an investigation over two days to test our ideas about light's role in warming up (or not warming up) the water in a cup and how various cup surfaces might affect how light interacts with the cups.

2 · LIGHT AND TEMPERATURE INVESTIGATION

35 min

MATERIALS: Light and Temperature Investigation, science notebook, calculator, note cards and tape, markers (optional), class Temperature Change table, markers

Explain the purpose of the investigation. Display **slide C** and distribute the handout *Investigating Light's Effect on Warming Up Water* to each student. Set up the cups for the class light measurements in the front of the classroom and show students the types of cups we will be testing.



✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Students have used their models to brainstorm predictions about how light interacts with the surface of various materials. In this investigation, focus students on using their models to plan for testing their ideas and gathering data about how light warms the liquid in their cup systems. As students work, help them stay focused on thinking about how the investigation is testing light as an energy input to the cup systems, even though we cannot observe the energy itself.

Explain that we will use this investigation to answer the two questions on the slide. Read aloud, *Does light affect the temperature of the water inside the cup system?* To answer this question, students will compare the temperature of water in the cups in light and dark conditions.

Read aloud, *How does the cup surface affect how light warms up the water inside the cup?* To answer this question, students will shine light on various types of cups.✱

ADDITIONAL GUIDANCE	*How to Make the Test Cups for the Light and Temperature Investigation* provides directions for preparing cups to test in the investigation. Modify the lab according to class size. Ideally you want at least 2-3 Group A's testing the clear plastic versus foil-covered cups and 2-3 Group B's testing the white-painted versus black-painted cups. You can either have only 1 Dark Group or modify the lab to have 2-3 groups test the dark condition. Students will pool their data to calculate averages, so having several Group A's and Group B's is important, and it could also be beneficial with the dark condition if your class is large enough.

Explain the purpose of each cup type. Because we have already identified the importance of lids, you have modified the clear plastic cups we have been investigating because they have lids and are all the same size. Use the pictures on **slide C** to point out the different test cups. The foil-wrapped cup is a proxy for a metal cup with a lid and a reflective surface. Students will use the white- and black-painted cups to investigate how the color of opaque cups affects how light warms up water inside them.

Display **slide D**. Ask, *In which cup do you think water would warm up the most? The least?* Give students a minute to turn and talk. Then bring them back together and poll the class about their ideas, but do not elicit students' justifications right now. Have students record their predictions on their handout.

Give an overview of the investigation. Display **slide E**. Explain that the class will be working in groups of 3 to figure out how each cup surface affects how light warms up the water inside the cup system. Some groups (Group A's) will test the clear plastic cup and the foil-covered cup, while others (Group B's) will test the painted cups, and at least one group will test all 4 cups in the dark (there may be more than one Dark Group if you have a large class). Show students the cabinet or box that you have set aside for the cups in the dark condition.

Explain that while we are waiting to see if the water temperature changes in the cups in the light and dark conditions, we will form a Scientists Circle to measure how much light hits, transmits through, and reflects off each cup surface in the light condition.

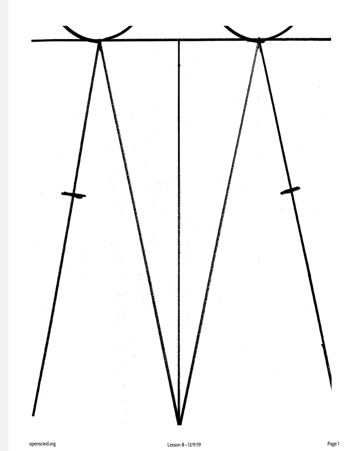
Assign students to Group A's, Group B's, and the Dark Group(s). Distribute the lab bins of materials.

Explain the lamp setup. Display **slide F** to show students how to use the *Light Measurement Template* to position the cups with respect to the lamp. This will be relevant for Groups A's and B's. Demonstrate how to adjust the clamp so that the lamps are standing as vertically as possible. The edge of the lamp should be flush with the edge of the template, with the center line aligned with the light bulb. Ask, *Why do you think we are using this template to position the cups and take our measurements?* Students should articulate reasons that include ensuring that all the cups are the same distance from the light source and that the measurements are taken at the same place for each cup.

Explain that the Dark Groups will conduct the investigation in the dark.

Explain the temperature setup and averaging data. Display **slide G**. Explain that when they set up their test cups, students should insert a thermometer through the lid's straw hole and position it so that they can easily read the temperatures above 0°C. You will provide the initial temperature reading based on the temperature of the water in the pitchers. Ask a student to use a thermometer to measure the classroom's ambient temperature, which everyone should record on their handout. Explain also how students will average their data.

Begin the temperature investigation. Have the groups set up their materials according to the template and the *Water Temperature Procedures* in their handout. When all the groups are ready, prompt students to pour 400 mL of cold water into each test cup, place the lid on each cup, and start the timer. Remind students that after 15 minutes, they will record their final temperatures in the data table on their handout and calculate and record the temperature changes. Remind them that one person from each group will record their data on the class *Temperature Change* table in the rows for their cup types.



Collect light measurements as a class. Have students gather in a Scientists Circle around the two lamps at the front of the class. Remind students to keep an eye on the time so that they are able to collect all of their temperature measurements at the 15-minute mark.

Display **slide H**. Show students how to use the *Light Measurement Template* and the *Light Measurements Procedures* on their handout (*Investigating Light's Effect on Warming Up Water*) to guide their measurements of the incoming, reflected, and transmitted light for each cup. We have found that the key to collecting reliable data is measuring the light for each cup in the same location. The sample data provided below was collected with the cups positioned on the left side of the template.

Display **slide I**. Ask volunteers to take each light measurement for each cup and record them on chart paper titled *Light Measurements*. Take 2-3 measurements and then average them as a class. Students can record the averaged class data on their handout.

ADDITIONAL GUIDANCE

When taking incoming and reflected light measurements, the light meter should be held horizontally with the center of the light sensor aligned with the template's center line. **Reflected light** should be measured by having the sensor aligned with the center line, facing the cup and behind the dash. **Transmitted light** should be measured by placing the light sensor vertically inside the cup so that it hits the bottom and is close to the cup wall. **Incoming light** should be measured by aligning the sensor over the center line with the back of the sensor hitting the cup.

As much as possible, use new light bulbs so that the amount of incoming light is comparable across groups. Due to expected fluctuation in the data, encourage students to use the highest number that is consistently displayed on the light sensor.

It might be helpful to calculate the ambient light levels. Hold the light meter with the sensor facing upwards approximately 1 foot above the template in front of the second lamp. This measures the amount of light around the system that could be detected by the light meter. It is not necessary to subtract the ambient light from the collected measurements. However, it is helpful for students to know about the ambient light, particularly when light is detected while measuring light transmission through the opaque foil (see sample data below).

Explain the rationale for measuring percentages of light. Explain that the light meters are very sensitive and there might be some variability with the lamp setups (slightly different positioning or light bulbs). Therefore, students will be calculating the percentage of incoming light that transmits through and reflects off the cup walls to account for any variability with the lamps. In addition, the percentages help us focus on what portion of the incoming light actually contributes to warming up the water.

Display **slide J**. Use the sample data on the slide to help students practice calculating the percentages of transmitted and reflected light. Students will use the formulas on *Investigating Light's Effect on Warming Up Water* with the class light measurement data to calculate the percentage of incoming light transmitted through and reflected off the cup walls and record their percentages on their handout.

Students can calculate the percentages in their small groups either before or after collecting their water temperature data, as time allows. Have students complete the *Light Measurements Procedures* through step 3, but stop before the *Analysis* section.

Gather the final temperature data. Stop students working on light calculations, if necessary, to reconvene their small groups at the 15-minute mark. Direct students to record their final temperature measurements and calculate the temperature changes. Students should then clean up their lab areas, return supplies to the appropriate location, and send one group member to the class *Temperature Change* table to post their group's data. Remember to have students use note cards and tape if you want to reuse the table from class to class.

Have students return to their seats for today's final step. As a class, calculate the average temperature change for each cup (display **slide G** if needed). Have students record these averages on their handout. If you have more than one Dark Group, make space on the handout for a Dark Group average. Below are sample data collected with 450 mL of water.

Water Temperature over Time (°C)
Initial Water Temperature: 4°C; Air Temperature: 21°C

	Condition	**0 min**	**10 min**	**15 min**	**△T**
Light	Clear	4	8	10	+6°C
	Foil	4	7	7.5	+3.5°C
	Black	4	9	10	+6°C
	White	4	8.5	8.5	+4.5°C
Dark	Clear	4	5	6	+2°C
	Foil	4	5	6	+2°C
	Black	4	5	5.5	+1.5°C
	White	4	5	5.5	+1.5°C

Water Temperature Change versus Light Measurements (lux)

Ambient: 60 lux

Condition	△T	Incoming	Transmitted	Reflected
Clear	+6°C	1680	1360	230
Foil	+3.5°C	1660	10*	650
Black	+6°C	1600	0	490
White	+4.5°C	1600	190	710

* Error due to ambient light

ADDITIONAL GUIDANCE

Between classes, look at the classroom data to see whether there are any outliers that might affect the overall data. In the next class, students will be interpreting the class average data for analysis. Between classes, we encourage you to calculate the average values so that you are prepared for the discussion and can anticipate discussions about outliers and potential sources of error (e.g., errors with data collection, light bulbs, lamp positioning).

End of day 1

3 · NAVIGATION

3 min

MATERIALS: science notebook, class Temperature Change table

Navigation. Ask students to take out *Investigating Light's Effect on Warming Up Water*. Display **slide K** and ask students to recall the questions that were guiding our investigation. Ask the following questions to help students remember the purpose of the respective controls for the experiment.

Suggested prompt	Sample student response
What was the purpose of testing the cups in the dark?	*To compare to water temperature inside the other cups to see whether light leads to changes in the water's temperature.* *To understand whether water can warm up without light.*
What was the purpose of testing the cups in the light?	*To see how the water warms up inside cups with different surfaces.*

4 · ANALYZE DATA FROM LIGHT AND TEMPERATURE INVESTIGATION

22 min

MATERIALS: calculator, class Temperature Change table, whiteboard and chart paper, markers

Discuss approaches to analyzing and interpreting the class data. Display **slide L**. Say, *We collected a lot of data yesterday. What could we do to help us understand the relationship between the temperature changes in the water and the amounts of reflected and transmitted light?* The goal of this discussion is to have students look at patterns in the data rather than individual data points and to be able to identify and account for outliers that might be due to error rather than representing actual phenomena.✱ Use the following prompts to guide the discussion.

Suggested prompts	Sample student responses	Follow-up questions
What could we do with the data to help us understand the relationship between the temperature changes in the water and the amounts of reflected and transmitted light?	*Take averages of data.* *Identify and take out outlier data.*	*Why is calculating averages helpful?* *Why might identifying outliers be useful when analyzing this data set?*
Why is calculating averages helpful?	*We're looking at how changing one thing affects another. We want to see if there is a pattern.* *It makes sure no one measurement is the only thing we use for data.*	*Do we include outliers (if they are present) when calculating averages?*

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

Reinforce to students what they learned in Lesson 4 about the role of averaging data. Have students apply the concepts of averaging to analyze and characterize data. When collecting data, increasing the number of data points for pattern analysis is important for enhancing the reliability of the stated claims. The identification of outliers is an important skill related to this practice, particularly when figuring out whether high or low points are part of the pattern or due to error. When discussing potential sources of error in this investigation, the presence of an open system that admits ambient light when measuring light transmission through the cup wall will lead to some error. Measurement error could also be due to light bulb variations or lamp or light sensor positioning. We asked students to take each light measurement twice and calculated all measurements in terms of percentage of incoming light. In addition, we minimized

Suggested prompts	Sample student responses	Follow-up questions
What do you think might have caused some of the variability in our data?	*Errors with measuring the light.* *The angle of the lamp.* *Light coming in from the top of the cup when measuring the light transmitted through the cup wall.* *Each light bulb might have had a different level of brightness.*	*How did we try to account for these potential sources of error in our experiment?*

Average Water Temperature Change vs. Light Measurements (% Incoming Light)

	Condition	△T	Transmitted	Reflected
Light	Clear	+6°C	81%	14%
	Foil	+3.5°C	0%	39%
	Black	+6°C	0%	31%
	White	+4.5°C	12%	44%
Dark	Clear	+2°C	0%	0%
	Foil	+2°C	0%	0%
	Black	+1.5°C	0%	0%
	White	+1.5°C	0%	0%

Calculate average values for each measure. Display **slide M**. Have students work on their own to record the class data in a combined data table, which is the first question in the *Analysis* section of the *Investigating Light's Effect on Warming Up Water* handout. Give students a minute to quietly scan the data for patterns.

Construct a Notice and Wonder chart. Display **slide N**. Based on the average data, have students work with a partner to record on their handout what they notice and wonder about the data. When doing so, they should keep in mind the questions we posed in the last class: "Does light warm up the water?" and "How does the cup surface affect how light warms up the water?" Students should continue to use patterns as a lens for making sense of the data.✱

As students analyze the data in the form of a Notice and Wonder chart, they should examine the relationships between cup types and the amounts of reflected and transmitted light and how those amounts contributed to the observed temperature changes.✱

Engage in a Building Understandings Discussion. Reconvene the whole class. Develop a class Notice and Wonder chart on chart paper or a whiteboard space. Have each pair of student partners share at least 1 noticing and wondering from the data.

error from light reflecting off nearby cups by testing only one cup at a time per lamp and spacing the lamps apart.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING PATTERNS

Emphasize to students to focus on patterns as they analyze their data and to avoid getting too focused on a single data point. It is challenging to obtain accurate light sensor measurements, so focusing on single data points may lead students toward problematic conclusions. Focusing on patterns from the light and temperature data, coupled with students' wealth of related experiences with light warming objects up, will prove more beneficial.

✱ SUPPORTING STUDENTS IN ENGAGING IN ANALYZING AND INTERPRETING DATA

To support students' analysis of the data, it might be helpful to have them group the cups by these types to see how differences between those groups might reveal information about the relationship between the cup surface, light, and temperature change:

1. cup that is transparent
2. colored cups (white and black) that are opaque
3. reflective foil-covered cup that is opaque

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Coupling this data analysis with constructing models will help students move beyond identifying surface-level patterns (correlation) to identifying mechanisms (causation). Transition students from thinking about patterns to trying to make sense of the data in terms of mechanisms. Use this opportunity to examine issues related to cause versus correlation. Students may associate transmitted light with temperature changes, but other factors might mediate that effect. For example, opaque objects do not transmit light through them, but they do warm up due to the absorption of energy. Make certain students do not conclude a causal relationship simply from the patterns they identified. In Lesson 15 students will return to light, focusing more on a mechanistic explanation.

KEY IDEAS

Purpose of the discussion: To identify that the evidence supports that light does lead to warming of the cup surface and the water inside the cup, but to have lingering questions about other mechanisms that warm up the cups and the water inside.

Listen for these ideas:

- Black and clear cups warmed up the most and reflected the least light.
- White and foil cups warmed up the least and reflected the most light.
- The water inside the cups in the dark warmed up without light.
- Something else happens to light that is not transmitted or reflected; light is absorbed by the cup and the water inside the cup.

Below are sample noticings and wonderings that students might come up with.

Notice	Wonder
The temperature of the water increased in all conditions. Temperatures changed in cups where light didn't transmit through the cup wall. Temperature changed in cups in the dark. The clear plastic cup and the black cup had the greatest temperature change. The foil cup had the least temperature change, followed by the white cup.	How does the light cause the water temperature to change if light doesn't pass through the cup wall? Where did all of the light go that did not transmit through or reflect off the cup surface? How is it possible for the water to warm up without light? Why did the foil cup result in a lower temperature change than the white cup?

Display **slide O**. Say, *Based on our data, it seems that the cup surface does affect how light warms up the water inside. Having a lot of data can seem a little overwhelming. So first, let's try to figure out how light in general affects how the water warmed up.*✱ You may use the following prompts to guide the discussion.

Suggested prompt	Sample student response
How does the amount of transmitted light affect the water's temperature?	*Transmitted light tends to warm up water more.*
How does the amount of reflected light affect the water's temperature?	*The more reflected light, the less the temperature goes up.*

Display **slide P**. Say, *One of the interesting things you noticed in the data is that the amount of transmitted light and reflected light don't add up to the whole amount of the incoming light. Where did the rest of the light go? Do you think this light affected the water temperature in some way?* The intent of these questions is to guide thinking about how light can be absorbed by the cup wall and then warm up the water, because the amount of transmitted and reflected light cannot explain the increased temperatures. Now is your opportunity to reintroduce the idea of light being absorbed by matter, which was a lingering question for students following the light and matter unit.

Say, *Based on our data, we know that light can transmit through the cup wall, reflect off the cup wall, and do something else. We call this something else* absorption, *because the light energy is being absorbed and transferred to the matter. Using this information, how do you think this absorbed light affects the water's temperature?* Give students a moment to think, and then elicit a few of their initial ideas.

Explain that to help us answer these questions, we're going to construct models to help us explain how the cup surface affects how light warms up the water.

ADDITIONAL GUIDANCE

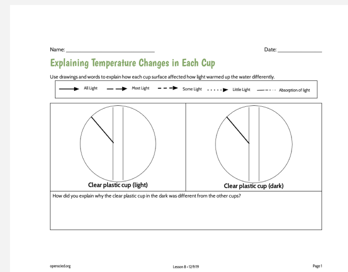
In the next part of the lesson, we create the space for students to think about the mechanism by which absorbed light warms the water, but we do not talk about this mechanism in terms of *conduction* until later in the unit (Lessons 12-15).
Due to measurement errors and scattering of light, it's difficult to calculate absorbed light. Students will need to focus on the transmissive and reflective data not adding up to the total incoming light as a proxy for thinking about light absorbed by the matter.

5 · DEVELOP MODELS TO EXPLAIN TEMPERATURE CHANGE

15 min

MATERIALS: science notebook, *Explaining Temperature Changes in Each Cup*

Develop models to explain findings. Display **slide Q**. Explain that we're going to draw models to explain how and why the water warmed differently in the various cups. Distribute the handout *Explaining Temperature Changes in Each Cup* to each student. Explain that the models focus on one area of the cup wall and that the illustrations include a light ray that represents the incoming light that we measured. Students' models should account for the data collected about how the percentages of reflected and transmitted light differed between the cups and how those differences affected the changes in water temperature.


Name: ______ Date: ______

Explaining Temperature Changes in Each Cup

Use drawings and words to explain how each cup surface affected how light warmed up the water differently.

How did you explain why the clear plastic cup in the dark was different from the other cups?

openscied.org Lesson 8 • 12/9/19 Page 1

Remind students to use the representations for different amounts of light that were developed in the previous unit on light and matter. The key is provided on the handout. You may want to discuss the representation of absorption at this time.✱

Give students time to construct models. Ask students to first work individually to represent their ideas about what happens to light as it encounters the cup wall. Give students up to 5 minutes to think about each model and to choose the representation (i.e., dashed arrow) they want to use to show amounts of light doing different things.

Discuss students' models. Ask students to share their models with a partner seated near them for about 2-3 minutes. Encourage students to add to their models as they share.

Convene students for a whole-group discussion of the models. Have students or partner pairs share one model they developed for a particular cup. Ask other students to compare this model to their own and ask questions or offer alternatives. Encourage students to use their data when explaining and justifying their models. Continue until models for each cup type are discussed.

ASSESSMENT OPPORTUNITY

As students work on their models individually, circulate to see how they are applying the model conventions from the light and matter unit. Encourage students to use the dashed arrows to represent the different amounts of transmitted and reflected light. When students share their models, pay attention to how they are showing what happens when a variable in their cup system--the cup surface--changes. Look for students' ideas such as these:

- which cups reflected the most light and how this relates to the resulting temperature change
- which cups transmitted the most light and how this relates to the resulting temperature change
- what else could be happening to the light not transmitted or reflected

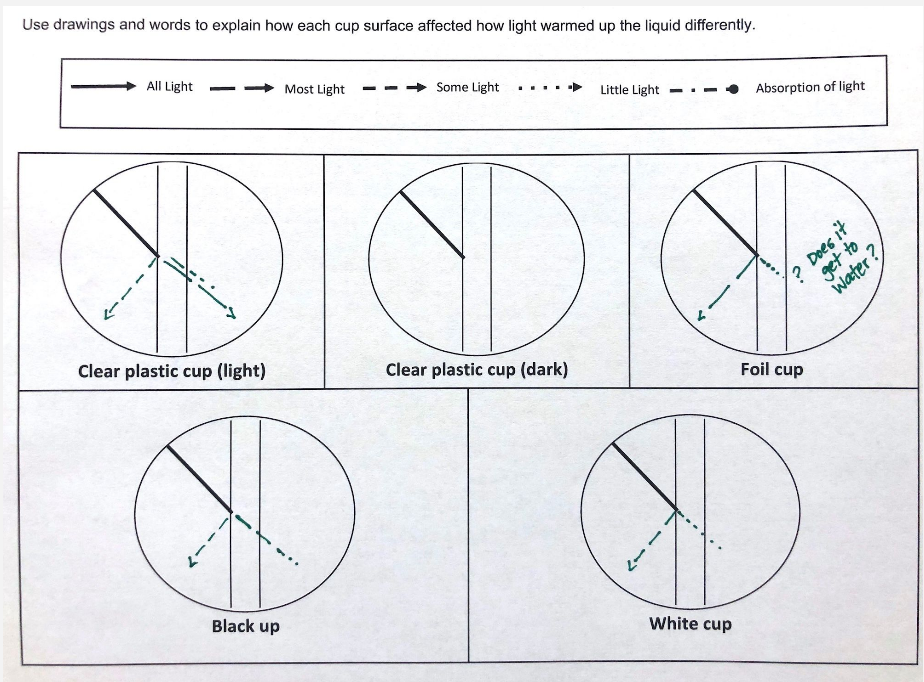
Example prompts for probing and challenging students' ideas are included below.

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

We encourage using the conventions developed in the light and matter unit, which were solid lines to represent all light and dashed and dotted lines to represent relative differences in the amount of light. We will assume the same incoming light for each cup, which is represented by a solid line. Students may want to use percentages to create a key for what constitutes "all", "most" (50%-99%), "some" (16%-49%), and "little" light (1%-15%). How students represent the absorption of light can vary, though a suggestion is provided on the handout: drawing longer dashes transitioning to dots as more light is absorbed and less is transmitted.

Suggested prompts	Sample student responses	Follow-up questions
How did you explain why the water in the black cup warmed up more than the water in the white cup?	*I showed more light being reflected by the white cup compared to the black cup.* *I showed more light being absorbed by the cup wall in the black cup compared to the white cup.*	*How do you think the absorbed light warms up the water?*
How did you explain why the clear plastic cup in the dark warmed up the water the least?	*There was no light present.*	*How did you explain why the water was still able to warm up without the presence of light?*
How did you explain why the foil-covered cup kept the water cooler than the black and white cups?	*The foil reflected the light.*	*What happened to the other light?* *Why didn't the absorbed light cause the water to warm up?*

Below are example models for each cup type:



6 · UPDATE PROGRESS TRACKER AND NAVIGATION

5 min

MATERIALS: science notebook

Update progress tracker. Display **slide R**. Say, *It looks like we've figured some stuff out, but we still have some questions.* Ask students to take out their science notebooks and update their Progress Trackers with what they learned during this lesson. This work can be done individually or with a partner. Example points are included below.

Question	What figured out in words/pictures
How does a cup's surface affect how light warms up a liquid inside the cup?	• When light that falls on a surface isn't reflected or transmitted, it is absorbed. • Transmitted and absorbed light can warm a liquid. • Light that reflects off a cup's surface does not affect the temperature of the liquid inside. • Temperature changes can still occur even if light isn't able to transmit through the cup *and* even if there's no light.

Navigation. Encourage students to post any additional questions on the DQB. Based on what students say, problematize the need for more investigation. Say, *So we figured out that the water warmed up even when there was no light or in situations where light couldn't travel through the cup wall. How did the water warm up? What else is going in or out?*

Suggested prompts	Sample student responses	Follow-up questions
How did the water warm up if light couldn't pass through the cup wall or when there was no light at all?	*The absorbed light warmed up the cup wall, which then warmed up the liquid.* *Heat or cold moved through the cup wall.*	*What is heat?* *How did the light warm up the cup wall?* *How did the water get warmed up?* *What's the difference between matter (e.g., the liquid) that is at one temperature versus another?*

Additional Lesson 8 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.Math.Content.6.RP.A.3.c: Find a percent of a quantity as a rate per 100 (e.g., 30% of a quantity means 30/100 times the quantity); solve problems involving finding the whole, given a part and the percent.

Converting actual light measurements to percentages of incoming light is helpful for accounting for variation in experimental setups and facilitating comparisons between treatment conditions. The focus of this task is not the actual process of calculating percentages; rather, we are focused on students' ability to compare percentages and use them to explain differences in observed temperature changes. However, during the 6th-grade year students learn about calculating percent in their math courses. If you anticipate challenges with these calculations, talk to the math teacher prior to the lesson to learn when and how students are taught this concept. Consider pairing students who may have difficulty with students who are able to help them.

Lesson-Specific Teacher Materials

How to Make the Test Cups for the Light and Temperature Investigation

Materials needed for constructing one set of cups

- 4 16-oz clear plastic cups with lids
- white acrylic paint
- black acrylic paint
- 2 1-inch-wide foam brushes
- paper towels
- aluminum foil
- clear tape
- scissors
- utility knife or box cutter (optional)

1. **Paint black and white cups.**
   a. Make a fist and place it into one of the cups.
   b. Use a foam brush to evenly apply a single coat of white paint to the outside of the cup. It is not necessary to paint the bottom of the cup. Repeat this with a lid (on the upper surface) if desired; this is optional but needs to apply to all the lids of all the cups in the investigation.
   c. Let the paint dry for at least 30 minutes before applying a second coat.
   d. Repeat this procedure with the second foam brush and black paint on the other cup (and the lid if desired).
   e. Ensure that the cups (and lids) are dry before conducting the investigation.

2. **Cover a cup with foil.**
   a. Spread out a piece of foil with the shiny side down. Place the cup at an angle and use a piece of tape to secure the first edge of the foil to the side of the cup.

   b. Wrap the foil tightly around the cup and secure the second edge with tape. It might be helpful to turn the cup upside down and place your hand inside the cup as you wrap to minimize gaps between the cup and the foil.

c. With scissors, trim the excess foil on the top of the cup until it is nearly flush with the top of the cup. Press the edge of the foil toward the inside and over the top edge of the cup.

d. Trim the excess foil on the bottom and top of the cup with scissors and secure with tape if needed.

3. **Cover a lid with foil (optional).**
    a. With scissors, cut a piece of foil to fit the lid and wrap the foil's edge around the lid's edge.
    b. Trim the foil as needed so that the lid fits on the cup.
    c. Use the tip of the scissors or a utility knife to make a criss-cross incision at the straw hole to permit insertion of a thermometer.

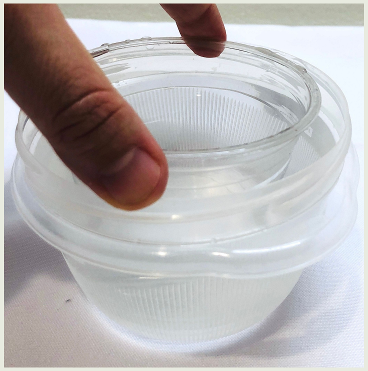
LESSON 9: How does the temperature of a liquid on one side of a cup wall affect the temperature of a liquid on the other side of the wall?

PREVIOUS LESSON *We tested how various cup surfaces affect how light warms up water inside cups. We found out that the water warmed up when the cup surfaces allowed light to pass through and the water absorbed light. We wondered how the water warmed up when light could not pass through the cup wall and also in cups in the dark condition.*

THIS LESSON

INVESTIGATION

1 day



We brainstorm how to test whether heat or cold is entering or leaving a cup system. We plan and carry out an investigation to place the cup in a water bath and measure the temperature inside and outside the cup to see if heat or cold is moving between the two systems. We figure out that when there is a temperature change inside the cup system, there is also a temperature change outside the system. We conclude that heat or cold moves through the cup wall and that the greater the temperature difference between the cup and water bath systems, the more energy is transferred between the two.

NEXT LESSON *We will watch a video demonstration, conduct an investigation involving food coloring and water, and complete a reading to better understand how hot and cold liquids differ at the particle scale. We will consider the relationship between a liquid's temperature and the movement of particles in that liquid.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Carry out an investigation to measure temperature inside and outside a cup system to test whether heat or cold moves through the wall of the system.

WHAT STUDENTS WILL FIGURE OUT

- When the temperature of a sample of matter in one system decreases, the temperature of the matter in the neighboring system increases.
- When the temperature difference between two neighboring systems is great, more energy transfers between them.
- Heat or cold can move through the wall of the cup system.

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review Lesson 7's models for light and heat or cold and motivate the need to test heat or cold moving through the cup wall.	A	
2	10 min	**INITIAL IDEAS DISCUSSION ABOUT TESTING THE MOVEMENT OF HEAT OR COLD** Facilitate an Initial Ideas Discussion to brainstorm ways we can test whether heat or cold moves through the wall of the cup system.	B-C	
3	25 min	**WATER BATH LAB AND DISCUSSION** Gather students in a Scientists Circle for the *Water Bath Lab*. This is presented as a whole-class investigation, but two alternative format options are offered for teachers' consideration.	D-F	Water Bath Lab
4	5 min	**NAVIGATION** Review the main conclusions from the *Water Bath Lab* and administer an exit ticket in which students share what they already know about the difference between hot and cold matter.	G	note card

End of day 1

Lesson 9 • Materials List

	per student	per group	per class
Water Bath Lab materials	• *Class Investigation: Heat or Cold through the Cup Wall* • calculator		• 400 mL room-temperature water • 400 mL water heated to 50°C • 400 mL water chilled to 6°C • 4 9-oz single-wall plastic cups • 4 Rubbermaid TakeAlong Twist and Seal containers (size: 2 cup) or 16 oz deli container • 8 thermometers • beaker • timer • marker
Lesson materials	• science notebook • note card		

Materials preparation (25 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1: Water Bath Lab

- **Group size:** Whole class
- **Setup:** The day before the lab, fill a pitcher or large beaker with at least 400 mL of water per class to come to room temperature. Make enough ice to chill at least 600 mL of water per class. The day of the lab, fill an electric kettle with at least 600 mL of water per class to heat to a temperature close to 50°C, and fill a pitcher with at least 600 mL of ice-water per class to chill to a temperature close to 6°C.
- **Notes for during the lab:** Gently insert the cups inside the containers to avoid spilling or mixing the waters.
- **Safety:** Make sure your hot water is not above 55°C. If students are assisting, have those students wear safety goggles throughout the lab.

The 16 oz Rubbermaid Takealong containers can be replaced with any 16 oz round containers, such as the round, clear plastic containers used at deli counters at the local grocery store. A replacement container must (1) fit the 9 oz plastic cup inside it, (2) the water line of the water inside the cup and outside the cup needs to be near equal, and (3) the container needs to seal, either by a twist on or snap on lid.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 7, students developed models for energy transfer into a cup system from light and heat or cold. Lesson 8 allowed students to explore light's role in warming up water in a cup. This lesson should address, to some extent, how heat moves into and out of systems. The purpose of this lesson is to motivate Lessons 10-14, which will build students' understanding of thermal energy transfer via conduction. This lesson will problematize how heat or cold crosses the cup wall to enter or exit the system, though students will not fully explain how this happens until Lesson 13. Continue to talk about energy with your students, with regard to light and heat both having energy that can transfer into the water. When the temperature difference between inside the cup system and outside the system is great, more energy transfers between the two.

Where We Are NOT Going

Since this is the first in a series of lessons to establish particle motion, kinetic energy of particles, particle collisions and conduction, and the direction of thermal energy transfer from hot to cold, be mindful not to give away too much information yet. This lesson should serve as an initial source of evidence that heat and cold cross the cup wall even when matter cannot. How that happens will be developed later in the unit.

LEARNING PLAN for LESSON 9

1 · NAVIGATION

5 min

MATERIALS: science notebook

Summarize the big ideas about light from the previous lesson. Show **slide A** and read the prompts aloud. Ask students to turn and talk about the prompts with a elbow partner. The purpose is to support students in identifying light as part of the explanation for our original phenomenon of the iced drink warming up, but not the only thing that is causing that temperature change.

Listen for students to identify these results from the previous investigation:

- The water warmed up more in transparent cups and dark-colored cups than in reflective cups.
- The water in the cups seemed to warm up most when light was transmitted or absorbed.
- The water still warmed up in cups in the dark condition, so something other than light must have been warming it up.

Review the Lesson 7 heat and cold models. Direct students to revisit their models of heat and cold from Lesson 7. Have students share with their partner how they think heat or cold could move through the cup wall. Then ask 3-4 students to share their ideas with the whole class, focusing on different ways this movement may happen.

Say, *We've figured out a few things about light moving into our cup systems, and we have evidence that light is related to warming up water inside them, but our cups in the dark also warmed up. Seems like we need to get more data on whether heat or cold moves through the cup wall to help us explain all the things that are happening to warm up the water.*

2 · INITIAL IDEAS DISCUSSION ABOUT TESTING THE MOVEMENT OF HEAT OR COLD

10 min

MATERIALS: None

Brainstorm ideas for investigation. Ask students to think about different ways we could investigate the movement of heat or cold from outside to inside the cup system and vice versa. Example prompts for the Initial Ideas Discussion are given below.

KEY IDEAS

Purpose of the discussion: To generate investigation ideas to probe students' thinking about heat and cold moving into or out of the cup system.

Listen for these ideas:

- controlling and adjusting the temperature of the air outside the cup system
- measuring how fast (the rate at which) the water in the cup warms up
- applying very hot or very cold things to the outside of the cup, such as a stove, hot pack, cold pack, hot oven air, or hot or cold water

✱ ATTENDING TO EQUITY

Broadening to students' related experiences is a critical move at this moment in instruction. Students need to see how the water bath investigation helps them explain a variety of related experiences. Avoid focusing students too much on the water bath and cups alone, instead interjecting students' related experiences when it makes sense to use the *Water Bath Lab* to explain a different phenomenon (e.g., feeling hot in a tub of hot water, getting chilled in a cold pool, using warm air to dry clothes).

Suggested prompt	Sample student response
What are some different ways we can test whether heat from outside the cup is going through the cup wall or whether cold from inside the cup is coming out?	*We could measure the temperature near the outside of the cup wall. We would need to measure the temperature inside the cup wall too.*
How can we control how much heat we put on the outside?	*Change the air temperature outside the cup to certain degrees.* *Take the cup outside on a hot day and on a cold day.* *Put the cup in an oven or on a stove and adjust the dial on the oven or stove to control the heat.*

Say to students, *It sounds like one thing you are suggesting is that we make the air outside our cup system really warm. If I turned up the classroom thermostat 10 degrees, think about how that would change the way the water inside the cup is warmed up.* Don't elicit responses just yet. Have students silently think about the idea.

Display **slide B** and read the question together. Have students turn and talk about what they predict would happen if we controlled the temperature outside the cup by making the air warmer or colder. Then elicit predictions from several partner pairs. Listen for these ideas:

- Warmer air outside will warm up the water inside faster.
- Colder air outside may warm up the water inside if the air is still warmer than the water.
- Really cold air outside would freeze the water inside.

Broaden initial ideas to related experiences. Say, *If we can control the temperature outside the cup, we think we can cause a temperature change inside the cup. Think about experiences you've had of putting something in really hot or really cold air, or a hot or cold liquid, or a solid, and getting a temperature change.*✱

Show **slide C**. *Say, Let's imagine we set our iced drink in a tub of hot water. Do you think the drink would warm up? What experiences have you had that make you believe this would happen?* Elicit a few responses from students.

Students may report temperature-change experiences such as these:

- taking a hot bath
- jumping into a cold pool or other body of water
- putting a metal spoon in a hot food or beverage
- putting clothes in a clothes dryer
- putting soda cans in an ice chest full of ice

Then ask, *Do you think the tub of hot water would be cooled down by the cold cup sitting in it? What experiences have you had that make you believe this would happen?* Elicit additional responses.

Conclude the discussion by emphasizing that students have a lot of evidence from their prior experiences to support the idea that when we put something cold into hot air or hot water, the cold thing will warm up, and that when we put something hot into cold air or cold water, the hot thing will cool down. Use this prediction to motivate the need for a systematic test to gather data on how heat or cold move between systems.

3 · WATER BATH LAB AND DISCUSSION

25 min

MATERIALS: Water Bath Lab, science notebook

Preview the investigation plan. Gather students in a Scientists Circle. Tell students to bring their notebooks with them. Pass out the handout *Class Investigation: Heat or Cold through the Cup Wall* to each student. Display **slide D**. Explain to students that the class will work together to gather evidence of how heat or cold moves through the walls of the cups. You will spend up to 10 minutes setting up the test together, 5 minutes conducting the test, and 10 minutes analyzing and interpreting the data.

ALTERNATE ACTIVITY

The purpose of the lab is to (1) satisfy students' curiosity about whether heat and cold move through the cup wall and (2) problematize a need to understand what heat and cold are and how they can move across the cup wall. Any of the following three options listed below will fulfill this purpose, so you can decide which works best given your students' needs and the time and resources available to you.

Option 1: This is the default approach to the *Water Bath Lab* described in the remainder of this lesson plan, using *Class Investigation: Heat or Cold through the Cup Wall*. Students conduct the investigation together in a Scientists Circle, focusing on Planning and Carrying Out Investigations. Students practiced writing or modifying investigation plans in Lessons 3, 4, and 8. This lesson is different, however, because it offers an opportunity to review an investigation plan as a class so that you can reteach the aspects of Planning and Carrying Out Investigations with which students need additional support (e.g., writing a testable question, deciding on control variables). Conducting the lab as a class also requires less time and materials.

Option 2: Turn the *Water Bath Lab* into a small-group investigation. Use *Small-Group Investigation: Heat or Cold through the Cup Wall* and have students plan and carry out their investigations in small groups. This option requires more time and materials but will give your students more practice writing investigation plans.

Option 3: If your students have done well with planning and carrying out investigations but need more help with Data Analysis and Interpretation, skip the lab and provide students with sample data using *Data Set and Analysis: Heat or Cold across the Cup Wall*. Spend the classroom time making sense of the data instead of setting up the investigation plan. The sample data is for a 9-oz cup, but additional data of the lab with a 16-oz cup is provided in *Sample Data Sets for Water Bath Lab*.

Review and discuss the investigation question and variables. Work together to complete *Part 1: Investigation Plan* on the handout.

- Determine the investigation question, which will be similar to the lesson question but worded in a testable format such as this:
    - How does changing ___________ (e.g., the temperature of the water outside the system) affect _______________ (e.g., the temperature of the water inside the system)?
- Take this opportunity to connect with any relevant questions on the DQB. Prompt students to think about how answering the investigation question will help them work toward answering questions on the DQB.
- Review the independent variables and then decide how to measure the effect using temperature as the dependent variable. The issues include these:
    - how many thermometers to use
    - where to place the thermometers inside and outside the cup and water bath systems
    - when to take the first measurement
    - when to take the final measurement
    - how to take the measurement to get the most accurate temperature (e.g., wait 10 seconds, 30 seconds, or 1 minute before reading the thermometer, making sure the thermometer is in the center of the water and not touching the cup wall or container wall)

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

In this discussion, emphasize to students the importance of discussions to planning and carrying out investigations. Investigations are not just about doing hands-on activities. Provide support and space for students to talk about the plans for the investigation and what they expect to figure out, as well as time for students to discuss their conclusions. Use this time to gauge student progress on developing investigation plans, including developing testable questions, independent and dependent and control variables, and other factors for completing a fair test.

- Move to control variables next. Remind students of the work they have done to set up fair tests. Show students the variables they will control. As you do, ask them *why* controlling that variable may be important. The control variables include these:
    - using the same amount of water inside the cup system as outside the cup system
    - starting with the same temperature of water for all of the cold, hot, or room-temperature conditions
    - using the same type of cup (the same size and material) and container for all of the conditions
    - closing the systems with the lids at the same time

Ask students if they want to include any additional control variables.✱

ASSESSMENT OPPORTUNITY	Listen for students to readily note control variables and to scrutinize the procedures to make certain they are detailed to conduct a fair test. If students are not identifying important controls, use challenge questions, such as these: • What if I only placed 100 mL outside the cup--would that matter? • What if we don't seal the containers--would that change our results? • What if we measure temperature with the thermometer touching the bottom of the cup or container as opposed to the middle--do we think the temperature reading would be the same?

Preview the procedures and show students the materials to be used in the test.

Conduct the *Water Bath Lab*. Convene the class in a Scientists Circle and follow *Part 2* on the handout. Have 4 student volunteers assist you with the temperature measurements and sealing the containers.

- Fill 2 Rubbermaid TakeAlong containers or deli container with 200 mL room-temperature water each.
- Fill 1 Rubbermaid TakeAlong containers or deli container with 200 mL cold water.
- Fill 1 Rubbermaid TakeAlong containers or deli container with 200 mL hot water.
- Fill 2 9-oz single-wall plastic cups with 200 mL cold water each.
- Fill 2 9-oz single-wall plastic cups with 200 mL hot water each.
- Place a thermometer in each of the 4 cups and each of the 4 Rubbermaid/deli containers.
- Wait the agreed-upon time (approximately 10 seconds) and then have the student volunteers read the first temperature measurement for each cup-container pair.
- Pair the cups and containers to produce the following combinations and label each combination with letters a, b, c, and d:
    a. hot cup, room-temperature container
    b. hot cup, cold container
    c. cold cup, room-temperature container
    d. cold cup, hot container
- The waterline in the container should be displaced enough to align with the waterline inside the cup.
- Seal each container's lid by twisting it tightly down.

ADDITIONAL GUIDANCE

The described version of the *Water Bath Lab* uses 9-oz cups, but this lab can also be completed using the familiar 16-oz single-wall plastic cup inserted inside an OXO Good Grips POPs 0.9L container (or another container of similar size and height). If this option is chosen, you will need to use 400 mL of water both inside and outside the cup. You will need to squeeze lightly on the lip of the cup as you gently insert the cup inside the OXO container. When the container is sealed, the waterline outside the cup will rise to the level of the water inside the cup. You will also need to wait 10 minutes for the temperature change, and then gently pop the container top to remove the cup.

While waiting for the final temperature measurement, display **slide E**. Give students 1 minute to turn and talk about what they expect to happen in each condition. Then elicit ideas from 1 or 2 partner pairs about each condition.

After 5 minutes, open the containers, remove the cups from the containers, and take the final temperature measurement. Record on students' data table, then calculate the change in temperature and record on the data table.

Analyze the data. Direct students to *Part 3* of their handout and display **slide F**. Have them spend 1-2 minutes analyzing the data on their own and answering the handout's questions. Then give students 1-2 minutes to talk with a elbow partner in the Scientists Circle. They should take turns comparing their initial ideas about the data and should feel free to add to their responses.

- What patterns do you notice in the data?
- What patterns do you notice about the final temperature measurements?
- What happens when the temperature difference between the water inside the cup and the water outside the cup is increased?

Draw conclusions from the data. Keep **slide F** visible to students and facilitate a Building Understandings Discussion to have students draw conclusions from their evidence. Example prompts for the discussion are given below.

KEY IDEAS

Purpose of the discussion: Have students use evidence from the *Water Bath Lab* to support the idea that heat and cold move through the cup wall.

Listen for these ideas:

- The hotter water cools down while the colder water warms up, regardless of whether it's inside or outside the cup system.
- If the temperature difference between two neighboring liquids is greater, more energy transfers between them.
- The temperature of the water inside the cup and outside the cup becomes almost equal after 5 minutes.

Suggested prompts	Sample student responses	Follow-up questions

Suggested prompts	Sample student responses	Follow-up questions
What patterns do you notice in the data?	*The hotter liquid of the two gets cooler.* *The colder liquid of the two gets warmer.*	*Is this consistent with what you would expect?* *Does this evidence match what you drew in your model for heat or cold?*
What patterns do you notice about the final temperature measurements?	*The temperatures are almost the same at the end.*	*What do you think this means?* *If we kept the experiment going another 5 minutes, what would you expect to happen?*
What happens when the temperature difference between the water inside and outside is increased?	*If the temperature difference is greater between the cup and the water bath, then more energy would move between them.* *The colder water would get even warmer and the hotter water would get even cooler.*	*Would it actually get cooler, or would the change happen faster?*
Using this data, what can we predict about how the temperature of the air around our cup could affect the iced drink inside?	*When the drink warms up, the air around the cup must be cooling down.*	*What if we had a really hot day compared to a spring day? How would this affect the warming up of the drink inside our cup?*

Conclude the discussion. Emphasize to students, *We just figured out something really important. We can get heat and cold to go through the cup wall by changing the temperature outside and inside the cup system. If we create a big temperature difference between the cup and the water bath, the energy transferring between the systems seems to happen faster. So it seems like heat and cold are another way to get energy into the cup even if the cup is sealed.*

4 · NAVIGATION

5 min

MATERIALS: note card

Summarize the lesson. Say, *We think that heat is causing the drink to warm up, or that the drink loses cold. We aren't quite sure what heat and cold are, but we know that we can change the temperature of water by exposing it to something else that is hot or cold. We also are not sure if heat is entering the cup or if cold is leaving the cup.* Tell students that over the next few lessons we want to figure out what heat and cold are, and which one is moving between the cup system and the outside system.

Complete an exit ticket. Show **slide G** and pass out one note card to each student. Have students look at the images of a cup of hot tea and a cup of iced tea. The cup of hot tea has a lot of "heat" and the cup of iced tea has a lot of "cold". Ask students to model what they think it would look like to zoom in to the particles that make up the tea in the two cups, and what would be similar or different about them.

Lesson-Specific Teacher Materials

Sample Data Sets for Water Bath Lab

Sample data set for the 9-oz cup option. This data is not for sharing with students unless the data analysis option is chosen instead of the student lab option. All temperatures are in °C. The data set below includes more test conditions than those included in the student lab option. This data set is for 200 mL of water inside the cup and outside the cup in the water bath, with temperature measurements taken after 5 minutes. Materials include 9-oz single-wall plastic cups submerged in Rubbermaid TakeAlong Twist and Seal containers (size: 2 cups).

Cold water inside

		0 min	5 min	Δ Temp
Inside	Cold	8.5	23.0	**+14.5**
Outside	Hot	51.5	27.0	**-24.5**

		0 min	5 min	Δ Temp
Inside	Cold	6.0	18.0	**+12.0**
Outside	Room temp	27.0	21.0	**-6.0**

Hot water inside

		0 min	5 min	Δ Temp
Inside	Hot	43.0	23.0	**-20.0**
Outside	Cold	8.0	23.0	**+15.0**

		0 min	5 min	Δ Temp
Inside	Hot	54.5	38.0	**-16.5**
Outside	Room temp	27.0	37.0	**+10.0**

Room-temperature water inside

		0 min	5 min	Δ Temp
Inside	Room temp	25.5	34.0	**+8.5**
Outside	Hot	52.0	34.5	**-17.5**

		0 min	5 min	Δ Temp
Inside	Room temp	25.0	17.0	**-8.0**
Outside	Cold	7.0	16.0	**+9.0**

Sample data set for the 16-oz cup option. This data set is for 400 mL of water inside the cup and outside the cup in the water bath, with temperature measurements taken after 10 minutes. Materials include 16-oz single-wall plastic cups submerged in 0.9-L OXO POPS containers.

Cold water inside

		0 min	10 min	Δ Temp
Inside	Cold	6.0	23.0	**+17.0**
Outside	Hot	52.0	25.5	**-26.5**

		0 min	10 min	Δ Temp
Inside	Cold	10.5	20.0	**+9.5**
Outside	Room temp	25.0	20.0	**-5.0**

Hot water inside

		0 min	10 min	Δ Temp
Inside	Hot	53.0	26.0	**-27.0**
Outside	Cold	5.0	24.0	**+19.0**

		0 min	10 min	Δ Temp
Inside	Hot	55.0	39.0	**-16.0**
Outside	Room temp	25.5	35.0	**+9.5**

Room-temperature water inside

		0 min	10 min	ΔTemp
Inside	Room temp	26.5	37.0	**+10.5**
Outside	Hot	53.5	36.5	**-17.0**

		0 min	10 min	Δ Temp
Inside	Room temp	24.0	20.0	**-4.0**
Outside	Cold	14.0	19.0	**+5.0**

LESSON 10: What is the difference between a hot and a cold liquid?

PREVIOUS LESSON *We carried out an investigation to test whether heat or cold moves into or out of a cup system. Our data revealed that when a temperature change happened inside the system, there was a temperature change outside the system too. We concluded that heat or cold moved through the cup wall and that energy transferred between the inside and the outside of the cup system.*

THIS LESSON

INVESTIGATION

2 days

We investigate the differences between hot and cold liquids at the particle scale. A video showing candy dissolving in hot, warm, and cold water motivates us to investigate how water behaves differently at varying temperatures by adding food coloring to hot, room-temperature, and cold water. After collecting qualitative evidence that correlates movement in water to temperature, we read about a historical study supporting the idea that movement of water particles and temperature are closely connected. All three sources of information reinforce the ideas that (1) liquids are made of particles and (2) particles move more when a liquid is hotter and less when a liquid is colder.

NEXT LESSON *We will consider what happened in the Food Coloring Lab at the particle scale. We will observe a simulation and obtain evidence that hot liquids have particles that move faster and cold liquids have particles that move slower. We will call that movement kinetic energy and add it to our models. We will brainstorm how particles got more kinetic energy when our original iced drink warmed up.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Develop models based on evidence to explain that matter is made of particles that are in motion, and though the individual particles are not visible to the eye, their collective behavior can be observed as more or less movement depending on the matter's temperature.

WHAT STUDENTS WILL FIGURE OUT

- The movement of particles is related to the temperature of the water, with particles in colder water moving less than particles in hotter water.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**UPDATE PROGRESS TRACKER** Have students update their individual Progress Tracker with a new question about the difference between a hot and a cold liquid.	A	
2	12 min	**INITIAL IDEAS DISCUSSION AND PREDICTIONS** Facilitate an Initial Ideas Discussion to draw out students' starting notions about the differences between hot and cold liquids, particularly at the particle level.	B-D	
3	12 min	**VIDEO DEMONSTRATION OF DISSOLVING CANDY** Show a video of peppermint candy dissolving at different rates in cold, warm, and hot water. Have students consider a possible relationship between the speed of particles spreading out in the water and the temperature of the water.	E	https://youtu.be/Bjy9av_hm4Y
4	16 min	**MOTIVATE AND CONDUCT THE FOOD COLORING LAB** Guide students to use food coloring to visualize the difference between hot and cold water particles. Prompt students to look for visual patterns to better understand the behavior of water particles at varying temperatures.	F-H	Food Coloring Lab
				End of day 1
5	5 min	**QUICK REVIEW OF THE FOOD COLORING LAB** Have students review their observations of the *Food Coloring Lab* with a partner not from their original lab group.	I	
6	20 min	**READ ABOUT JAMES JOULE'S EXPERIMENT** Guide students as they use the close reading strategy to learn about James Joule's famous experiment in which he built a device to investigate the relationship between the movement of water and temperature.	J-P	*James Joule's Experiment*
7	15 min	**MAKING SENSE OF MULTIPLE SOURCES OF INFORMATION** Facilitate a discussion in which students use information from the video demonstration, the *Food Coloring Lab*, and a reading to explain how cold and hot liquids (i.e., water) are different at the particle scale.	Q-S	
8	5 min	**PROBLEMATIZING HOW AND WHY PARTICLE MOTION CHANGES OVER TIME** After concluding that particles in liquids move and that particles tend to move less in cooler liquids and more in warmer liquids, have students think about why particle movement would change over time.	T	note card
				End of day 2

Lesson 10 • Materials List

	per student	per group	per class
Food Coloring Lab materials		• 3 9-oz plastic cups • 1 drop of food coloring for each cup • 500-mL beaker • 250 mL of cold water (6°C) • 250 mL of room-temperature water (22-24°C) • 250 mL of hot water (50°C).	• 1 previously chilled plastic pitcher of cold water • 1 previously set-out plastic pitcher of room-temperature water • electric kettle to heat water
Lesson materials	• science notebook • *James Joule's Experiment* • note card		• https://youtu.be/Bjy9av_hm4Y

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Have the video https://youtu.be/Bjy9av_hm4Y loaded on your computer for day 1 .

In advance of day 2, make 1 copy of *Reading on James Joule's Experiment* for each student.

Have at least one note card per student for the exit ticket on day 2.

Day 1: ***Food Coloring Lab***

- **Group Size:** 2-3 students
- **Setup:** The night before the lab, make ice cubes or refrigerate a pitcher of water to chill water to 6°C (enough for 250 mL per group). Set out a pitcher of water overnight to bring water to room temperature at 22–24°C (enough for 250 mL per group). Prepare an electric kettle to heat water to roughly 50°C (enough for 250 mL per group). Note: Do not heat water to more than 55°C or it will damage the plastic cups. Each group will need 3 9-oz plastic cups, 3 drops of food coloring, and 1 500-mL beaker to measure water for the cups.
- **Safety:** Warn students about handling hot liquids. Be sure to have one pair of safety goggles for each student when using hot water.

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

This lesson reinforces 5-PS1-1, “Develop a model to describe that matter is made of particles too small to be seen,” but extends students’ learning by building a particulate model of matter that adds particle motion and accounts for differences in motion when the temperature of matter varies.

In this lesson, students develop a particle-level model to describe how cold and hot liquids differ. Although students already know that liquids are made of particles that are loosely spaced, they now add that these particles are in motion and that this motion is related to the liquid’s temperature. Students establish the pattern that higher-temperature (hotter) liquids have particles that move more than lower-temperature (colder) liquids.

Where We Are NOT Going

Students do not equate particle movement with kinetic energy or heat until Lessons 11-12. Students may wonder whether the greater movement of food coloring in hot water indicates that the water has more energy or heat. However, it is just as likely that students will think that the cold water possesses “cold” properties as opposed to less heat, and/or that it contains cold particles that move. All these possibilities set up the next series of lessons in which students investigate whether heat or cold may be moving between systems and, in the case of the anchoring phenomenon, entering or exiting a cup system that contains an iced drink. Therefore, it is not essential to introduce *kinetic energy* or *heat* during this lesson.

LEARNING PLAN for LESSON 10

1 · UPDATE PROGRESS TRACKER

5 min

MATERIALS: science notebook

Update Progress Tracker. Display **slide A**. Remind students that at the end of the previous class, they shared their thinking about the difference between a cup of hot tea and a cup of iced tea, which got them thinking more about the difference between hot and cold. Also remind students that they were curious about which one--heat or cold--is moving between the systems.

Ask students to find the pages in their science notebook reserved for the Progress Tracker and to draw a line below their previous entry or to start a new page. Prompt students to record in the left column the question, "What is the difference between a hot and a cold liquid?" Ask students to work quietly for 3-4 minutes to update the right column of their Progress Tracker with words and/or pictures that indicate what they have learned about this question in previous investigations. As students work, circulate around the room to probe their thinking as needed.✱

✱ ATTENDING TO EQUITY

This class period is a good opportunity to be intentional about bringing new voices to the table. Be aware of which students have already shared often throughout the unit and which students have been less involved. Encourage all students to share at least one idea with the class today. For those less willing to share publicly, consider using strategies to make their thinking public. For example, look at several exit ticket responses while students are writing in their Progress Tracker. Select a few responses to share and ask for permission before doing so.

2 · INITIAL IDEAS DISCUSSION AND PREDICTIONS

12 min

MATERIALS: science notebook

Facilitate an Initial Ideas Discussion. Project **slide B**. Ask students to refer back to their exit ticket from Lesson 9. Say, *In our last class, we thought about similarities and differences between hot tea and iced tea. What do you think we would see in those liquids if we zoomed in really close?*✱ *What might be similar or different at the particle scale?* Let students think quietly about these questions for a few moments. Then have students turn and talk to a elbow partner for 1 minute about what they included in their exit ticket.

After 1 minute, bring students back together and ask for volunteers to share their thoughts or drawings during a brief class discussion.✱ A discussion prompt and potential responses are shown below.

KEY IDEAS	**Purpose of the discussion:** to elicit from students a wide variety of ideas about similarities and differences between hot and cold liquids of the same kinds of particles (e.g., tea, water, etc.). **Listen for these ideas:** • Particles may be hot or cold. • Hot particles have more energy. • Cold particles have more "cold" or properties of being cold. • Hot particles may be closer to evaporating, while cold particles may be closer to freezing.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

Use this opportunity to talk about why looking at phenomena at different scales is useful. Hot and cold tea, for example, look mostly similar at the macroscopic scale, but they feel very different to the touch. Ask students to think about why looking at the tea at a particle scale could be helpful to them in answering their questions.

✱ STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

In this discussion, do not correct students' misuse of language. An Initial Ideas Discussion is used to generate divergent thinking and to encourage students to share their prior knowledge on a topic. Referring to hot or cold particles should be expected. Students will refine their understanding of hot versus cold particles in terms of kinetic energy in Lesson 11.

Suggested prompt	Sample student responses
What might be similar or different at the particle scale?	*The particles are similar because they are the same size.* *The number of particles will be the same in both cups if you start with the same amount of tea.* *Iced tea may have solid particles (ice), so they are closer together.* *Hot tea may have gas particles (steam) and be farther apart.* *The hotter tea has more energy than the colder tea.*

Construct predictions about the original cup of water over time. After sharing several similarities and differences between hot and cold liquids, remind students that liquids change temperature over time. Say, *We have some ideas of what is similar and what is different between the same type of liquid but at different temperatures. Let's also remember that when we left out a cup filled with ice-water in this room, it didn't stay cold. It began to warm up over time.*

Project **slide C**. Review what students already know about the original iced drink in the regular plastic cup from Lesson 1 and then direct students to the questions:

- If we zoomed in to that original cup of cold water at 0 minutes and later at 30 minutes, how would the particles be the same or different?
- If we zoomed in to a cup of hot water at 0 minutes and later at 30 minutes, how would the particles be the same or different?

Ask students to visualize the particles at the start and after 30 minutes. After a moment for visualization, direct students to turn and talk with their partner about what they think is happening to the particles at each time point.

Introduce the idea of movement of particles. Say to students, *One thing I'm hearing is that warm or hot liquids lead to steam and particles escaping or evaporating, while cold liquids are closer to freezing and becoming ice. Let's review how that happens.*

Suggested prompt	Sample student response
What is happening when water turns to steam or ice?	*When water gets really hot, some particles can evaporate.* *When water gets really cold, it can freeze.*
Do the particles change?	*No, it's still water.*
What changes about it?	*The steam particles get heated up and change to vapor. The water particles get cooled down and change to ice.*
How does a "steam particle" start moving into the air as steam? Is it moving in the water to begin with?	*We don't know. Maybe.*

Summarize by saying, *It seems like there may be a relationship between temperature and movement--like with the hot water, when particles move into the air.* Show **slide D**. Say, *Do we think any particles in the hot water also move? What about particles in the cold water?* Prompt students to use the evidence from earlier lessons to brainstorm ideas about if and how particle movement may be related to temperature.

3 · VIDEO DEMONSTRATION OF DISSOLVING CANDY

12 min

MATERIALS: science notebook, https://youtu.be/Bjy9av_hm4Y

Introduce students to a related phenomenon. Say, *This topic reminds me of something I've seen before. What happens when we pour a drink mix packet into a cup of water?* Explain to students that the idea of particles moving is analogous to this related phenomenon. It's not essential that students use the term "dissolving" to describe what is happening. Instead, try to guide them to consider what is happening as the little pieces of sugar spread throughout the cup of water.

Say, *The drink mix powder seems to move in the water some, but I also need to mix it in with a spoon, so I'm not sure if the water particles are actually moving. If I added the drink powder to hot water, would it spread out differently than if I added it to cold water?*

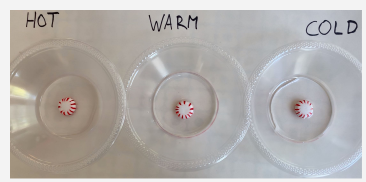
Listen for these ideas:

- It would melt and mix faster.
- It would spread out faster in hot water.

Prepare for the video demonstration. Say, *From our discussion I'm hearing some ideas that the temperature would affect the particles and how fast something would spread out in the water. I have a video of someone placing peppermint candy in water at different temperatures. Let's see what happens.*

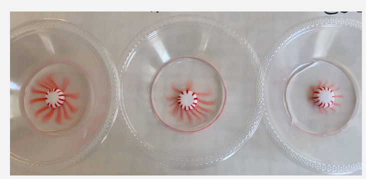
Project **slide E**. Have students find a new page in their notebook and title the page "Candy in Water". Have students draw a Notice and Wonder chart. Explain to students that they will have an opportunity to watch the video twice, recording observations both times.

Present the video, record observations, and discuss. Play the video https://youtu.be/Bjy9av_hm4Y for the first time. The video lasts approximately 1 minute and shows peppermint candies dissolving in water at three temperatures. For reference, in this video the hot water is at 67°C, the warm water is at 30°C, and the cold water is at 3°C.



Ask students to record what they notice and wonder after the first viewing. Give students 1 minute to turn and talk with a elbow partner about their observations.

Replay the video and prompt students to record additional noticings and wonderings. Bring students together for a discussion of their observations and questions.



Say, *What does this video tell us about the particles from the candy and the temperature of the water?*

Listen for these ideas:

- The candy particles break off faster when the water is warmer.
- The candy particles move away from the candy faster in warmer water.
- The hot water particles seem to move the candy particles around faster.
- Maybe the speed of the candy particles has something to do with the water temperature.
- In warmer water, particles may be moving faster.

4 · MOTIVATE AND CONDUCT THE FOOD COLORING LAB

16 min

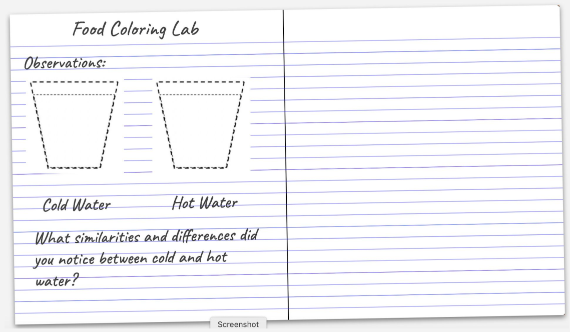
MATERIALS: Food Coloring Lab, science notebook

Motivate the *Food Coloring Lab*. Project **slide F**. Prompt students to consider whether they might see similar patterns with only a cup of water that has no candy in it. Say, *What if we just had a plain cup of hot or cold water? Could there be particles moving around in the water?*

Students may offer ideas but voice concerns about not being able to actually see the particles in the water because they are "invisible" or "too tiny to be seen". Follow up with a suggestion for how to "see" particles moving in the water.

Introduce food coloring as a visualizing aid. Say, *We have some ideas about the movement of candy particles in water at different temperatures. To see if the same thing may be happening in the water by itself, we can add some food coloring. The food coloring may help us visualize the behavior of water at different temperatures.* Explain that to see what is happening in the water, we need to add something that makes it more "visible." Tell students that the food coloring will help make any movement in the water more evident to our eyes.

Set up the lab. Project **slide G**. Direct students to find a new page in their science notebook and to title the page "Food Coloring Lab". Explain that we will test only cold and hot water at first. Tell students that they will draw and label their observations on this page. Use **slide G** to help them set up their notebooks with the heading "Observations" and diagrams of cups labeled "Cold water" and "Hot water".



Assemble students in small groups for the lab. Present the materials and the procedures, which are outlined in the *Lesson 10 Student Procedures*. Allow time for students to ask clarifying questions. Go over expectations and norms for working in small groups as well as any additional logistics for how to get the materials, return and/or recycle the materials, and clean up.

SAFETY PRECAUTIONS

Reiterate safety precautions for working with hot liquids. Review why wearing safety goggles for the entire lab is required and how you expect students to obtain and handle the hot water throughout the lab. To ensure greater safety, you should pour the hot water from the kettle into an additional cup or beaker for each group.

Preview recording observations and begin the lab. Explain that because the cold and hot water will change temperature quickly, as seen in prior lessons, students should draw and write their observations on the cup diagrams in their notebook promptly (30-60 seconds) after adding the food coloring.

Prompt students to conduct the first part of the lab procedure with the cups of cold and hot water. After students record their visual observations of the food coloring, ask them to write down and respond to the question "What similarities and differences did you notice between the cold and hot water?" below their diagrams.

Prompt students' predictions and continue the lab. Display **slide H**. Once students finish their first page of observations, have them set up their next notebook page as shown on the slide, with the heading "Room-Temperature Water" and two more cup diagrams labeled "Prediction" and "Observation". Ask them to draw and write on the first cup diagram what they predict we will see when food coloring is added to a cup of room-temperature water. Walk around the room to get a sense of students' ideas.

Once students have recorded their predictions, instruct them to conduct the second part of the lab procedure with the room-temperature water. Prompt them to record their observations of the food coloring on their final cup diagram. Announce the temperatures of the cold, hot, and room-temperature water, and have students record these temperatures as part of their observations.

Wrap up the lab. Direct students to clean up and return materials. After students pour out and rinse their cups of water, ask for one or two volunteers to summarize their observations before the end of class. Example prompts are shown below.

Suggested prompt	Sample student response
Can someone recap what we've just seen in the Food Coloring Lab?	*We saw the food coloring spread out more quickly in hot water than in cold water.*
Did your final observation match your prediction for the room-temperature water? In what ways was it the same or different?	*My prediction matched my observation for the room-temperature water because I thought the food coloring would spread out more than in the cold water but less than in hot water and that's what I saw!*

End of day 1

5 · QUICK REVIEW OF THE FOOD COLORING LAB

5 min

MATERIALS: science notebook

Review observations from the *Food Coloring Lab*. Project **slide I**. Prompt students to review their observations from the *Food Coloring Lab* for a minute. Then ask them to turn and talk with a new partner (someone not in their original lab group) to share observations they think are important.

Reconvene the class and say, *Remember that we're trying to figure out the difference between something that is cold versus something that is hot. What was something similar between your drawings of the cold, hot, and room-temperature water? What was something different?*

Ask students to share one thing they discussed in partners. Listen for these ideas:
- The food coloring particles spread out more in the hot water than in the cold water.
- The food coloring particles move faster in the hot water than in the cold water.

After 2-3 minutes of sharing, announce that we have a short reading describing one historical experiment that examined the connection between the movement of water and temperature. Tell students that this experiment may help us understand what is happening in water at different temperatures.

6 · READ ABOUT JAMES JOULE'S EXPERIMENT

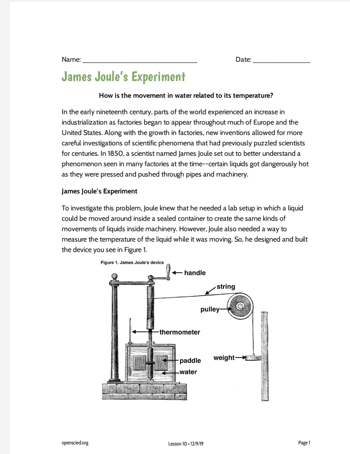
20 min

MATERIALS: *James Joule's Experiment*

Introduce the reading. Say, *I came across this article that describes how scientists were looking at this same phenomenon more than 150 years ago! It would be interesting to see if they talked about some of the same things we are discussing.*

✱ ATTENDING TO EQUITY

Distribute a copy of *James Joule's Experiment* to each student. There is a copy of this reading, *Reading on James Joule's Experiment*, in the Student Edition for reference as well.✱ Project **slide J**. Tell students about the device depicted on the slide that was designed to shake and spin water very fast to see if moving the water could cause a temperature change.



Name: ____________________ Date: __________

James Joule's Experiment

How is the movement in water related to its temperature?

In the early nineteenth century, parts of the world experienced an increase in industrialization as factories began to appear throughout much of Europe and the United States. Along with the growth in factories, new inventions allowed for more careful investigations of scientific phenomena that had previously puzzled scientists for centuries. In 1850, a scientist named James Joule set out to better understand a phenomenon seen in many factories at the time--certain liquids got dangerously hot as they were pressed and pushed through pipes and machinery.

James Joule's Experiment

To investigate this problem, Joule knew that he needed a lab setup in which a liquid could be moved around inside a sealed container to create the same kinds of movements of liquids inside machinery. However, Joule also needed a way to measure the temperature of the liquid while it was moving. So, he designed and built the device you see in Figure 1.

Figure 1. James Joule's device

opensciED.org Lesson 10 • 12/9/19 Page 1

The reading contains words that you may want to discuss with your students before they begin to read, or pause to discuss as students encounter them in the text. These words include *industrialization* and *pulley*.

Model the close reading protocol. Project **slide K**. Explain that close reading requires reading more than once and with different purposes and strategies for interacting with the text. Choose to have students read on their own, with a partner, or as a class based on your norms for reading together.

Guide students through the following steps, pausing at each step:

1. Project **slide L**. Say, *Let's do one together.* Ask students the question we are trying to answer using this reading. Tell them to circle the question "How is the movement in water related to its temperature?" at the top of the handout. This strategy reminds us of the purpose of what we are doing and the type of information we are looking for in the reading. Explain that reading this case study will help us answer this question.
2. Project **slide M**. Give students time to read the first paragraph on their own.
3. Project **slide N**. Demonstrate step 3 by rereading the first paragraph aloud. As you read, pause and share your thinking, highlighting a few ideas that answer our question.
4. Give students about ten minutes to continue reading, highlight key ideas on their own, and analyze the images embedded in the text. Remind them to be selective about what they highlight and to look for things that help answer their questions.
5. Project **slide O**. Tell students to work with a small group (or with a partner) to summarize the key ideas from the reading that answer the question.

Discuss the reading as a class. Project **slide P**. Facilitate a brief class discussion about the reading. The purpose of this discussion is to summarize the idea that the movement in water is directly related to its temperature, meaning that increased water movement correlates with an increase in temperature.

Suggested prompt	Sample student response
What key ideas did you summarize that help us answer our question about how the movement in water is related to its temperature?	*When there is an increase in movement in water, the temperature of the water rises. When the movement in water decreases, the temperature of the water goes down.*

7 · MAKING SENSE OF MULTIPLE SOURCES OF INFORMATION

15 min

MATERIALS: science notebook

Discuss the connections between sources of information. Project **slide Q**. Frame the discussion by saying, *Remember that we started this lesson by asking what is the difference between a cold and hot liquid? Now, we have several pieces of information to help us understand this better.*

Replay the dissolving candy video again as a visual reminder, if necessary. Then, ask students to turn and talk to a neighbor as they review information from the dissolving candy video, the *Food Coloring Lab*, and the reading.

After 2 minutes, project **slide R** and ask students to draw in their notebook, as shown on the slide, what they think the particles are doing in cold water. Then, ask students to draw what these particles will look like later as the cold water warms up to room temperature.

✱ STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

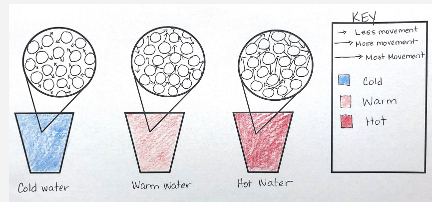
Students do not need to agree upon a representation to show particle movement. The purpose of this discussion is to have students connect their evidence to representations on diagrammatic models.

ASSESSMENT OPPORTUNITY

Students have had an opportunity to discuss three sources of information regarding the relationship between a liquid's temperature and the movement of particles in the liquid. By this point, the students' drawings should indicate the following:

- Cold water and room-temperature water both contain particles that move around.
- The number of particles in the cold water and room-temperature water should be equal.
- The particles in the cold water are moving less than the particles in the room-temperature water.

Compare models with a classmate. Project **slide S.** Ask students to turn to a partner and compare drawings. Say, *What was something similar between your drawings? What was something different?* Give students a few minutes to compare.

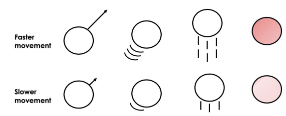


Bring students back together for a brief Building Understandings Discussion. Say, *Before we move on, we need to brainstorm ways to show whether particles are moving very little or whether they are moving more. We need a common way to represent some of our ideas.*

Generate ideas about representation of movement in models. Discuss each of the suggested representations and allow students to choose a way to represent greater and lesser particle movement in a liquid that they think is consistent with the evidence they have collected. The class can agree on the representation now or wait until Lesson 11 to agree on it, however you will need to tentatively choose one representation to use for a class model now, that can be retained or modified later. ✱

ADDITIONAL GUIDANCE

You may want to share a few options for representations with your students. These may include arrows, motion lines, tails, or color differences, which are the representations that students will encounter in the Lesson 12 interactive. Each representation can be useful for showing motion; no one representation is better. From this lesson through Lesson 12, students can use these representations to refine their thinking about movement and kinetic energy. By Lesson 12, the class should agree on one representation going forward that is easy for everyone to include in their models.



Guide the class towards thinking about energy. Say, *We seem to be leaning towards the idea that energy is what is entering or leaving our cup system. What did the dissolving candy video,* Food Coloring Lab, *and reading seem to tell us about how energy is involved?* Examples of prompts for discussion are given below.

Suggested prompt	Sample student response
In the dissolving candy video, which situation seems to have more energy and why?	*The candy dissolves faster and pieces of it move faster in hot water, so maybe that one had more energy.*
What evidence did you gather about energy in the Food Coloring Lab?	*The food coloring moves more and spreads out faster in hot water, so there was more energy.*
What did the reading seem to tell us about the movement of particles and energy?	*When there is more movement in water, the temperature of the water is higher.*

Suggested prompt	Sample student response
If we had to use today' evidence to decide if heat was entering the system or cold was leaving the system, what would this evidence support more?	*The peppermint dye and food coloring spread throughout the hot water, so maybe that means cold can move.* *The Joule experiment showed that you can warm up water by moving it a lot, so maybe movement is a way to get heat into a system.*

Transition by saying, *We are starting to collect some useful evidence to help us figure out what heat and cold mean and which one of them is moving between the cup system and the outside. Let's keep this as part of our thinking as we collect more evidence.*

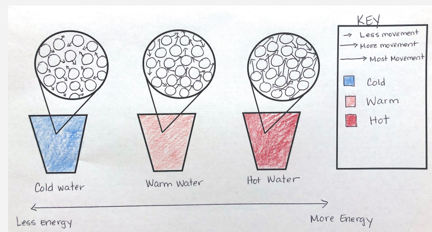
8 · PROBLEMATIZING HOW AND WHY PARTICLE MOTION CHANGES OVER TIME

5 min

MATERIALS: note card

Summarize the class consensus. Say, *We just figured out something really important about something we cannot even see! There is a very important difference between cold liquids and hot liquids, and it has to do with the movement of particles and the energy those particles have. Let's summarize some of the key ideas we've figured out.* Focus on the concept of energy as a way to emphasize an important idea that is starting to emerge for students. Students can layer energy on the model, as shown in the image.

Ask students to volunteer their ideas. You should hear ideas such as:



- Liquids are made of moving particles.
- When a cup of cold water warms up, its particles must be moving more and they seem to have more energy.
- When a cup of hot water cools down, its particle must be moving less and they seem to have less energy.
- As water warms up, its particles start to move more and they seem to get energy from somewhere.
- As water cools down, its particles start to move less and their energy seems to go somewhere else.

Problematizing the next lesson by using an exit ticket. Project **slide T**. Read the slide together. Say, *We've now figured out that as the temperature of a liquid changes, the movement of its particles also changes. If we think back to our original cup with an iced drink warming up over time, what could cause the particles to move more over time?* Ask students to write responses to the questions on a note card as an exit ticket before they leave the classroom.

Additional Lesson 10 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.** Explain to students that scientists must often consider multiple sources of evidence or pieces of information when figuring something out. Here, students compare and contrast the information gained from a video demonstration and a lab investigation with that gained from a reading about a related historical experiment.

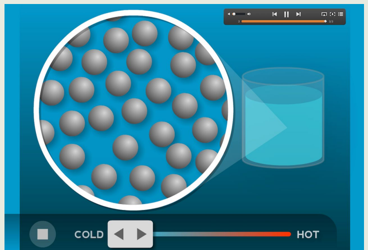
LESSON 11: Why do particles move more in hot liquids?

PREVIOUS LESSON *We combined information from a video demonstration, a hands-on investigation involving food coloring and water, and a reading to better understand how liquids of different temperatures differ at the particle scale. We reviewed that liquids are made of particles, and we figured out that those particles move more when a liquid is warmer and less when a liquid is colder.*

THIS LESSON

INVESTIGATION

1 day



American Chemical Society

We wonder what happened in the Food Coloring Lab at the particle scale and how this relates to energy. We make observations from a simulation and obtain evidence that hot liquids have particles that move faster and cold liquids have particles that move slower. We call this energy of movement kinetic energy. We spray perfume on one side of the classroom and smell it on the other side, evidence that particles in gas move freely like particles in liquids. We use new ideas about kinetic energy to explain our previous lab observations. We revisit our original iced drink warming up in the regular plastic cup and wonder where the kinetic energy came from.

NEXT LESSON *We will use a simulation to investigate how individual particles in a gas do not have the same kinetic energy, and how the energy of individual particles constantly changes due to collisions. We will argue from evidence that temperature is a measure of the average kinetic energy of the particles in a sample of matter, and that the total energy of that sample is the sum of the kinetic energy of all its particles combined.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Construct an explanation about why food coloring moves more in hot water than in cold water using the idea that at the particle scale, particles in liquids at warmer temperatures have more kinetic energy than particles in liquids at cooler temperatures.

WHAT STUDENTS WILL FIGURE OUT

- A particle's speed is related to how much kinetic energy it has.
- The particles in hot liquids and gases have more kinetic energy than the particles in cold liquids and gases.
- Liquids and gases are made of particles that can move around freely.

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Have the class consider two claims for energy transfer between the cup system and the outside, and add evidence to the claim posters in support of one claim or another or both/neither.	A	3 claim posters, 4 evidence cards from *Evidence Cards 1*, tape
2	10 min	**OBSERVE THE HEATING AND COOLING A LIQUID SIMULATION** Review observations from the peppermint candy video and the *Food Coloring Lab*. Make observations and generate questions from the simulation showing particle motion in cold, warm, and hot liquid.	B-C	http://bit.ly/heating-and-cooling
3	15 min	**FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION ABOUT KINETIC ENERGY** Ask students to share observations from the simulation. Introduce the term *kinetic energy* to describe the energy of the particles moving. Broaden from liquid particles to gas particles with an odor demonstration, and add kinetic energy to students' emerging models of particle motion from Lesson 10.	D-G	Driving Question Board, note cards, markers, perfume or scented oil
4	8 min	**EXPLAIN THE FOOD COLORING LAB OBSERVATIONS** As a class and then individually, construct an explanation for why food coloring moved around more in hot water, using new ideas about kinetic energy.	H	
5	4 min	**NAVIGATION** Revisit the anchor scenario's iced drink in the regular plastic cup that warmed up over time and discuss how the drink gained kinetic energy. Problematize where that energy came from and share initial ideas.	I-J	

End of day 1

Lesson 11 • Materials List

	per student	per group	per class
Lesson materials	• science notebook		• 3 claim posters • 4 evidence cards from *Evidence Cards 1* • tape • http://bit.ly/heating-and-cooling • Driving Question Board • note cards • markers • perfume or scented oil

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare three claim posters using chart paper. Title the posters as follows:

- Claim 1: Heat is entering the cup system.
- Claim 2: Cold is leaving the cup system.
- Does not support either claim over the other or supports both equally.

Prepare four evidence cards on 8.5-×-11 paper using *Evidence Cards 1*.

Check to make sure the simulation works on your computer. You can play the simulation from the slides or from the OpenSciEd website. Alternatively, you can download the .swf file and Elmedia player from the American Chemical Society Middle School Chemistry page and play the simulation directly from your computer. If you plan to have students explore the simulation in small groups on their own computers (the alternate activity), check to make sure the simulation works on the devices your students will use.

Link to American Chemical Society simulations:
http://bit.ly/heating-and-cooling

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

Students come into this lesson having observed that the peppermint dye and food coloring in hot water moved more than in cold water. They have constructed models for describing this difference in motion. However, they don't yet know that this difference is caused by faster particle movement in warmer matter related to the particles' kinetic energy. Do not prompt students to make this connection until after watching the simulation. Following the simulation, you will introduce the term *kinetic energy* as a way of describing the particles' movement. Students will refine their models of energy entering and leaving systems using the concept of kinetic energy.

If students continue to refer to "hot particles" and "cold particles", work today on supporting their development of the concepts and language around "particles with more kinetic energy" and "particles with less kinetic energy". You will continue working on this language development throughout the remainder of the unit.

Where We Are NOT Going

It is OK for students to describe particle motion as being uniform within a sample of matter at a certain temperature. For example, all particles in cold matter move slower than all particles in hot matter. Students will refine their understanding of average kinetic energy in the next lesson and recognize that, on average, particles are moving slower or faster, respectively.

LEARNING PLAN for LESSON 11

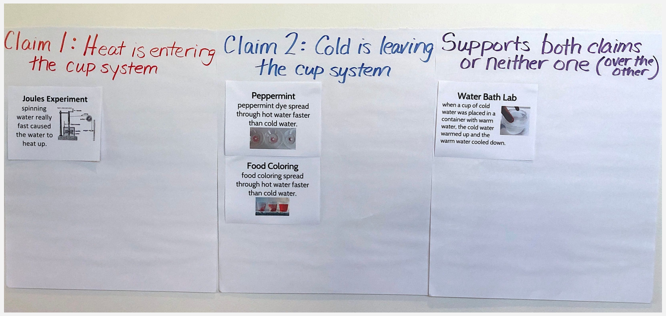
1 · NAVIGATION

8 min

MATERIALS: science notebook, 3 claim posters, 4 evidence cards from *Evidence Cards 1*, tape

Add evidence to the claim posters. Display **slide A**. Introduce students to the claim posters and the evidence cards. Ask, *Which claim does our evidence support so far?* Have students turn and talk with a elbow partner about their responses to that question, working with these pieces of evidence:

- *Peppermint Dye*: Peppermint dye spread through hot water faster than through cold water.
- *Food Coloring Lab*: Food coloring spread through hot water faster than through cold water.
- *Water Bath Lab*: When a cup of cold water was placed in a container of hot water, the cold water warmed up and the hot water cooled down.
- *Joule's Experiment*: Spinning water very fast caused the water to heat up.



After 2 minutes, bring students back together to brainstorm as a class where the evidence fits onto the claim posters.✱ Add each evidence card to the poster for which students agree the evidence best supports the claim. If students cannot agree, place the evidence card between the posters for which it is being debated.

Say, *Let's collect additional evidence to help us better decide between these two claims. We probably need to figure out more about why particles move more in hot liquids and move less in cold liquids and how this happens.*

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

While arguing from evidence is not the focal practice in this lesson, this particular activity focuses students on starting to organize the evidence they gather to help them engage in argumentation about directionality of energy transfer, which will happen in Lesson 14. Over the course of the next few lessons, students will add evidence to these claims posters. When students add new evidence, they can also re-evaluate and re-sort previous evidence as they learn more and their understanding develops. It is not necessary that all the evidence be accurately sorted; rather, use students' sorting to surface where they are making sense of new information and where they are struggling.

2 · OBSERVE THE HEATING AND COOLING A LIQUID SIMULATION

10 min

MATERIALS: science notebook, http://bit.ly/heating-and-cooling

Review previous observations of the peppermint dye and food coloring. Project **slide B**. Facilitate a brief sharing of ideas during a whole group discussion. Use this time to motivate the need to zoom into particles in the hot, warm, and cold liquids to see how they are moving differently. Don't linger too long on reviewing students' ideas, but devote enough time to this discussion to lay a foundation for the simulation that comes next.

Introduce the simulation. Say, *When scientists are interested in something that they can't see, sometimes they can collect evidence of its behavior that they can see, which is what we did in the last class. They can also use computer models to help them understand things that are not observable. I have a simulation that can help us see what's happening in liquids up close. Maybe it can help us figure out why particles move more in warmer liquids.*✱

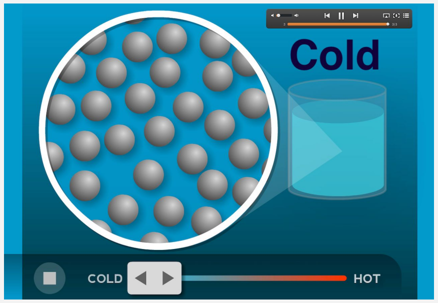
Prepare to observe the simulation. Project **slide C**. Have students find a new page in their science notebook to title "Heating and Cooling a Liquid Simulation". Below the title, students should draw a Notice and Wonder chart to record observations and questions.

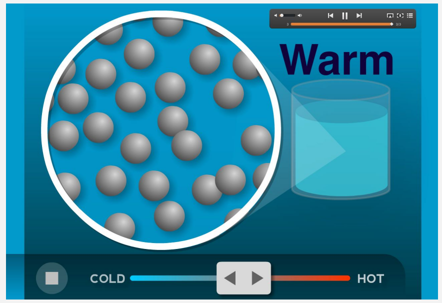
Make observations of the simulation. Project the *Heating and Cooling a Liquid* simulation from the slides, from your computer, or from the American Chemical Society Middle School Chemistry website. Share with students that this simulation shows what is happening with particles in hot liquids and cold liquids.

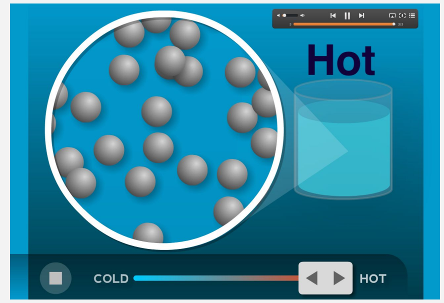
✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

Encourage students to use scale as a way to frame their work in this lesson moving between the particle scale and macroscale. Students have now gathered evidence of phenomena at the macroscale that indicate something is occurring at the particle scale that is not observable. This is true of the work done by James Joule. Throughout this lesson, emphasize that when we are trying to figure something out, it's important to question whether something that could be helpful to our thinking is happening at a scale too small, too large, or too long for us to observe.

Keep the simulation on the "Cold" setting for at least 30 seconds and have students write observations in their notebook. Then move the slider bar to the "Hot" setting and pause for students to make observations. Then move the slider bar to the middle, or "Warm" setting and pause for students to make observations. Have students quietly record observations and questions in their science notebook. Adjust the slider bar as necessary if students want to revisit a certain temperature.







Discuss observations with a partner. Have students share what they noticed and wondered with a elbow partner. Encourage students to pay attention to observations or questions their partner made that they may not have noticed.

Make observations of the simulation a second time. Prompt students to watch the simulation again, focusing on anything new they heard from their partner. Have students record additional noticings and wonderings in their science notebook.

ALTERNATE ACTIVITY	If time permits and you have access to 1:1 or 2:1 computers, have students visit the simulation, manipulate the slider bar, and make observations on their own and then in pairs.

3 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION ABOUT KINETIC ENERGY

15 min

MATERIALS: science notebook, Driving Question Board, note cards, markers, perfume or scented oil

Guide a Building Understandings Discussion. Project **slide D**. Have students share their observations and questions with the class, and then move students toward thinking more about the energy of particles. Example prompts are given below.

KEY IDEAS	**Purpose of the discussion:** to help students make sense of multiple points of evidence that show the motion of particles in a sample of matter changes with the temperature of the sample. **Listen for these ideas:** • Matter that is warming up have particles that are moving more. These particles have more kinetic energy. • Matter that is cooling down have particles that are moving less. These particles have less kinetic energy. • There are no "hot particles" or "cold particles", just particles with different amounts of kinetic energy.

✱ ATTENDING TO EQUITY

The new vocabulary *kinetic energy* is intentionally introduced after students have developed an understanding that particles can move more and faster or less and slower. Students have had the opportunity to construct a conceptual understanding first and are now given the scientific language to describe that concept. This should be a word students earn in this unit, so revisit and add to the term on the word wall as students build their understanding of it.

✱ STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Suggested prompt	Sample student response
What did you notice in the simulation?	*Particles move more in hot water and move less in cold water.* *Particles move faster in hot water and slower in cold water.* *Particles bounce off each other in both hot and cold water.* *Particles are more spread out in hot water and closer together in cold water.* *Particles bounce off each other farther in hot water than in cold water.*
What new questions do you have?	*(Add new student questions to the Driving Question Board.)*
Drawing on evidence from the Food Coloring Lab, the peppermint candy video, the reading about Joule, and this simulation, what can we summarize about the differences between particles in a cold liquid and particles in a hot liquid?	*Particles in hot water move more, faster, and farther apart.* *Particles in cold water move less, slower, and closer together.*

Introduce the term *kinetic energy*. Project **slide E**. Now that students have constructed the idea that some particles move faster and some move slower, introduce the term *kinetic energy* to describe the speed of particle movement.✱ Kinetic energy is the energy of movement, and students will be using this concept throughout the remainder of the unit.

Record and apply the new vocabulary. Add *kinetic energy* to your classroom word wall if you have one (kinetic energy--the energy of movement) and/or have students jot down the new term in their notebook. Record a consensus definition of *kinetic energy*. Students can also draw a picture that connects their conceptual understanding to the term. Discuss as a class how much kinetic energy the simulated particles (cold, warm, hot) have and connect this to the observed speed of the particle movement.

Suggested prompt	Sample student response
In the simulation, which particles had the most kinetic energy? Why?	*Hot particles, because they were moving faster.*
Which particles had the least kinetic energy? Why?	*Cold particles, because they were moving slower.*

Broaden to gas particle movement. The purpose of this part of the discussion is to generalize what we just figured out about liquid particle movement to gases.✱

Summarize by saying, *Now we know that liquid particles move around freely at different speeds. We've figured out that particles in cold liquid move slower, so they have less kinetic energy, and particles in hot liquid move faster, so they have more kinetic energy. Let's consider gases.* Project **slide F**.

Review what we know about gas particles and discuss what we'd see if we tested our ideas by spraying perfume on at one side of the classroom.

Suggested prompt	Sample student response
Do gas particles move around like liquids?	*Yes, they move around freely.*

As you transition from liquid to gas, guide students to use evidence collected with liquids as a way to predict what would happen in gases. Encourage students to bring in their personal experiences of odors in gases, and incorporate the idea that the speed at which an odor reaches you could vary by air temperature. Students do not need to agree on every idea at this point but should be able to point to evidence to support the ideas they are sharing aloud.

Suggested prompt	Sample student response
If gas particles move freely, what can we expect if we spray this perfume at one side of the room?	*We'll be able to smell it at the other side of the room because the air particles will move the perfume around the classroom.*

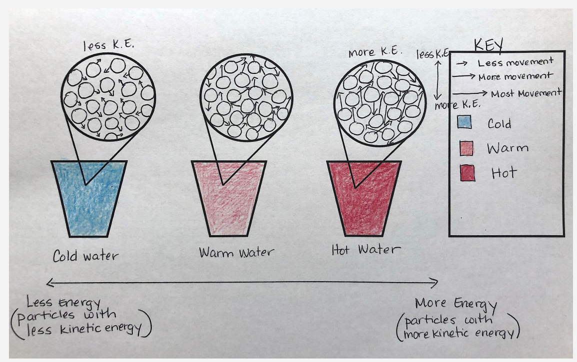
Demonstrate particle movement through the air. Spray perfume or a strongly scented oil (e.g., orange or lemon oil) on one side of the classroom. Wait until everyone in the room can smell it.

ADDITIONAL GUIDANCE	If your students are sensitive to chemical fragrances, you can use a strong-smelling scented oil, such as orange or lemon oil, or a strong-scented food, such as an orange peel, garlic, or a can of tuna fish.

Discuss gas particle movement. Lead the class in a short discussion about gas particle movement and how it's similar to liquid particle movement. Predict how the movement of the perfume (or alternative) through the classroom air would be different if the classroom were very cool compared to very warm.

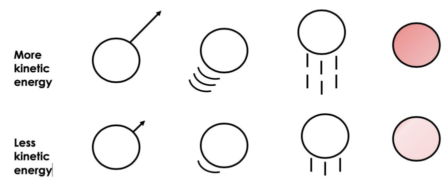
Suggested prompt	Sample student response
How are gas particles similar to liquid particles?	*They move freely like liquids.*
If it were a very hot day, how would the speed at which we smelled the perfume change? What about a very cold day? Why?	*On a hot day, we'd smell the perfume faster because the air particles would be moving faster.* *On a cold day, it would take longer to smell the perfume because the air particles would be moving slower.*
What about solids? Do solids move around like liquids and gases?	*No, they are locked in place.*

Refine our models to include kinetic energy. Project **slide G**. Have students work with a partner to develop and revise their models from the *Food Coloring Lab* to include kinetic energy. Once groups have generated ideas, have each group share them with the class. Encourage students to share different ways they added kinetic energy to their diagrams, which could include adding it to the key and adding arrows, labels, or a short written explanation. Modifications to their models should be minor but are important.



ADDITIONAL GUIDANCE

This is another opportunity to approach consensus about how the class wants to represent kinetic energy of particles. It is not necessary to push for consensus right now, but in the next lesson, the class will need to evaluate each potential representation and decide which one to use going forward, so continuing the conversation from today will set students up for this Consensus Discussion in Lesson 12. Options for representations are included below. Note the subtle shift from more and less movement in Lesson 10 to more and less kinetic energy in Lesson 11.



4 · EXPLAIN THE FOOD COLORING LAB OBSERVATIONS

8 min

MATERIALS: None

Construct an explanation as a class. Project **slide H**. Remind students what we observed in the *Food Coloring Lab*. Focus them on explaining why the food coloring particles moved more in the hot water than the cold water. Make sure the new idea of kinetic energy is included.

Practice creating an explanation together, verbally, using the sentence frames on **slide H**. Ask several students to share what they placed in the different blanks of the sentence framers. These sentence frames will support students in developing a claim and backing it up with evidence from the *Food Coloring Lab*, the peppermint candy video, the Joule reading, and the simulation.✱

- Sentence frames:

Our claim is that the food coloring spread out more in hot water because ____________.
Our evidence is ______________ and _________________.

- Example explanation:

Our claim is that the food coloring spread out more in hot water because the water particles have more kinetic energy, which means they're moving faster and moving the food coloring particles around more. Our evidence is that in the simulation, we observed water particles in hot water moving faster and water particles in cold water moving slower. We already read that moving water very fast warms it up because the particles in the water are moving faster.

Record an individual explanation. Give students time to record an individual explanation in their science notebook.✱

ASSESSMENT OPPORTUNITY

Collect student notebooks to check students' individual explanations to see if and how they are connecting ideas about kinetic energy and particles moving faster in hot water to what they observed with the spread of the food coloring and the peppermint dye as well as what they read about in Joule's experiment. Look for students citing evidence from these different sources of information to back up claims that particles in hot water move faster, and also that making particles move faster will result in an increased temperature.

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLAINING AND DESIGNING SOLUTIONS

Sentence frames support students to construct an explanation by breaking it into components including developing a claim and providing evidence to support that claim. Students practice developing a verbal explanation first as a class so they have an example before they complete the task individually in writing.

✱ ATTENDING TO EQUITY

If you want to challenge your students, have them write an explanation for what they observed in the peppermint candy video as opposed to or in addition to the *Food Coloring Lab*. Alternatively, you can construct an explanation of the peppermint candy video together and then have students work on their own to write an explanation for the *Food Coloring Lab*. If your students seem confused or need remediation, you can use two helpful simulations from Concord Consortium.

- Have students think about explaining the food coloring by visiting "Molecular view of a liquid": http://bit.ly/molecular-view-liquid

Mark two atoms or trace an atom. Prompt students to use our observations of the simulation to explain how food coloring particles move through the water particles.

- Likewise, have students visit "Molecular view of a gas": http://bit.ly/molecular-view-gas

Mark two atoms or trace an atom to explain how the smell of perfume moves through the air.

5 · NAVIGATION

4 min

MATERIALS: None

Revisit the anchoring phenomenon. Project **slide I**. Revisit the idea that the iced drink in the regular plastic cup warmed up over time. Discuss as a class what happened to the kinetic energy of the particles in the drink and how it must have increased because warmer liquid particles move faster.

Problematize where the new energy came from. Project **slide J**. Summarize by saying, *If the drink is warming up, that means its particles are moving faster and have more kinetic energy. So where does that energy come from?*

Give students time to talk with a partner about their initial ideas of where that energy could have come from.

Additional Lesson 11 Teacher Guidance

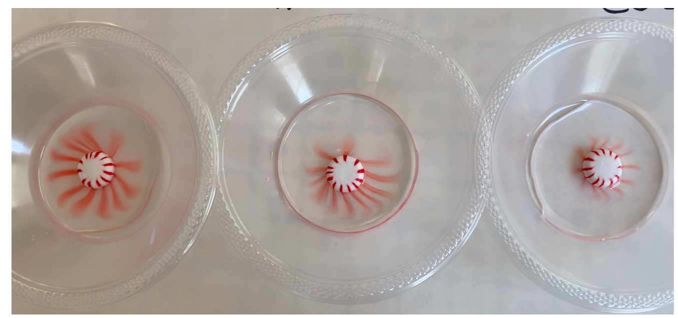
SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6-8 texts and topics*.** Students build their understanding of kinetic energy as the energy of motion. In this lesson, students are learning about kinetic energy with respect to particle motion and speed (i.e., how fast or slow the particle is moving). Students add this term to the word wall and will refine their understanding of kinetic energy over the next few lessons, adding to the word wall. This will be a word that students earn in the unit. **CCSS.ELA-Literacy.W.6.1.b: Support claim(s) with clear reasons and relevant evidence, using credible sources and demonstrating an understanding of the topic or text.** **CCSS.ELA-Literacy.W.6.1.c: Use words, phrases, and clauses to clarify the relationships among claim(s) and reasons.** Students construct an explanation of a phenomenon in which they are to apply their new understanding of particle motion and kinetic energy. They use sentence frames to help them write a claim and support that claim with evidence.

Lesson-Specific Teacher Materials

Evidence Cards 1

Peppermint Dye

Peppermint dye spread through hot water faster than through cold water.

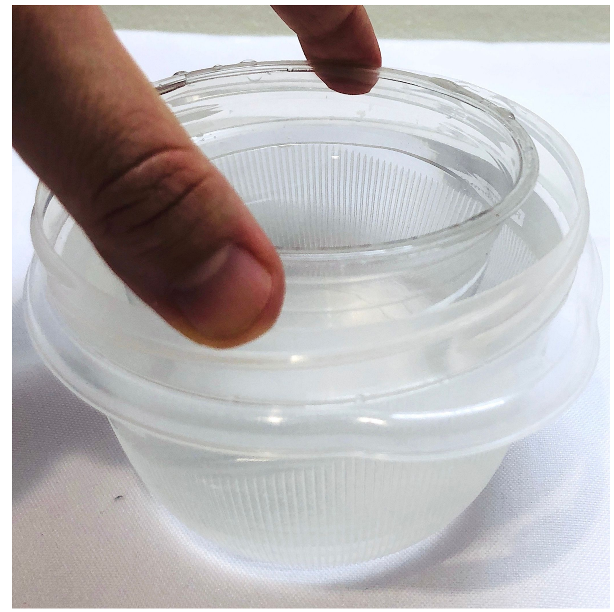


Food Coloring Lab

Food coloring spread through hot water faster than through cold water.

Water Bath Lab

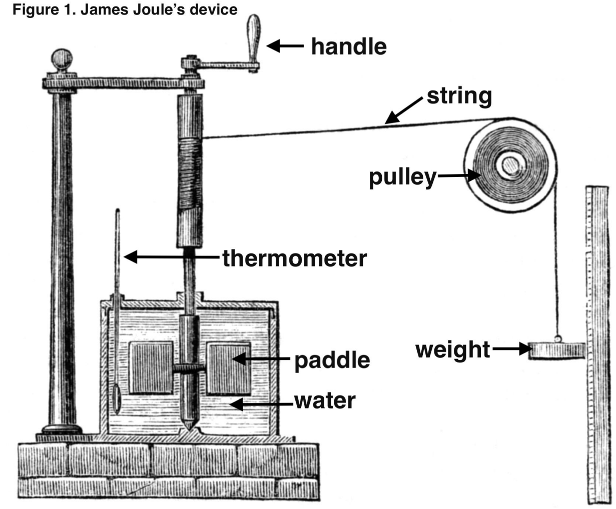
When a cup of cold water was placed in a container of hot water, the cold water warmed up and the hot water cooled down.



Joule's Experiment

Spinning water very fast caused the water to heat up.

Figure 1. James Joule's device



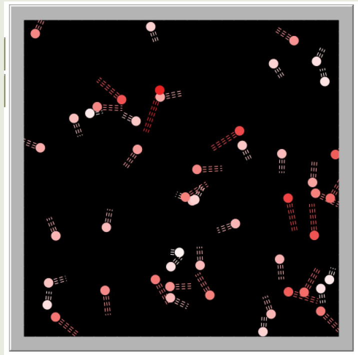
LESSON 12: How does the motion of particles compare in a sample of matter at a given temperature?

PREVIOUS LESSON *We observed a simulation and obtained evidence that hot liquids have particles that move faster (more kinetic energy) and cold liquids have particles that move slower (less kinetic energy). We added kinetic energy to our models. We revisited our original iced drink warming up in the regular plastic cup and wondered where the kinetic energy came from.*

THIS LESSON

INVESTIGATION

2 days



We use a simulation to investigate how individual particles in a sample of gas do not have the same kinetic energy, and how the kinetic energy of each particle is constantly changing as the particles collide with one another. We argue that temperature is a measure of the average speed of the particles in the matter, and that the total energy of a sample of matter is the sum of the kinetic energy of all the particles in the sample combined. Using these key ideas, we update our Progress Trackers and the class claims posters.

NEXT LESSON *We will use a computer simulation to analyze particle speeds before and after a collision. We will use marbles to investigate the effects of collisions on particle speed in different situations to simulate interactions between particles in a gas, a liquid, and a solid. We will use a computer simulation to analyze particle interactions in different solids in contact with each other at different temperatures.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Carry out an investigation to look for patterns in data generated by using an interactive simulation of the particles in a gas (which are too small to be observed) to observe the kinetic energy of individual particles and the transfer of energy when they collide.

Analyze and interpret data to mathematically represent the cause-and-effect relationships between the average kinetic energy of the particles of a gas, the temperature of the gas, and the total kinetic energy of all the particles in the gas.

WHAT STUDENTS WILL FIGURE OUT

- Not all particles in a sample of matter have the same kinetic energy.
- Kinetic energy is transferred from one particle to another in a particle collision.
- Temperature is a measure of the average kinetic energy of the particles in a sample of matter.
- The total kinetic energy of a sample of matter is the sum of the kinetic energy of all the particles in that sample. If you add more particles to the sample, the total kinetic energy increases but the temperature (the average kinetic energy) might stay the same.

Lesson 12 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review what we figured out about the kinetic energy of the particles in hotter and cooler liquids, and motivate the need to figure out how particles of matter gain and lose energy.	A	three claims posters
2	20 min	**ORIENT STUDENTS TO THE ONLINE INTERACTIVE SIMULATION** Introduce the online interactive simulation that students will use to further investigate the kinetic energy of and interactions between particles in a gas.	B-G	
3	20 min	**EXPLORE THE INTERACTIVE SIMULATION** Give students time to explore the online interactive simulation that they will use to further investigate the kinetic energy of and interactions between particles in a gas.	H-K	*Particle Interactions in Gases*, laptop or tablet, timer, chart paper, markers
				End of day 1
4	3 min	**REVIEW WHAT WE FIGURED OUT** Take time to review what we figured out on day 1 using the interactive simulation to further investigate the kinetic energy of and interactions between particles in a gas.	K	
5	10 min	**OBSERVE INTERACTIONS AND RECORD DATA USING INTERACTIVE SIMULATION** Use the online interactive simulation to collect data to figure out the relationship between the temperature of a sample of matter and the kinetic energy of the particles that make up the sample.	L-M	*Particle Interactions in Gases*, laptops or tablet
6	20 min	**HAVE A BUILDING UNDERSTANDINGS DISCUSSION IN A SCIENTISTS CIRCLE** Look for patterns in the small-group data to figure out the relationship between the temperature of a sample of matter and the kinetic energy of the particles that make up the sample.		*Particle Interactions in Gases*, chart paper, markers
7	10 min	**UPDATE THE PROGRESS TRACKER** Ask students to document evidence to support their thinking while updating their Progress Trackers.	N-O	*Particle Interactions in Gases*, *Progress Tracker* or *Progress Tracker 2*
8	2 min	**NAVIGATION** Motivate the need to investigate collisions between the particles of samples of different types of matter.		
				End of day 2

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Particle Interactions in Gases* • *Progress Tracker* or *Progress Tracker 2*	• laptop or tablet • laptops or tablet	• three claims posters • timer • chart paper • markers

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Students need laptops or tablets (at least one for each small group) with an internet connection so that they can access and explore the online simulation.

Charge laptops or tablets overnight so that they are fully charged for the investigation. If your classroom's internet connection is wifi, make certain your wifi router can allow all the computers to connect.

Prior to class, make sure that the online simulation works on your computer and on student laptops or tablets. Also, to ensure that the lesson flows smoothly, minimize the internet browser window with the simulation, then open the lesson slides and project them. Keep the simulation minimized until needed later in the lesson.

Website for the simulation: https://openscied.org/gas-particle-motion/

You will also need chart paper and markers to record students' ideas.

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

Early in Lesson Set 2, students tested their ideas about light and heat causing a change in the temperature of a cold drink inside a cup system. They determined that light has some impact but heat has a much greater impact, and that the greater the temperature difference between two objects, the faster energy transfers between them. Lesson 10 reinforced student understanding that particles in liquids move and that when cold liquids warm up, the particles in the liquid move more, and when hot liquids cool down, the particles in the liquid move less. In Lesson 11, students used an online simulation to observe the motion of the particles in a liquid at different temperatures. They learned that a particle's speed is related to how much kinetic (motion) energy it has, and that the particles in warmer liquids have more kinetic energy than those in cooler liquids.

In this lesson, students again use an online simulation to observe particle motion, this time in a gas. They observe that the individual particles in a gas do not all have the same kinetic energy, and that the particles' kinetic energy is constantly changing as they collide with one another. From these observations, students figure out that temperature is a measure of the *average* kinetic energy of the particles in a sample of matter, and that particle collisions result in transfers of energy between particles. They also figure out that the total energy of a sample of matter is the sum of the kinetic energy of all the particles in that sample, and that if more particles are added to it, the total energy increases but the temperature (average kinetic energy) might or might not change.

Where We Are NOT Going

Up to this point in Lesson Set 2, students have investigated particle motion in liquids in a variety of ways, and have collected and analyzed data to determine the role of light and heat in warming up a cold drink inside a closed cup system. Like the previous lesson, this lesson focuses on the use of an online simulation to observe a phenomenon that cannot be observed directly--the particle motion of matter. The simulation helps students figure out the relationship between the kinetic (motion) energy of the particles of a sample of matter, the temperature of that sample, and its total energy. Through this lesson, students observe the interactions between the particles in a sample of a single liquid or a gas and figure out what happens when those particles interact.

When thinking about the cup system and how the drink inside it warms up, students will need to determine how energy moves from a gas (air) to a solid (the wall or walls of the cup system) to the liquid inside. Therefore, in subsequent lessons, students will determine the direction that energy flows and apply their understandings from this lesson set to explain interactions between the different states of matter associated with the closed cup system.

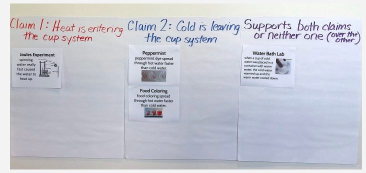
LEARNING PLAN for LESSON 12

1 · NAVIGATION

5 min

MATERIALS: three claims posters

Review the particle nature of matter. Project **slide A** and say, *Based on our last few investigations on heat, what have we figured out about the particles that make up warmer and cooler matter?* Tell students to turn and talk with a partner. Remind them to use evidence that we have documented on our class claims posters to support their thinking.



Give partner pairs time to talk, then ask a few students to share their thinking with the class.

Suggested prompt	Sample student response
What have we figured out about the particles that make up warmer and cooler matter?	*Warmer matter has particles that move more, and cooler matter has particles that move less. We know this is true because the food coloring moved through the hot water faster than it moved through the cold water.* *The particles in warmer liquids have more kinetic energy, and the particles in cooler liquids have less kinetic energy. We know that particles in warmer matter move more than those in cooler matter. In the simulation, we saw that a particle's speed is related to how much kinetic energy (or motion energy) it has.*

Motivate the need for further investigation. Tell students, *The last simulation was very useful for observing what's going on at a scale that we can't see with our eyes. We figured out that a particle's speed is related to the amount of kinetic energy it has. But we were left wondering how particles gain or lose energy. We also still need to figure out how this helps us explain how our original iced drink warms up in each of the cup systems that we tested, and if it's because cold is leaving the system or heat is entering the system. So, we need to gather more evidence about the kinetic energy of particles.*✱

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

Keep the evidence at the foreground of activities and discussions in today's lesson. Students are working toward developing an argument from evidence that energy transfers from hotter regions to colder regions (Lesson 14), and they will add to their argument by gathering more evidence from another simulation.

2 · ORIENT STUDENTS TO THE ONLINE INTERACTIVE SIMULATION

20 min

MATERIALS: science notebook

Prepare to use the simulation. Display **slide B**. Say, *We need to get ready to record observations in our science notebooks. Turn to a new page in your notebooks and write the lesson question at the top: "How does the motion of the particles compare in a sample of matter at any given temperature?"*

Give students a few moments to copy the question.

ADDITIONAL GUIDANCE	Prior to the lesson, make sure that the lesson slides and a web browser with the simulation are both open on your computer. The simulation is located at https://openscied.org/gas-particle-motion/ . You can begin the lesson with both minimized, which allows you to have the simulation and the slides ready for use and gives you the freedom to move back and forth between the two as needed.

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Emphasize to students that they are using a computer model to help them generate data to test their ideas about how energy enters or exits a sample of matter. The simulation is useful because it allows students to not only make observations of particle motion but also quantify that motion for further analysis.

Introduce the simulation. Animate the text box and image of the simulation on the right side of **slide B**. Say, *Because we cannot see particles of matter with our eyes, we will again use a virtual model, but this simulation is a bit different from the previous one. It is interactive, which means we can change components of the system and observe what happens. This will allow us to observe the behavior of particles in a gas under different conditions.*✱

Focus student attention on the control panel. Display **slide C**. Tell students, *We need to take a few minutes to explore the simulation's control panel before we begin our investigation.* Use the animation in the slide to point out the parts of the control panel as you say, *The control panel is made up of buttons, sliders, drop-down menus, and data boxes in three different colors. The color gives us a clue to the function of each.*

Display **slide D**. Say, *Let's begin by looking at the three blue buttons.*

- *"Setup" allows you to set up and reset the simulation whenever you want to change one or more component.*
- *"Go/Pause" allows you to start or pause the motion in the simulation.*
- *"Follow a particle/Reset view" allows us to follow a single particle as it moves.*

Display **slide E**. Tell students, *There are two green sliders and a green drop-down menu. Let's focus on the green sliders first.*

- *"Initial gas temperature" allows us to choose the temperature of the gas.*
- *"Initial # of particles" allows us to select or adjust the number of particles to observe.*
- *Each green slider has an up/down function that allows us to adjust the numbers as desired.*

Minimize the lesson slides on your computer and display the simulation https://openscied.org/gas-particle-motion/ , which should already be open and minimized on your desktop. Tell students, *Let's take a minute or two to practice using these two sliders.*

Explore the green sliders as a class. Tell students, *Let's set the initial temperature of the gas at 100°C and the number of particles at 10.* Set the parameters using the two green sliders. Note: Make sure that the "Visualize particle speeds" drop-down menu is set at "none." Say, *Now I need to click on "Setup" and "Go" to start the simulation. Watch what happens. Turn and talk with a partner and describe what you see.*

Give students a minute or two to observe the simulation and share their observations with a partner. Then say, *What do you notice is happening in the simulation?* Have a few students share their thinking with the class.

Suggested prompts	Sample student responses	Follow-up questions
What do you notice is happening in the simulation?	*The particles are all red.*	*Is the color exactly the same for all the particles?*
The particles are moving around, and sometimes they collide into one another.	*What do you notice happening when particles collide?*	
It looks like the particles might be moving at different speeds, but it's hard to tell by just watching the particles moving.	*Is there anything on the screen that might help us know if the particles are moving at different speeds?*	
The temperature of the entire gas is not the same, because the total kinetic energy of all the particles is different.	*How do you know that?*	

Describe the function of the "Visualize particle speeds" drop-down menu. Minimize the simulation and continue to display **slide E**. Say, *We noticed a number of things happening in the simulation, but we also noticed that it was not easy to see if there were any differences in the motion of the individual particles or if anything happens when they collide. So, we might need to adjust or change another component of the simulation.*

Animate **slide E** to show its additional text. Say, *Let's look at another way that we can adjust the simulation. "Visualize particle speeds" is a drop-down menu that gives options for seeing and comparing the speed of the particles in the gas.*

Display **slide F**, which shows the open drop-down menu. Ask, *What are our options for visualizing particle speeds?* After students respond, use the follow-up questions below before allowing students to see how each option will change the simulation.

Suggested prompts	Sample student responses	Follow-up questions
What are our options for visualizing particle speeds?	*The menu has four choices:* • *"None"* • *"Different shades"* • *"Trail length"* • *"Trail length and shades"*	*What changes do you think will result when selecting each of these options?* *Why might these changes be helpful to us?*

Describe the function of the yellow data boxes. Tell students, *Before we explore how the options change the simulation, I want to show you one more thing on the control panel.* Display **slide G** and say, *There are four yellow data boxes:*

- *"Temperature of the entire gas"*
- *"Total kinetic energy"*
- *"Speed of slowest particle"*
- *"Speed of fastest particle"*

These data boxes give us numerical information about the gas and the particles in the gas. What do you think the number in each data box means? Turn and talk to a partner about this.

Give students a minute or two to talk, then have them share out their ideas for each of the yellow data boxes. Use the follow-up questions below as students share their thinking.

Suggested prompts	Sample student responses	Follow-up questions
What do you think the number in each yellow data box means?	*"Temperature of the entire gas" is the same as the temperature that we initially set using the green "Initial gas temperature" slider.*	*Do you think this number will always be the same as the number that we set using the "Initial gas temperature" slider? Why or why not?*
"Total kinetic energy of all the particles" gives us a larger number.	*How do you think this number is determined?*	
"Speed of slowest particle" and "Speed of fastest particle" are different numbers. So, in this gas, one of the 20 particles is moving at the slowest speed and another particle is moving at the fastest speed.	*What does this information tell you about the particles in this gas?*	

Prepare students to explore the simulation. Say, *Now that we have taken a look at each of the buttons, sliders, drop-down menus, and data boxes in the control panel, you are ready to spend a little bit of time exploring the simulation, focusing on making changes using the blue and green controls.* Instruct students to do this in pairs or in small groups, depending on how many laptops or tablets are available.

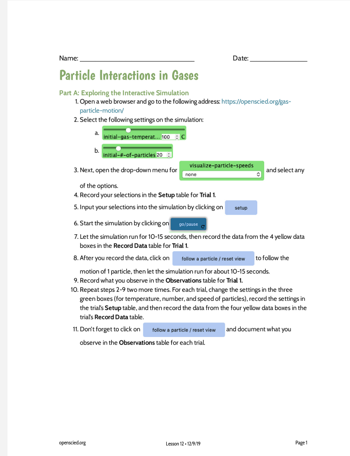
ADDITIONAL GUIDANCE	It would be ideal for students to work in pairs, if you have enough laptops or tablets for each pair of students to have one. If not, it is best to keep groups at 3-4 students per laptop or tablet.

3 · EXPLORE THE INTERACTIVE SIMULATION

20 min

MATERIALS: *Particle Interactions in Gases*, science notebook, laptop or tablet, timer, chart paper, markers

Explore the simulation using the handout. Pass out *Particle Interactions in Gases* and show **slide H**. Use the slide to orient students to the student procedures on the handout. Say, *Part A of the handout will guide you as you explore the simulation. Follow the procedure on the first page, and record your data and observations in the tables on pages 2-4. You will need to work quickly. Pay attention to the effects on the simulation caused by the changes you make in the control panel. We will discuss what you learned about the simulation when the timer goes off.*


Name: ______________________ Date: ______________

Particle Interactions in Gases

Part A: Exploring the Interactive Simulation

1. Open a web browser and go to the following address: https://openscied.org/gas-particle-motion/
2. Select the following settings on the simulation:
   a. initial-gas-temperat... 100 C
   b. initial-#-of-particles 20
3. Next, open the drop-down menu for visualize-particle-speeds none and select any of the options.
4. Record your selections in the **Setup** table for **Trial 1**.
5. Input your selections into the simulation by clicking on setup
6. Start the simulation by clicking on go/pause
7. Let the simulation run for 10-15 seconds, then record the data from the 4 yellow data boxes in the **Record Data** table for **Trial 1**.
8. After you record the data, click on follow a particle / reset view to follow the motion of 1 particle, then let the simulation run for about 10-15 seconds.
9. Record what you observe in the **Observations** table for **Trial 1**.
10. Repeat steps 2-9 two more times. For each trial, change the settings in the three green boxes (for temperature, number, and speed of particles), record the settings in the trial's **Setup** table, and then record the data from the four yellow data boxes in the trial's **Record Data** table.
11. Don't forget to click on follow a particle / reset view and document what you observe in the **Observations** table for each trial.

Set your timer for 8 minutes, then let students work through *Part A: Exploring the Interactive Simulation*. Circulate around the room and provide guidance as needed.✱

Debrief students' exploration of the simulation. Display **slide I** and direct students to title a new page in their notebooks "Part A: Exploring the Interactive Simulation". Have them create a Notice and Wonder chart on that page, then say, *As you made changes to the simulation using the controls, what did you notice? What did you wonder? Record your thoughts in the chart in your notebooks.*

Give students two minutes to record their thinking. While they are working, minimize the slides on your computer and display the simulation. Then, draw the chart (shown below) on chart paper, filling in only the column and row headings.

When you are ready, tell students, *Think about what you noticed and wondered as you explored the simulation. We will discuss one button, slider, or drop-down menu at a time, and I will record the changes you made using each. I will also listen for a description of the effect that those changes had on the simulation and on the data that you recorded from the yellow data boxes.*

Beginning with the "Follow a particle/Reset view" button, document the changes and effects into the chart as students share what they noticed and wondered. Sample ideas are in the chart below:

Button, slider, or drop-down menu	Changes	Effects on the simulation
Follow a particle/Reset view	Click on the button while the simulation is running	Allows us to observe an individual particle and the changes that happen to it as it moves around and collides with other particles.
Visualize particle speeds	None	All the particles are red.
	Different shades	The particles range in color from white, to pink, to red. The darker the shade of the color, the faster the particle is moving.
	Trail length	The particles each have trails behind them. The longer the trail, the faster the particle is moving.
	Shades and trail length	Both color and trail length are used to indicate the speed of the particles.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

Students use the online interactive simulation to generate and collect data to figure out the relationship between the kinetic energy of the particles in a gas and the temperature of the gas. Emphasize during this experience that the data will serve as the basis for evidence to answer our questions about how energy transfers into or out of systems.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING PATTERNS

The online simulation uses different shades of color and/or varying lengths of trails to indicate the speed (amount of kinetic energy) of individual particles of a gas. As students observe particle motion in the simulation, focus students on looking for recurring patterns in the changes that occur as the particles collide. Prompt to notice if the kinetic energy of particles increases, decreases, or stays the same after collisions.

Initial gas temperature	Temperature can be adjusted from -20°C to 400°C.	The higher the temperature, the faster the particles moved. The "Temperature of the entire gas" always matched the "Initial gas temperature". The "Total kinetic energy of all the particles" increases and decreases with corresponding changes in the "Initial gas temperature". The "Speed of the slowest particle" and "Speed of the fastest particle" changes constantly.
Initial # of particles	The number of particles can be adjusted from 1 to 100.	Using very few or a lot of particles makes it harder to see differences or changes in the motion and collision of the particles. The "Total kinetic energy of all the particles" increases and decreases with corresponding changes in the "Initial # of particles". The "Speed of the slowest particle" and "Speed of the fastest particle" changes constantly.

Summarize what we figured out as we explored the simulation. Show **slide J** and tell students, *While we explored the simulation, what were some of the things we figured out about the kinetic energy of the particles in a gas, the total kinetic energy of the particles in the gas, and the temperature of the gas? Turn and talk with a partner.*

Give students a minute to talk, then ask a few to share their thinking. Summarize by showing **slide K** and saying, *We now know that:*

- *The individual particles have different amounts of kinetic energy, even though the gas is at a given temperature.*
- *The kinetic energy of individual particles changes as the particles collide with one another.*
- *The temperature of the gas stays the same as the initial temperature that we set.*
- *The total kinetic energy of all the particles increases when we increase the temperature of the gas and/or when we increase the number of particles.*
- *The total kinetic energy of all the particles decreases when we decrease the temperature of the gas and/or when we decrease the number of particles*

To figure out how the cup system can keep a cold drink from warming up, we need to investigate further. We need to understand the relationship between temperature, the number of particles, and the total kinetic energy. To do this, we need to be strategic about the adjustments we make to the "Initial gas temperature" and the "Initial # of particles", and the data that we collect. Tomorrow we will look at the settings each group will use while collecting data.

End of day 1

4 · REVIEW WHAT WE FIGURED OUT

3 min

MATERIALS: None

Review what we figured out during day 1. Show **slide K** and say, *Turn to your partner and review the things we figured out as we explored the simulation yesterday.*

Give students a minute to talk, then say, *To figure out how the cup system can keep a cold drink from warming up, we need to investigate further. As I said yesterday, we need to understand the relationship between temperature, the number of particles, and the total kinetic energy of the gas. To do this, we need to be strategic about the adjustments we make to the "Initial gas temperature" and the "Initial # of particles", and the data that we collect. So, let's look at the settings each group will use while collecting data.*

5 · OBSERVE INTERACTIONS AND RECORD DATA USING INTERACTIVE SIMULATION

10 min

MATERIALS: *Particle Interactions in Gases*, science notebook, laptops or tablet

Collect data using the simulation. Show **slide L** and assign setups to small groups. Students can still work in pairs on laptops or tablets, but each group of 4 will be assigned the same setup. Tell students, *Turn to Part B: Collecting Data, which is on page 5 of the handout . Record the setup information assigned to your small group from the chart on the slide.*

Give students a few moments to record their assigned setups, then show **slide M**. Say, *Conduct 4 trials using the setup assigned to your group. Make sure you use "Follow a particle" to observe what happens to an individual particle over time. Feel free to adjust "Visualize particle speeds", if you need to, and record your data for each trial. You should take about 2 minutes for each trial.*✱

Give students time to set up and run 4 trials, document their data, and add additional observations on pages 5-6 of the handout.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

As students observe recurring patterns of change in particle speed due to collisions, they determine a cause-and-effect relationship between the kinetic energy of individual particles and the transfer of energy that occurs when particles collide. Support students in first identifying this pattern, and then in using this pattern to construct a cause and effect relationship. Students will then be ready to use the cause and effect relationship to make predictions about changes in the temperature of particles in other types of matter as they interact.

6 · HAVE A BUILDING UNDERSTANDINGS DISCUSSION IN A SCIENTISTS CIRCLE

20 min

MATERIALS: *Particle Interactions in Gases*, science notebook, chart paper, markers

Make sense of the small-group data. Ask students to bring their handouts, science notebooks, and a chair and gather in a Scientists Circle. Let students get settled, then use the following questions to guide the discussion.

Suggested prompts	Sample student responses	Follow-up questions
What did you observe when you tracked a single particle over time?	*The particle collides with other particles.*	*As these collisions happen, does the temperature of the gas change? Does the total kinetic energy of all the particles change? What does this tell us about temperature and total kinetic energy?*

Suggested prompts	Sample student responses	Follow-up questions
Any other observations?	*When the particle collides with other particles, it speeds up or slows down.* *When the particle that we are following is moving slowly and collides with a faster-moving particle, the first particle speeds up and the second slows down.* *When the particle that we are following is moving fast and collides with a slower-moving particle, the first particle slows down and the second speeds up.*	*When does the particle speed up? When does it slow down?* *What does that tell us about the kinetic energy of the particle that you are following and the particle that it collides with?* *What is happening with energy as the particles collide?*
What patterns did you see in the "Temperature of the entire gas"?	*The "Temperature of the entire gas" always matched the "Initial gas temperature", even when we added additional particles to the gas.*	*What does that tell us about temperature?*
What patterns did you see in the "Total kinetic energy" of the gas?	*When we added particles or increased the "Initial gas temperature", the "Total kinetic energy" of the gas increased.*	*What does this tell us about the total kinetic energy of the gas?*

Document what we have figured out. After using the data that students collected to build their understanding of particle motion, temperature, and total kinetic energy of the particles in a gas, ask, *What we have figured out using this simulation?*

As students share their thinking, record their ideas on chart paper.

Suggested prompt	Sample student response
What have we figured out about the kinetic energy of individual particles in a gas, the temperature of the gas, and the total kinetic energy of the particles in the gas?	*Not all particles have the same kinetic energy.* *The kinetic energy of particles change when they collide.* *When particles collide, energy goes from particles with more kinetic energy to those with less kinetic energy.* *Temperature is a measure of the average kinetic energy of the particles in the matter, not a measure of the total energy of all the particles and not a measure of the kinetic energy of individual particles.* *Total energy is the KE of all the particles added up, so if you add more particles, the total energy increases but the average energy can stay the same.*

7 · UPDATE THE PROGRESS TRACKER

10 min

MATERIALS: *Particle Interactions in Gases*, science notebook, *Progress Tracker* or *Progress Tracker 2*

Update the Progress Tracker. Show **slide N**. Pass out a copy of the Progress Tracker to each student (the version your students use). Give students a few moments to get their science notebooks ready as shown on **slide N**, then show **slide O**. Say, *Document what you have figured out about the kinetic energy of the particles in a sample of matter, the temperature of the sample, and the total kinetic energy of all the particles in the sample. Document evidence to support your thinking in the upper right-hand section of your Progress Tracker.* Give students time to complete their Progress Tracker. Collect their notebooks at the end of the lesson for formative assessment.

ASSESSMENT OPPORTUNITY

At this point in the lesson, students should be able to use evidence from the simulation to support the following understandings:

- Not all particles in a sample have the same kinetic energy.
- The kinetic energy of particles is constantly changing as particles collide with each other.
- When particles collide, energy is transferred from particles with more kinetic energy to those with less kinetic energy.
- Temperature is a measure of the average kinetic energy of the particles in a sample of matter.
- The total kinetic energy of a sample is the sum of the kinetic energy of all the particles in the sample. If you add more particles to a sample, the total kinetic energy increases but the temperature, or average kinetic energy, might stay the same.

Use students' Progress Trackers to assess their current understanding of these ideas and how well they can use evidence to support their thinking.

8 · NAVIGATION

2 min

MATERIALS: None

Preview the next investigation. Once students finish recording in their Progress Trackers, say, *Now that we know that the particles in a sample constantly collide, and that energy transfers during those collisions, I wonder if that happens when two different types of matter come into contact with one another. Think about the cup system (the cup, the liquid inside, the air above the liquid inside the cup), as well as the air outside the cup. Do the particles of these different types of matter collide and transfer energy? We need to investigate this idea next.*

Additional Lesson 12 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.Math.Content.6.SP.A.2: Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

In this lesson, students are required to reason mathematically particularly as they grapple with relating average kinetic energy (KE)to total KE in a sample of matter, as follows: (1) they increase and decrease the temperature of the gas and the number of particles in the gas to generate data they can use to explain what they observe in the simulation, (2) they collect and compare data (the temperature of the gas, the total KE of all the particles in the gas, and the speed of the slowest and fastest particles in the gas), and (3) they look for patterns in the data, and use those patterns to figure out the relationship between average KE and total KE of the particles in a sample of matter. Make it apparent to students whenever they will be using mathematical reasoning in the lesson, and provide support to students who may need it.

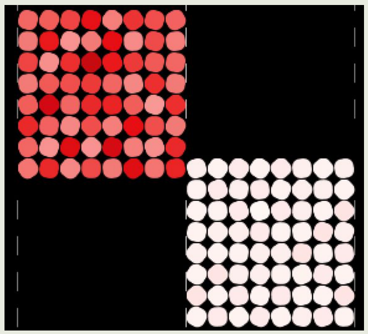
LESSON 13: How could the motion of particles on one side of a solid wall affect the motion of the particles on the other side of that wall?

PREVIOUS LESSON *We used a simulation to investigate how individual particles in a gas do not have the same kinetic energy, and how the energy of individual particles constantly changes due to collisions. We argued from evidence that temperature is a measure of the average speed of the particles in the matter, and that the total energy of a sample of matter is the sum of the kinetic energy of all the particles combined.*

THIS LESSON

INVESTIGATION

2 days



We use a computer simulation to analyze particle speeds before and after a collision. We use marbles to investigate the effects of collisions on particle speed in different situations to simulate interactions between particles in a gas, a liquid, and a solid. We use a computer simulation to analyze particle interactions in different solids in contact with each other at different temperatures.

NEXT LESSON *We will sort evidence collected over previous lessons to support claims about the cause for temperature changes in the cup system: heat moving in or cold moving out. We will collect additional evidence and use what we figure out to revise our cup system models and explain a new phenomenon.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Carry out investigations using a particle model of matter (with marble manipulatives and computer simulations) to generate evidence that one way the temperature of matter changes over time is that kinetic energy is transferred in collisions between the particles (matter) within and between solids, liquids, and gases.

WHAT STUDENTS WILL FIGURE OUT

- Particles in a solid vibrate back and forth in place.
- Collisions between particles in a solid, liquid, and/or gas can transfer kinetic energy (KE or motion energy) from one particle to another.
- The more particles in a sample of matter that are in contact with another sample of matter the greater the amount of particle KE is transferred from the warmer piece of matter to the cooler pieces of matter over time.
- The more particles an object is made of, the more energy must leave or enter the system in order to change the temperature of that object.

Lesson 13 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Connect to what we have figured out so far about speed changes in particles and temperature.	A	computer and projector
2	10 min	**ANALYZE THE MOTION OF COLLIDING PARTICLES IN A COMPUTER SIMULATION** Analyze motion changes of two particles colliding in a computer simulation.	B	Computer Simulation--Activity #1
3	10 min	**INVESTIGATE CHANGES IN PARTICLE MOTION IN COLLIDING MARBLES** Use a baking sheet and glass marbles to investigate what happens to particle speed when two particles collide.	C	*Investigating Particle Collisions in Different States of Matter*, chart paper, markers, timer, Marble Collisions--Activity #2
4	8 min	**USE MARBLES TO EXPLORE COLLISIONS BETWEEN PARTICLES IN A GAS AND A LIQUID** Investigate the effects of a single marble collision with a group of marbles to simulate a gas particle colliding with a group of particles in a liquid.	E-F	*Investigating Particle Collisions in Different States of Matter*, timer, Marble Collisions--Activity #3
5	8 min	**USE MARBLES TO EXPLORE COLLISIONS BETWEEN PARTICLES IN A GAS, LIQUID, AND SOLID** Investigate the effects of a single marble colliding with a group of particles to simulate energy transfer between a gas and a liquid and a solid.	G, H	*Investigating Particle Collisions in Different States of Matter*, timer, Marble Collisions--Activity #4
6	5 min	**APPLY THESE IDEAS TO THE RESULTS FROM ONE OF OUR CUP EXPERIMENTS** Explain how the results of these activities apply to the results of a previous cup experiment.	I	
				End of day 1
7	5 min	**NAVIGATION** Connect what we figured out yesterday to what we predict we would see in a computer simulation.	J-K	*Particle Collisions within and between Solids*
8	10 min	**ANALYZE THE MOTION OF PARTICLES IN SOLIDS IN A COMPUTER SIMULATION** Use a computer simulation to analyze how the motion of particles in a solid at a lower temperature compares to that in a solid at a higher temperature.	L-O	*Particle Collisions within and between Solids*, timer, Computer Simulation--Activity #5
9	8 min	**INVESTIGATE PARTICLES MOTION IN SOLIDS AT DIFFERENT TEMPERATURES** Use a computer simulation to investigate how particles in solids move at different temperatures.	P-Q	*Particle Collisions within and between Solids*, timer, Computer Simulation--Activity #6
10	8 min	**INVESTIGATE CHANGES IN PARTICLE MOTION BETWEEN TWO SOLIDS IN CONTACT** Use a computer simulation to investigate how the amount of contact area between two solids at different temperatures affects the rate and/or amount of temperature change in them.	R-U	*Particle Collisions within and between Solids*, timer, Computer Simulation--Activity #7
11	8 min	**INVESTIGATE THE EFFECT OF MASS ON CHANGES IN PARTICLE MOTION** Use a computer simulation to investigate how the amount of particles (mass) in solids at different temperatures affects the rate and/or amount of temperature change in them.	V-W	*Particle Collisions within and between Solids*, timer, Computer Simulation--Activity #8
12	5 min	**NAVIGATION** Connect what we figured out today about energy transfer at a particle level to explain how room temperature matter outside a cup can cause cold liquid inside the cup to warm up. Assign home learning.	X	
				End of day 2

Lesson 13 • Materials List

	per student	per group	per class
Computer Simulation--Activity #1 materials			• computer and projector • https://openscied.org/gas-particle-motion/ • https://openscied.org/collisions-up-close/
Marble Collisions--Activity #2 materials		• 1 steel baking tray • 1 plastic cup with 2 glass marbles	
Marble Collisions--Activity #3 materials		• 1 steel baking tray • 1 plastic cup with 2 glass marbles • 1 plastic cup with 13 glass marbles	
Marble Collisions--Activity #4 materials		• 1 steel baking tray • 1 plastic cup with 2 glass marbles • 1 plastic cup with 13 glass marbles • 1 plastic cup with 20 magnetic marbles	
Computer Simulation--Activity #5 materials		• tablet or laptop	
Computer Simulation--Activity #6 materials		• tablet or laptop	
Computer Simulation--Activity #7 materials		• tablet or laptop	
Computer Simulation--Activity #8 materials		• tablet or laptop	
Lesson materials	• *Investigating Particle Collisions in Different States of Matter* • science notebook • *Particle Collisions within and between Solids*		• computer and projector • chart paper • markers • timer

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make 20 magnetic marbles per group of students. Watch https://youtu.be/6AFdGd___Nk to see how to use a hot glue gun to attach one small neodymium ring magnets to the bottom of each wooden ball.

Students need laptops or tablets (at least one for each small group) with wifi capability to access and explore the online interactive simulations.

Charge laptops or tablets overnight so that they are fully charged for the investigation.

Prior to class, make sure the online simulation works on your computer and on student laptops/tablets. Also, to ensure that the lesson flows smoothly, minimize the internet browser window with the simulation, then open the lesson slides for projection. Keep the simulation minimized until needed later in the lesson.

Websites for the interactive simulations:
- https://openscied.org/gas-particle-motion/
- https://openscied.org/collisions-up-close/
- http://openscied.org/Conduction-in-Solids-Reduced.html
- http://openscied.org/Conduction-in-Solids-Full.html

Day 1: Marble Collisions--Activity #2 to #4
- **Group size:** 3 students
- **Setup:** Prepare the following for each group:
    - 1 steel baking tray
    - 1 clear plastic cup with 20 magnetic marbles
    - 1 clear plastic cup with 13 glass marbles
    - 1 clear plastic cup with 2 glass marbles

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

4-PS3-2 is a 4th-grade PE in NGSS that deals with energy transfer in collisions. In it, students ask questions and predict outcomes about the changes in energy that occur when objects collide. The emphasis is on the change in energy due to the change in speed in the colliding objects, not on the forces as objects interact. The DCI that this PE draws on is PS3.C: *When objects collide, the contact forces transfer energy, so as to change the object's motion*. But as shown by the evidence statement for the PE, the focus is not on the contact forces as a mechanism, but rather on the evidence of energy transfer due to collisions resulting in motion changes.

This lesson uses that idea, again avoiding a focus on the forces involved in collisions, which is an idea that will be fully developed in 8th grade in OpenSciEd unit 8.1 (Contact Forces).

This lesson provides evidence that particles in solids may be moving back and forth a little bit while remaining relatively locked into place, and that this ability to move allows them to transfer energy due to collisions with neighboring particles (conduction).

Where We Are NOT Going

This lesson and unit do not focus on the nature of the forces that hold solid particles in place (this is beyond the grade-band focus of any related DCIs).

LEARNING PLAN for LESSON 13

1 · NAVIGATION

3 min

MATERIALS: computer and projector

Connect to results from prior lessons. Show **slide A**. Read the text on the slide aloud. Give students a minute to think about their answers to each of the questions, then discuss each question as a class.

Suggested prompt	Sample student response
What happens to the speed of the particles in the liquid when the temperature drops?	*Those particles are slowing down. Their average speed is decreasing.*
How about when the temperature goes up?	*Those particles are speeding up. Their average speed is increasing*
What were some things that seemed to cause changes in speed for a single particle as it moved about?	*The individual particles in the simulation changed speed when they collided with other particles. Maybe something like that is happening.*

If students don't raise the idea that particle collisions might cause changes in speed, that is fine. Either way, you will motivate looking at an individual particle's speed again in the simulation in this next activity.

ADDITIONAL GUIDANCE

Prior to the lesson, make sure that the lesson slides and a web browser with tabs for both simulation are both open on your computer. The first simulation is located at https://openscied.org/gas-particle-motion/ . The second simulation is located at https://openscied.org/collisions-up-close/ . You can begin the lesson with both minimized, which allows you to have the simulation and the slides ready for use and gives you the freedom to move back and forth between the slides and simulations as needed.

2 · ANALYZE THE MOTION OF COLLIDING PARTICLES IN A COMPUTER SIMULATION

10 min

MATERIALS: Computer Simulation--Activity #1

Say, *Let's revisit the simulation briefly to explore our question about changes in the speed of an individual particle and what could be causing them.* Show **slide B**.

Project the simulation located at https://openscied.org/gas-particle-motion/ . Press "Click to load the model" at the bottom of the webpage. Say, *Let's watch one particle really closely and describe what we notice happening to its motion over time.*

Have students relocate so they are standing as a whole class in a semicircle near the board or screen where they can see a projection of the simulation. When students are gathered and ready, run the simulation:

- Click on the "Setup" button.
- Click on the "Follow a particle/Reset view" button.
- Click on the "Go/Pause" button.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

To make cause and effect explicit to students, model for them how to describe the cause and effect relationship between particle collisions and change in direction (e.g., Say or write on the front whiteboard, "Colliding with another particle or a wall causes a particle to change direction). Then have students practice describing the cause

After a minute, ask students what sort of changes they noticed happening in the motion of the highlighted particle. Students will say that the particle changed its direction over time. Ask what they think caused this. Students will say that the particle changed direction because it was bouncing off the walls or running into other particles.

Ask about any other changes they noticed besides changes in direction. Some students will say t*hat the particle changed speed.* Ask what they think caused this. Some students may say that *running into another particle caused the change in speed.* However, there may be some disagreement about this. Ask whether the particle that the one we were tracking collided with also changed speed after the collision. There is likely to be some disagreement about this too.✱

Say, *It's really hard to tell what is happening to two particles in a collision with so many other particles in the simulation. Let's watch what happens to the particle speed with just a few particles in the simulation. I will load a different version where the box is smaller and we are zoomed in closer.*

Switch to the second simulation at https://openscied.org/collisions-up-close/ . Press "Click to load the model" at the bottom of the webpage. Say, *Again, let's watch one particle really closely and describe what we notice happening to its motion over time. But let's also see if we can tell whether anything happens to the motion of the particle it collides with.*

Run the simulation:

- Click on the "Setup" button.
- Click on the "Follow a particle/Reset view" button.
- Click on the "Go/Pause" button.

After seeing a couple of collisions, keep the simulation running. Ask students what they notice about the motion of both particles in a collision. Students are likely to respond as follows:

- Sometimes they change motion and sometimes they don't.
- When one particle changes direction from the collision, so does the particle it collided with.
- When one particle changes speed from the collision, so does the other.

Say, *This simulation allows us to display the speed of each particle too.*

Click the "show-speed?" checkbox on. Continue to run the simulation, pausing and resuming as needed by clicking on the "Go/Pause" button.

Ask students about the increases and decreases in speed that they noticed in both particles involved in a collision.

Suggested prompt	Sample student response
When the speed of one particle decreased in a collision, what happened to the speed of the other particle it collided with?	*It looked like the speed of the other particle increased.*
When the speed of one particle increased in a collision, what happened to the speed of the other particle it collided with?	*It looked like the speed of the other particle decreased.*

Problematize whether this occurs when real objects collide. Say, *Is this what happens in a real collision?*✱ *Would we see that same sort of thing with two particles that weren't simulated? Let's say we used marbles in place of simulated particles--do you think we would see the same sort of pattern in a collision?* Accept all predictions. Most students are likely to say yes. Use these predictions to motivate the next investigation.

and effect relationship between collisions and particle speed. If students do not agree that speed changes, wait until after the next simulation to construct this cause and effect relationship.

✱ ATTENDING TO EQUITY

This lesson includes multiple tools that support students' engagement with activities and sense-making (e.g., computer simulations and marble manipulatives). Using both simulations and marbles can support students in constructing a deeper understanding of how collisions affect objects' speed. The purpose of using both also allow students to engage in concept development using different modalities.

3 · INVESTIGATE CHANGES IN PARTICLE MOTION IN COLLIDING MARBLES

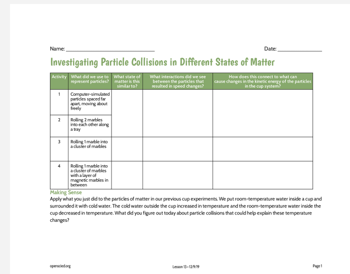
10 min

MATERIALS: Marble Collisions--Activity #2, *Investigating Particle Collisions in Different States of Matter*, chart paper, markers, timer

Explore a single marble collision. Say, *Let's see if the same sort of thing happens when we use marbles in place of simulated particles.*

Show **slide C**. Have students read through the directions. Ask if there are any questions. Each group needs one steel baking tray and a plastic cup with two glass marbles. Set the timer for 3 minutes for groups to get their materials and conduct this first marble investigation.

Record what each modeled collision is helping us figure out. Say, *Let's start keeping track of what we are figuring out from each of the activities we are doing.* Project **slide D**. Hand out a copy of *Investigating Particle Collisions in Different States of Matter*. Tell students that you want them to keep this handout loose for now, rather than attach it to their science notebooks, so they can turn it in at the end of the class for you to assess their understanding.


Name: Date:
Investigating Particle Collisions in Different States of Matter

Say, *The first column shows what we used to represent particles in the activity, and the second column is where we can record what state of matter it seemed most similar to. We've been considering three different states of matter in this unit: solids, like the walls and lids of cups or the table the cup is sitting on; liquids, like the drinks in cups; and gases, like the air above and around the cup. The term "state of matter" is a way to refer to whether something is a solid, liquid, or gas.*

Add this phrase to an anchor chart on the wall:
- Gases, liquids, and solids are three different states of matter.

Ask which state of matter the marbles best represented--a solid, liquid, or gas--and why. Ask the same for the particles in the computer simulation. Students should say they best represent particles of a gas because of their spacing (far apart) and being able to move about freely.

Have students add this idea to the second column in the first row of *Investigating Particle Collisions in Different States of Matter*:

Activity	What did we use to represent particles?	What state of matter is this similar to?	What interactions did we see between the particles that resulted in speed changes?	How does this connect to what can cause changes in the kinetic energy of the particles in the cup system?
1	Computer-simulated particles spaced far apart, moving about freely	Particles in a gas		
2	Rolling 2 marbles into each other along a tray			

Read the third column heading aloud. Ask students to summarize what we saw in the marble collision and in the simulation's collisions. Students should offer ideas similar to these:
- In a collision, the particles that collide can change speed.
- When one particle slows down, the other particle speeds up.

Have students add these ideas to the third column of the first row of the table.

Introduce the idea of energy transfer in collisions between particles in a gas. Read the fourth column heading aloud. Say, *Here, we want to think about how this applies to the cup system. We know there is air in and around the cup, so at the least we can think about what is happening between the particles of air in the cup and between the particles of air outside the cup. So what does this tell us can cause the motion energy of an individual gas particle to change?* Students should say a collision with another gas particle.

Say, *As you know, we use the phrase "kinetic energy" to refer to the amount of motion energy a particle has. I'll start a sentence with what we think is causing that to change.* Write this sentence stem on the board:

- Collisions between particles can cause the kinetic energy (KE) of one gas particle to go up and ...

Ask students to help describe how collision affects the kinetic energy of the other gas particles. Students should *say* it causes the kinetic energy of the other particle to go down.

Connect this idea to energy transfer. Prompts for this discussion are shown below.

Suggested prompt	Sample student response
What gave this particle that sped up this extra kinetic energy?	*The particle that collided with it.*
What evidence did we have that one particle gave away its kinetic energy in the collision?	*The faster-moving particle slowed down.*
Which particle did this kinetic energy go to?	*The slower-moving particles.*

Say, *Scientists describe this idea as the transfer of energy from one particle of matter to another. In our case, we would say that the faster-moving particle transferred some of its kinetic energy to the slower-moving particles in the collision.*

Have students add this idea to the fourth column of the first row of the table:

- Collisions between particles in a gas can transfer kinetic energy (KE or motion energy) from one particle to another.

Activity	What did we use to represent particles?	What state of matter is this similar to?	What interactions did we see between the particles that resulted in speed changes?	How does this connect to what can cause changes in the kinetic energy of the particles in the cup system?
1	Computer-simulated particles spaced far apart, moving about freely	*Particles in a gas*	*In a collision, the particles that collide can change speed.* *When one particle slows down, the other particle speeds up.*	*Collisions between particles in a gas can transfer kinetic energy (KE or motion energy) from one particle to another.*
2	Rolling 2 marbles into each other along a tray			

4 · USE MARBLES TO EXPLORE COLLISIONS BETWEEN PARTICLES IN A GAS AND A LIQUID

8 min

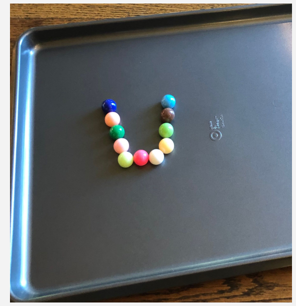
MATERIALS: Marble Collisions--Activity #3, *Investigating Particle Collisions in Different States of Matter*, timer

Explore a single marble collision with a group of marbles. Say, *Let's see if energy transfer occurs between particles of a gas and liquid. To do that we will have to think about how we can use marbles to simulate the particles in a liquid.*

Ask students how the spacing of particles in a liquid compares to a gas. Students should say they are more closely lumped together but still can move freely past each other. Demonstrate how we will simulate a cluster of particles in a liquid in the bottom corner of the tray. Hold up a slightly tilted tray that looks like the one shown here for students to see.

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Explain a limitation of using these manipulatives for modeling the motion of particles in a liquid.✱ Say, *It would be nice if we could show that the particles are moving to start with, because we know temperature is a measure of how much particle motion there is. And right now it looks like the particles aren't aren't moving at all. But in reality, particles are always moving. In every case where scientists have measured the temperature of the coldest liquids, they still found evidence of particles of the liquid moving. They moved slower the colder the temperature got, but they still had motion to them. That is something we cannot show easily with our tray of marbles while also simulating a moving gas particle hitting them. But let's still look for whether any of these marbles that aren't moving right now will speed up from a collision with a moving marble and whether that moving marble will slow down.*



Show **slide E**. Have students read the directions and ask if there are questions. Each group needs a second cup with 13 more glass marbles. Set the timer for 3 minutes for groups to get materials and conduct this second marble investigation.

Pause student exploration. Show **slide F**. Point out that the slide shows the addition of "A gas particle colliding with particles in a liquid" in the second column of the table. Have students add this to their table. Emphasize that you want to collect student responses on their handouts as an assessment at the end of the period. Give students 3 minutes to discuss their discoveries in their groups and record them in the row for activity #3 on their handouts.

Use this opportunity to point out to students the different ways they are modeling what happens at the particle scale using computer simulations, marbles, and eventually pictorial representations. Say that each of these kinds of models convey different aspects of underlying science ideas that they are trying to make sense of right now. It is important that students see that the same underlying science ideas can be represented in multiple ways, like what happens to the speed of objects when they collide as shown in the computer simulation and with the marbles.

5 · USE MARBLES TO EXPLORE COLLISIONS BETWEEN PARTICLES IN A GAS, LIQUID, AND SOLID

8 min

MATERIALS: Marble Collisions--Activity #4, *Investigating Particle Collisions in Different States of Matter*, timer

Explore a collision between particles in a gas, liquid, and solid. Say, *we are still missing observations for one state of matter. We haven't looked at whether energy transfer can occur in particles of solids. What kind of marbles did we use last time to represent particles of a solid, and why?* Students should say that we used magnetic marbles to represent particles of a solid because they stay in place, and we know that particles in solids don't move about freely like particles in liquids and gases.
Show **slide G**. Have students read through the directions. Ask if there are any questions. Each group needs a second cup with 20 magnetic marbles in it. Set the timer for 3 minutes for groups to get their materials and conduct this third marble investigation.

Pause student exploration. Show **slide H**. Point out that the slide shows the addition of "A gas particle colliding with particles in a solid, with particles of a liquid on the other side" in the second column of the table. Have students add this to their table. Give students 3 minutes to discuss their discoveries in their groups and record them in the row for activity #4 on their handouts.

6 · APPLY THESE IDEAS TO THE RESULTS FROM ONE OF OUR CUP EXPERIMENTS

5 min

MATERIALS: None

Develop individual explanations of how these activities apply to the results of a cup experiment. Show **slide I**. Remind students that you want to collect this handout at the end of the class.

Give students the remaining time to complete their responses to the "Making Sense" question on *Investigating Particle Collisions in Different States of Matter*. Collect the handout at the end of the class. Have one person from each group bring their tray up with the marbles sorted back into the three cups.

ASSESSMENT OPPORTUNITY

Use *Key for Investigating Particle Collisions in Different States of Matter* as a key to assess student responses.

End of day 1

7 · NAVIGATION

5 min

MATERIALS: science notebook, *Particle Collisions within and between Solids*

Connect the activity results from last time to the cup system. Show **slide J**. Read the text on the slide aloud. Give students a minute to discuss this question with a partner.

Show **slide K**. Read the text on the slide aloud to review what we know about particles in solids. Discuss the questions on the slide as a class. Prompts for the discussion are given below.

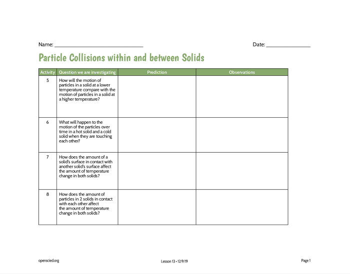
Suggested prompt	Sample student response
How do you think the motion of particles in a solid at a lower temperature would compare with the motion of particles in a solid at a higher temperature?	*They should be moving back and forth more at a higher temperature.* *The particles in a solid at a lower temperature would be moving more slowly.*
Do you think particles in solids can transfer kinetic energy to neighboring particles through collisions?	*Accept all predictions*

8 · ANALYZE THE MOTION OF PARTICLES IN SOLIDS IN A COMPUTER SIMULATION

10 min

MATERIALS: Computer Simulation--Activity #5, science notebook, *Particle Collisions within and between Solids*, timer

Introduce the next series of activities. Say, *Let's explore our predictions about solids further by using a new computer simulation.* Distribute copies of the handout *Particle Collisions within and between Solids*.


Name: ____________________ Date: __________

Particle Collisions within and between Solids

Activity	Question we are investigating	Prediction	Observations
5	How will the motion of particles in a solid at a lower temperature compare with the motion of particles in a solid at a higher temperature?		
6	What will happen to the motion of the particles over time in a hot solid and a cold solid when they are touching each other?		
7	How does the amount of a solid's surface in contact with another solid's surface affect the amount of temperature change in both solids?		
8	How does the amount of particles in 2 solids in contact with each other affect the amount of temperature change in both solids?		

openscied.org Lesson 13 • 12/9/19 Page 1

Show **slide L**. Have students follow the directions on the slide. Give students a couple of minutes to complete their predictions.

Show **slide M**. Read the text on the slide aloud to orient students to the control panel available in this simulation.

Show **slide N**. Orient students to the buttons, monitors, and graphs available in this simulation. Provide students with the URL to open the model: http://openscied.org/Conduction-in-Solids-Reduced.html

Have students conduct activity #5. Show **slide O**. Read the text on the slide aloud to orient students to the directions for the investigation. These directions are also included in the student procedures. Assign students to work in small groups. Give students four minutes to complete the investigation and record their observations on *Particle Collisions within and between Solids*.

9 · INVESTIGATE PARTICLES MOTION IN SOLIDS AT DIFFERENT TEMPERATURES

8 min

MATERIALS: Computer Simulation--Activity #6, science notebook, *Particle Collisions within and between Solids*, timer

Introduce and have students conduct activity #6. Show **slide P**. Have students follow the directions on the slide. Give students a couple of minutes to complete their predictions on their handouts.

Show **slide Q**. Read through the text on the slide to orient students to the directions for the investigation. Give students four minutes to complete the investigation and record their observations on *Particle Collisions within and between Solids*.

10 · INVESTIGATE CHANGES IN PARTICLE MOTION BETWEEN TWO SOLIDS IN CONTACT

8 min

MATERIALS: Computer Simulation--Activity #7, science notebook, *Particle Collisions within and between Solids*, timer

Introduce activity #7. Show **slide R**. Have students follow the directions on the slide. Give students a couple of minutes to complete their predictions on their handouts.

Show **slide S**. Orient students to the new control panel available in this simulation.

Show **slide T**. Orient students to the new buttons, data boxes, and graph available in this simulation. Provide student with the URL to open the model: http://openscied.org/Conduction-in-Solids-Full.html

Have students conduct the activity. Show **slide U**. Orient students to the directions for the investigation. Give students four minutes to complete the investigation in their small groups and record their observations on *Particle Collisions within and between Solids*.

11 · INVESTIGATE THE EFFECT OF MASS ON CHANGES IN PARTICLE MOTION

8 min

MATERIALS: Computer Simulation--Activity #8, science notebook, *Particle Collisions within and between Solids*, timer

Introduce activity #8. Show **slide V**. Have students follow the directions on the slide. Give students a couple of minutes to complete their predictions on their handouts.

Have students conduct activity #8. Show **slide W**. Orient students to the directions for the investigation. Give students four minutes to complete the investigation in their small groups and record their observations on *Particle Collisions within and between Solids*.

12 · NAVIGATION

5 min

MATERIALS: None

Connect this lesson's discoveries to the cup system. Show **slide X**. Have students turn and talk with a partner about the questions on the slide. Emphasize that we will share our ideas discussed next time.

Assign home learning. Have students select a related phenomena to explain in the next lesson. ✱

✱ ATTENDING TO EQUITY

Bring students back to their related phenomena and experiences to give students a chance to apply what they learned about particle collisions from the computer simulations and marble activities, to a real-world experience. This can help make abstract ideas about particle collisions more concrete for students and based within their experiences in the world.

HOME LEARNING OPPORTUNITY

Encourage students to select a related phenomena from the class chart or from a personal experience. They need to identify a phenomenon in which the temperature in one system affected the temperature in another system in contact. Ask students to brainstorm how energy transferred between the two systems when they came into contact, and to be prepared to share their ideas in the next class period.

Lesson-Specific Teacher Materials

Lesson 13: Answer Key

Key for Investigating Particle Collisions in Different States of Matter

<table>
<tr><th>Activity</th><th>What did we use to represent particles?</th><th>What state of matter is this similar to?</th><th>What interactions did we see between the particles that resulted in speed changes?</th><th>How does this connect to what can cause changes in the kinetic energy of the particles in the cup system?</th></tr>
<tr><td>1</td><td>Computer simulated particles spaced far apart, moving about freely</td><td rowspan="2">Particles in a gas</td><td rowspan="2">In a collision, the particles that collide can change speed.

When one particle slows down, the other particle speeds up.</td><td rowspan="2">Collisions between particles in a gas can transfer kinetic energy (KE or motion energy) from one particle to another.</td></tr>
<tr><td>2</td><td>Rolling 2 marbles into each other along a tray</td></tr>
<tr><td>3</td><td>Rolling 1 marble into a cluster of marbles</td><td>Gas particle running into some liquid particles</td><td>The rolling marble slowed down and changed direction after the collision ... One or more marbles on the other end of the marble cluster sped up ... the marbles in between shifted.</td><td>Collisions between gas particles and liquid particles transfer kinetic or motion energy (KE) from one particle to another.

Collisions between liquid particles transfer kinetic or motion energy (KE) from one particle to another.</td></tr>
<tr><td>4</td><td>Rolling 1 marble into a cluster of marbles with a layer of magnetic marbles in between</td><td>A free-moving particle (in a gas) running into particles in a solid with particles of a liquid on the other side</td><td>The rolling marble slowed down after the collision ... One or more marbles on the inside of the cup sped up ... the marbles in between shifted.</td><td>Collisions between gas, solid, and liquid particles transfer kinetic or motion energy (KE) from one particle to another.</td></tr>
</table>

Making Sense

Apply what you just did to the particles of matter in our cup experiments. We put room-temperature water inside a cup and surrounded it with cold water. The cold water outside the cup increased in temperature and the room-temperature water inside the cup decreased in temperature. What did you figure out today about particle collisions that could help explain these temperature changes?

- *Temperature is related to the average speed of the particles in an object or sample of matter. Collisions between particles in a gas, liquid, or solid can transfer kinetic energy (KE or motion energy) from one particle to another. When faster moving particles in something at a higher temperature collide with slower moving particles at a lower temperature, some of their motion energy can be transferred from the faster moving particles (slowing them down) to the slower moving particles (speeding them up).*

LESSON 14: Does our evidence support that cold is leaving the system or that heat is entering the system?

PREVIOUS LESSON *We used a computer simulation to analyze particle speeds before and after a collision. We used marbles to investigate the effects of collisions on particle speed in different situations to simulate interactions between particles in a gas, a liquid, and a solid. We used a computer simulation to analyze particle interactions in different solids in contact with each other at different temperatures.*

THIS LESSON

INVESTIGATION, PUTTING PIECES TOGETHER

3 days

We sort evidence collected during previous lessons to support or refute claims that temperature changes are due to heat or cold moving into or out of the cup system. We conduct an investigation to collect additional evidence, helping us figure out that heat moves into the cup system, causing a temperature change. We revise our cup system models and apply our new understanding to answer questions from the DQB and explain related phenomena.

NEXT LESSON *We will learn about the Cold Cup Challenge and consider what we still need to figure out about how cups keep drinks cold for a long time. We will do a jigsaw and a gallery walk to fill in the gaps in what we know. We will reach consensus about mechanisms for energy transfer to help us make design decisions to slow down this process.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Develop and use models to track how energy spontaneously transfers out of hotter regions and into colder ones and causes changes in the water's temperature within the cup system.

Construct written arguments supported by empirical evidence and scientific reasoning to support claims describing how energy spontaneously transfers out of hotter regions or objects and into colder ones.

WHAT STUDENTS WILL FIGURE OUT

- Temperatures change when energy moves from warmer to cooler matter.
- Energy is transferred when higher-energy particles come into contact with lower-energy particles.

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review our claims that heat moves into the cup system versus cold leaks out of the cup system.	A	
2	18 min	**EVIDENCE SORTING ACTIVITY** Have your students review and sort evidence from previous lessons to support claims about whether heat or cold enters or leaves the cup.	B-C	*Evidence Sorting chart*, marker, 10 small sticky notes, Three claims posters, *Evidence Cards 2*, tape
3	12 min	**BUTTER DEMONSTRATION** Conduct the *Butter Demonstration* as a class. Prompt students to use evidence to explain observations from the demonstration.	D-G	Butter Demonstration
4	5 min	**RE-SORT TO INCLUDE BUTTER DEMONSTRATION EVIDENCE** Have students revisit their *Evidence Sorting* chart and sticky notes to add the *Butter Demonstration* evidence.	H	*Evidence Sorting chart*, Three claims posters, *Evidence Cards 2*, tape
5	5 min	**NAVIGATION AND HOME LEARNING** Ask students to quietly review the Driving Question Board to see which questions they can now answer	I	
				End of day 1
6	7 min	**NAVIGATION** Have students gather in small groups to share their home learning examples and to practice explaining heat in each example. Monitor discussion to see how students describe heat.	J	
7	18 min	**REVISE THE CUP SYSTEM MODEL** Have students work on their own to revise a model for explaining how and why water warmed up inside cup system using particle movement and the flow of energy into the system. Then give students time to share their model with a small group.	K-L	*Modeling What Is Happening at the Cup Wall*, Driving Question Board
8	20 min	**CUP SYSTEM MODEL CONSENSUS DISCUSSION** Facilitate a consensus discussion in which students share their revised cup system models.	M	*Modeling What Is Happening at the Cup Wall*, pre-made chart paper diagrams of model template, tape
				End of day 2
9	25 min	**DRIVING QUESTION BOARD AND RELATED PHENOMENA** Return to the Driving Question Board to answer questions and have students develop an explanation to a related phenomena.	N-P	
10	20 min	**ICING INJURIES ASSESSMENT** Have students apply what they have learned to explain a related phenomenon for an individual assessment.	Q	*Icing Injuries Assessment*
				End of day 3

Lesson 14 • Materials List

	per student	per group	per class
Butter Demonstration materials			• Butter Temperature chart • 8-x-2 piece of aluminum foil • 2 6-in blocks of wood or similar prop • 4 thermometers • 1 tealight candle • lighter • 1-2 Tbsp butter • butter knife • 2-3 ice cubes
Lesson materials	• science notebook • *Modeling What Is Happening at the Cup Wall* • *Icing Injuries Assessment*	• *Evidence Sorting chart* • marker • 10 small sticky notes	• Three claims posters • *Evidence Cards 2* • tape • Driving Question Board • pre-made chart paper diagrams of model template

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

On day 1, have the three claims charts ready to add evidence from Lessons 12 and 13, plus today's new evidence. Make one copy of *Evidence Cards 2* for evidence cards to sort onto the chart in support of the claims.

Create a *Butter Temperature* chart on chart paper for the class to record temperature changes in the four thermometers in the *Butter Demonstration*.

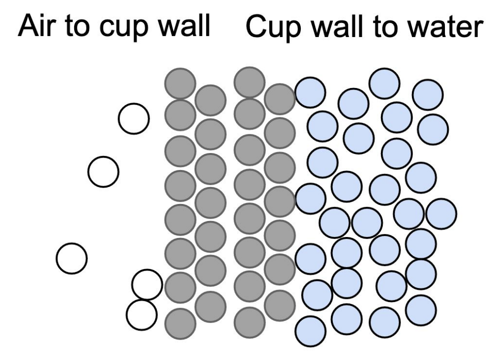
Time	4th (farthest)	3rd	2nd	1st (closest)
Start temp				
1 min				
Add 2 ice cubes				
2 min				
4 min				
6 min				
8 min				

For day 2, draw the following diagram on chart paper as the foundation of a classroom consensus model. Dots do not need to be filled in; they can be outlined in black (cup wall), blue (water), and another color (air).

- Alternatively, you can project **slide K** and have students post their table-group models on either side of the screen. However, it's important that the models are visible to the class in a Scientists Circle.

Day 1: Butter Demonstration

- **Group Size:** Whole class
- **Setup:** Use *Butter Demonstration* to obtain necessary materials and set up the *Butter Demonstration*. Steps 1-8 are to be done ahead of time The remaining steps are done during the demonstration.
- **Safety:** Remind students not to be too close to the candle or to touch the aluminum foil when taking temperature readings. Sleeves should be rolled up and hair tied back.
- **Disposal:** Discard foil and butter in trash.



Lesson 14 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students are given the opportunity to synthesize the evidence we have collected thus far to support claims about what is causing temperatures to change. The goal is for students to figure out and have the evidence to support the argument that it is heat, or energy, entering the cup system that leads to the observed temperature changes. The *Butter Demonstration* provides clear evidence of the directionality of how energy transfers from warmer to cooler matter or regions. Connecting claims with what was learned in Lesson 13, we figure out that temperatures changes occur when heat moves from warmer to cooler substances. Energy is transferred when higher-energy particles come into contact with lower-energy particles.

Students use what they have learned to represent what happens at the particle level at the cup wall and how energy transfers through collisions between particles in the air, cup wall, and water. The phenomena thus far have focused on actions that warm up matter. However, the related phenomenon for this lesson's assessment involves cooling down matter, which presents the opportunity to gauge whether students can discern where there is more energy and accurately describe how the movement of energy contributes to changing temperatures.

Where We Are NOT Going

Students identify that it is energy moving from warmer to cooler substances that leads to temperature changes. We describe the energy that is transferred as *heat*. Students focus on qualitative descriptions of what is happening rather than quantifying how much energy is moving from one location to another.

LEARNING PLAN for LESSON 14

1 · NAVIGATION

5 min

MATERIALS: None

Navigation. Remind students that we used a computer simulation and marbles to model what happens to particles when a sample of matter warms up. Show **slide A**. Say, *We've been using these simulations trying to understand why the cold water inside our cup system warmed up. What are some claims we can make about what is happening with the particles in the system that would cause the cold water inside the cup to warm up?* Students should articulate that:

- kinetic energy from outside the cup system enters the cup through particle collisions.
- as the water inside warms up, the particles have more kinetic energy (on average).

Some students may still raise the idea that cold leaks out of the cup. If students do not state cold leaving the cup as a possibility, raise it as an idea that students have shared in the past.

Explain that the purpose of today's lesson is to examine the evidence we've collected during Lessons 10-13 to decide whether the observed temperature changes inside the cup system are due to heat moving into it or cold leaving it, and more broadly, how energy is transferred into or out of systems.

2 · EVIDENCE SORTING ACTIVITY

18 min

MATERIALS: *Evidence Sorting chart*, marker, 10 small sticky notes, Three claims posters, *Evidence Cards 2*, tape

Review and sort our evidence. Display **slide B**. Ask students to review the list of evidence from Lessons 10-13 to see whether there is additional evidence that should be represented. As needed, add evidence to the slide or on the whiteboard and number it accordingly.

Arrange students in groups. Pass out about 10 small sticky notes, a marker, and the handout *Evidence Sorting chart* to each group. Ask students to write the numbers 1-9 on the sticky notes, one number per note (groups should have 1 extra sticky note they will use later). You can use small pieces of paper if sticky notes are unavailable. If your class identified additional pieces of evidence, have them write the additional numbers on sticky notes as well. Explain that these numbers correspond to the evidence shown on the slide (and the whiteboard, if used).

Display **slide C**. Explain that students will work with a small group to decide which claim the evidence could be used to support. Tell them to then attach each sticky note (piece of evidence) in the appropriate section on their handout. If the evidence could be used to support both claims, students should stick it in the "Heat and cold moving" section.

Display **slide B** again and give students time to work in their groups. Continue projecting the slide throughout their work and in the upcoming Scientists Circle. Give students about 5-8 minutes to work in groups, then bring them back together for whole group in a Scientist Circle.

#	Evidence
1	*Food Coloring Lab*: Food coloring spread through hot water faster than cold water.
2	*Peppermint Dye*: Peppermint dye spread through hot water faster than cold water.
3	*Water Bath Lab*: When a cup of cold water was placed in a container of warm water, the cold water warmed up and the warm water cooled down.

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

The purpose of this activity is for students to organize and use evidence to support claims that temperature changes are due to the movement of heat rather than cold between samples of matter.

4	*Joule's Experiment*: Spinning water very fast caused the water to heat up.
5	*Temperature and KE:* Simulations showed that warmer liquids and solids have particles with more KE.
6	*Particles colliding:* Simulations showed that when particles collide, one slows down and the other speeds up.
7	*Marbles collide:* When you roll a marble into another marble(s), the faster marble slows down and the slower marble (or resting marbles) speeds up.
8	*Marbles into a solid wall*: When you roll a marble into a wall of marbles, it slows down after the collision, but a marble on the other side of the wall speeds up.
9	*Amount of contact:* Simulations showed that when solids have more contact, energy transfers faster from the hotter solid to the cooler solid compared to when there is less contact.

ADDITIONAL GUIDANCE

Below is one example of how the evidence could be organized on the chart. Evidence pieces 1-5 could be considered neutral, as they simply show differences in particle movement or that changes occur without helping to tease apart what exactly causes the observed differences or changes in particle movement or temperature.

Heat moving **6, 7, 8, 9**	**Cold moving**
Heat and cold moving **1, 2, 3, 4, 5**	

Discuss students' ideas in a Scientists Circle. After 5-8 minutes, ask groups to bring their handout *Evidence Sorting chart*, science notebooks, and a chair to a Scientists Circle.

Once settled, say, *In groups, you sorted the evidence to see what could support one or both claims. Now, we're going to talk about what the class thinks so we can see where we all agree and disagree.*

Systematically go through each piece of evidence and poll students about whether it could be used to support claims that changes in temperature are due to heat or cold moving, or whether it could be used to support both claims (or neither claim)—in other words, that it could not be used to support one claim over another.

Based on the group consensus, place the class evidence cards (*Evidence Cards 2*) in the appropriate location on the class existing three claims posters used in previous lessons. If students disagree, have students ask each other to use evidence to support their arguments for where the evidence should go. If disagreement persists, place the evidence card in a location where the debate lies (e.g., between 2 of the posters) or to the side of the posters.

Transition to the next activity. Summarize the class's ideas. Explain that students will observe another demonstration that may help to determine the direction of energy flow. For example, say, *It seems like our class mostly thinks ____ moves, but some of us also think that ____ moves. Let's see whether the following demonstration can help us decide what moves when temperatures change and in what direction.*

3 · BUTTER DEMONSTRATION

12 min

MATERIALS: Butter Demonstration

Explain the demonstration and elicit predictions. Have students remain in the Scientists Circle for the demonstration. The goal of this demonstration is to use the direction of the melting to provide evidence for what's moving (heat or cold) and in what direction it moves. Display **slide D**. Use *Butter Demonstration* for advance preparation for the demonstration.

Explain that you have strips of butter on the aluminum foil and will place two ice cubes at one end of the aluminum foil and a candle at the other end. Say, *Turn to a partner to make predictions. What do you think will happen once the candle is lit at one end and ice cubes are placed on the other end?* Ask 2-3 students to share their predictions and justifications. Students should claim that the butter will start to melt on the side nearest the candle, but some may think the ice on the other side will keep the butter cold. Discussion prompts are given below.

Suggested prompts	Sample student responses	Follow-up questions
What do you think will happen?	*The butter strips will begin to melt.* *The side of the butter closest to the candle will melt first.*	*Will the butter strips melt evenly, or will they melt on one side before the other?* *What do you think is causing the butter to melt?*
	The side near the ice cubes will not melt. *Nothing will happen, because the ice counteracts the warming of the candle.*	*What happens when the cold meets the heat?*

Display **slide E**. In light of the claims we're trying to collect evidence to support, ask students to make predictions about what we expect to see if the observations are due to heat or cold moving. They can make predictions orally in partners or as a whole class. As needed, prompt students to consider the patterns or changes they expect to observe in the measured temperatures.

Suggested prompt	Sample student response
What do you predict will happen if heat leaves the candle and enters the butter?	*The butter on that side will melt first.* *Temperature will change from hottest on the candle side to colder on the ice side.*
What do you predict will happen if cold leaves the ice and enters the butter?	*Temperatures nearer the ice cube will decrease.* *The butter will not melt.*

Conduct the demonstration. Display **slide F**. Cut strips of butter and line up about 2-3 inches of butter across the top of the foil on top of the tips of the thermometers. Ask students to read the initial temperature from each thermometer and post the data on the *Butter Temperature* chart. Light the candle and ask students to help you take the temperature readings for each thermometer after 1 minute. At 1 minute, place 2 ice cubes on the other end of the foil and take the temperature readings (you can also start with the ice on the foil if your students feel strongly to do that). Record the temperatures every 2 minutes for 8 minutes.

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

The focus of this activity is to collaboratively construct an oral argument supported by empirical evidence and scientific reasoning. Students will begin this work by sorting the evidence based on the multiple claims under consideration. Later in this lesson students will work together, and then individually, to write an explanation of phenomena using evidence and supported by scientific reasoning.

ADDITIONAL GUIDANCE

The delayed inclusion of the ice shows that the butter melts due to the addition of the heat source rather than the addition of a cold source, but students may want to add both heat and cold at the same time and that is OK. Below is a 6-minute sample data set. The data at 2 minutes was collected after two ice cubes were added.

Time	4th (farthest)	3rd	2nd	1st (closest)
1 minute	25.0°C	27.2°C	33.0°C	47.8°C
Add 2 ice cubes				
2 minutes	25.0°C	29.0°C	38.0°C	58.0°C
4 minutes	24.5°C	30.0°C	41.0°C	63.0°C
6 minutes	24.0°C	31.0°C	44.0°C	76.5°C

Make sense of the *Butter Demonstration*. Project **slide G**. Say, *Turn to a partner and use our observations and data to make an argument for what moved (heat or cold?) to cause the butter to melt, and in what direction it moved.* After 2-3 minutes, ask 2-3 partner-pairs to share their responses with the class. Students should conclude that energy transfers from hotter objects or samples of matter to colder ones. Thus, it's not cold that is moving, but heat.

Say, *Let's re-examine the evidence that we've collected thus far. How could we use what we've figured out previously to help us explain our new observations of the demonstration? What happened with the butter particles?* Have students talk about these questions with a partner. Then ask 2-3 partner-pairs to share their ideas with the class.

- Students should say that the candle provides energy to the butter particles. These particles then move faster and have more kinetic energy. These particles then collide with and transfer energy to other particles that have less kinetic energy.
- Connect students' observations with the marble investigation from Lesson 13, in which the cause for marbles moving was a faster-moving marble hitting a slower-moving marble, to reinforce the directionality of the energy transfer from an object or sample of matter that has more energy to one that has less energy.

4 · RE-SORT TO INCLUDE BUTTER DEMONSTRATION EVIDENCE

5 min

MATERIALS: science notebook, *Evidence Sorting chart*, Three claims posters, *Evidence Cards 2*, tape

Revisit the *Evidence Sorting Activity*. Display **slide H**. Have students consider the evidence for today's investigation and where it should be placed in the three claims posters. If time allows, have students work with their group first (while still remaining in the Scientists Circle). If time is short, facilitate a whole class discussion to place the *Butter Demonstration* evidence card on the three claims posters.

5 · NAVIGATION AND HOME LEARNING

5 min

MATERIALS: None

Motivate the need to think about heat in everyday phenomena. Stand near the DQB. Have 2-3 students summarize important ideas they just figured out. Ask students, *Do we think some of these ideas we figured out can help us answer our questions? Start thinking about which of these questions we can now answer.*

Assign home learning. Ask students to identify either (1) a system in which heat moves through the system (e.g., handle on a hot pan) or (2) two systems where heat moves between the systems (e.g., touching a hot pan with your finger). They should write their example on a piece of paper and be prepared to share it in the next class.

End of day 1

6 · NAVIGATION

7 min

MATERIALS: None

Share home learning examples. Remind students of what they figured out about heat in the previous class. Then, arrange students in small groups. Display **slide J**. Read the slide and explain to students that each one will have 1 minute to share their example. Encourage students to practice using their knowledge of particle movement and particle collisions to help explain each example. Allow groups 3 minutes to share. Circulate among groups to listen to the way students' describe heat in each example.

7 · REVISE THE CUP SYSTEM MODEL

18 min

MATERIALS: science notebook, *Modeling What Is Happening at the Cup Wall*, Driving Question Board

Revise a model for explaining how and why water warmed up in the cup system. Stand near the Driving Question Board. Remind students that the reason for many of our previous investigations was to understand what caused the cold water in our cup system to warm up. Point to questions on the DQB related to heat entering the system or cold leaving the system. Explain that today they will develop answers to these questions. This should take about 3 minutes.

Display **slide K**. Pass out *Modeling What Is Happening at the Cup Wall*. Ask students to use what they have figured out thus far, specially about particles and the flow of energy, to revise their cup system model. In particular, we are focused on what students think is happening (1) between the air and the cup wall and (2) between the cup wall and the water that leads to the cold water in the cup system warming up.

Display **slide L**. Tell students that they are to explain what is happening at the two different places at location A by annotating the diagrams on the handout with drawing and written description. Ask students if they have any questions. ✱

Give students about 8 minutes to work quietly developing their model to explain how the water inside the cup warms up.

Arrange students in groups to share their models. Focus students on discussing how to represent the flow of energy from outside the cup to the water inside the cup. Give groups about 5 minutes to share their models and to discuss the way they represented their ideas.

✱ ATTENDING TO EQUITY

This modeling work can be differentiated based on your students' needs. If you prefer, arrange students in partners or heterogenous small groups from the beginning of the modeling activity. Struggling students may be overwhelmed with the modeling activity if they begin completely on their own. This will allow more advanced students to work with students who may still be struggling as a way for students to coach each other in the modeling activity.

8 · CUP SYSTEM MODEL CONSENSUS DISCUSSION

20 min

MATERIALS: *Modeling What Is Happening at the Cup Wall*, science notebook, pre-made chart paper diagrams of model template, tape

Co-construct a classroom consensus model. Arrange students in a Scientists Circle. Display **slide M** and have the pre-made chart ready to annotate as a class. The chart can have clear particles if that helps with coloring them as the class models energy transfer.

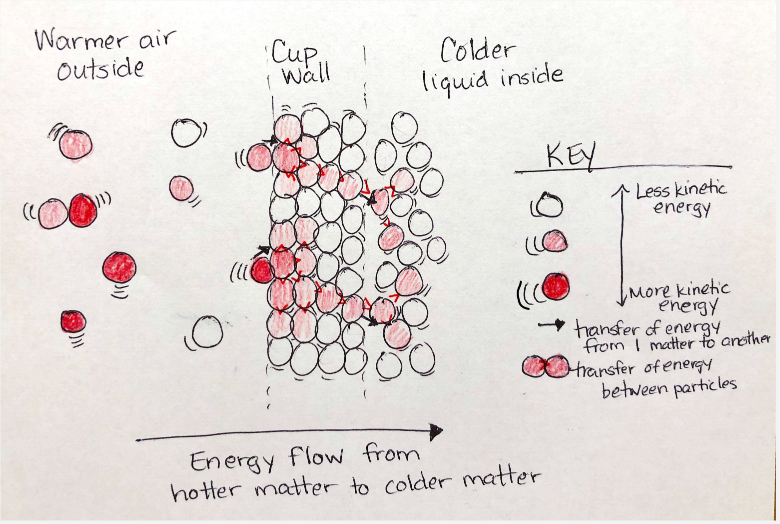
The class should create a key to use to explain the energy transfer as shown in the example model below. The key needs to include a way to represent particles with more or less kinetic energy and a way to represent when energy is transferred from particle to particle through collisions. Set up the key together eliciting suggestions from students and the way they modeled these ideas on their own.

Have the class first represent that each type of matter is made of particles with different amounts of energy, but the water inside is relatively colder than the air outside.

Then layer on the transfer of energy representations, such as arrows, to show the transfer from warmer air outside the cup to colder water inside the cup.

KEY IDEAS	**Purpose of the discussion**: to model energy transfer via conduction (particle collisions) to explain how energy from outside the system flows into the system. **Students should reach consensus on the following ideas:** • The air particles have more kinetic energy than the particles in the cup wall or water inside the cup. • When higher-energy air particles come into contact with lower-energy cup wall particles, energy is transferred. • Energy continues to be transferred through the cup wall, as higher-energy cup wall particles collide with lower-energy cup wall particles. • When lower-energy water particles come into contact with higher-energy cup wall particles, energy is transferred to them. • Energy continues to be transferred throughout the water as higher-energy water particles collide with lower-energy water particles.

Throughout, elicit from students how they represented the energy flow, and prompt students to share their models and suggest how to represent it as a class. When the class agrees on an idea, record it on the class chart.



Celebrate the new consensus model. Conclude the class period by celebrating that students have just figured out something big--they can now explain why the water in the cup warmed up, and likely how this works in other systems. Say, *Let's use some of these ideas in the next class to answer questions on our Driving Question Board and to see if we can explain other systems.* Have students attach their models to their notebooks in the Progress Tracker section of the notebook. Remind students to leave the notebooks in the classroom

End of day 2

9 · DRIVING QUESTION BOARD AND RELATED PHENOMENA

25 min

MATERIALS: None

Identify questions about heat and cold that can now be answered. Display **slide N.** Have students return to the DQB and identify questions related to heat, cold, energy, and light that can now be answered. Students should be able to answer questions about how energy flow into the cup system relates to the temperature change. Elicit from students the questions they believe they can now answer. Say, *Let's try to develop answers to these questions. Pick one question from the DQB you can answer and write an explanation in your Progress Tracker.* Revisiting and identifying questions from the DQB should take no more than 5 minutes.

Update Progress Tracker. Display **slide O**. Have students spend 5 minutes quietly writing in their Progress Tracker. The questions students are answering will vary, but should be related to energy and warming up of the drink.

Co-construct an explanation of the cup together. Display **slide P.** Bring students back together as a whole group and pose the question, *How does the drink warm up inside the cup?* Ask students what they believe they need to focus on in the explanation, and encourage students to actively use crosscutting concepts of matter and energy, scale, and cause and effect as they develop the explanation. Model for students, with student input, how to write an explanation of the water warming up using what students have learned about energy transfer from heat (particle collisions) and light and the evidence they have collected. ✱

Individual reflection on a related phenomenon. After whole group practice with writing an explanation, ask students to pick a related phenomena from the related phenomena poster. Give students 3-4 minutes to work with a partner to discuss how they would explain the phenomena. Encourage students to give each other feedback in this moment. Then give each student 5 minutes to write their own explanation, individually. They can add this explanation to a new page in their science notebook.

If time permits, have students share their written explanation with a partner for feedback. Encourage students to add to or edit their explanation based on partner feedback.

✱ ATTENDING TO EQUITY

This is an opportunity to differentiate for your students based on how much guidance and scaffolding your students need with writing an explanation. For advanced learners or those with more experience writing explanations, modeling how to write an explanation may not be necessary. For students with limited experiences writing explanations, emergent multilingual students, or students who struggle with writing, modeling an example of an explanation can support their learning. For these learners, model an explanation first, then give students practice writing their own explanation for a related phenomena.

10 · ICING INJURIES ASSESSMENT

20 min

MATERIALS: *Icing Injuries Assessment*, science notebook

Explain assessment to students. Display **slide Q**. Hand out the assessment *Icing Injuries Assessment* to each student. Say that now we want to try explaining a new related phenomenon, which is how ice can cool down skin and muscles after a workout.✱Explain that two athletic trainers, Steve and Sophie, are stating different claims about what's moving and the direction in which it's moving. Tell students that they must decide which pieces of the presented evidence can be used to support each claim. Students are then to construct models to explain what happens when the ice pack comes into contact with the skin. They should include particles for the ice pack, particles for the skin, how the particles are moving in each system based on their temperatures, and how energy is transferring between the systems.

Give students 20 minutes to complete and submit the assessment before the end of class.

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

This assessment focuses students on using the practices of modeling and argumentation to explain how energy transfers from hotter regions to colder regions. Encourage students to think about crosscutting concepts of matter and energy, scale, and cause and effect as tools for developing their models and explanations.

ASSESSMENT OPPORTUNITY	This task is a formative assessment into students' understanding about the underlying mechanisms involved in energy transfer, and in particular about directionality. This assessment leverages the following model ideas from Lessons 7-14: • A particle's speed is related to how much kinetic energy it has. • When particle movement increases, it is because energy is transferred into the matter. • When particle movement decreases, it is because energy is transferred out of the matter. • When a system is cooling down, energy is transferring out of it. When a system is warming up, energy is transferring into it. • Particles in solids can move slightly, but their movement is confined, so they are limited to vibrating in place. • When objects or samples of matter are in contact, energy transfer occurs mainly through particle collisions (i.e., conduction), which is when kinetic energy is transferred between particles. • Energy transfers from hotter objects or regions to colder ones. Use *Lesson 14 Assessment Scoring Guide* and *Rubric for Model in Lesson 14 Icing Injuries Assessment* for scoring guidance.

Additional Lesson 14 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.** Students compare a variety of evidence from simulations, videos, labs, and texts to determine which claim is best supported by the evidence. **CCSS.ELA-Literacy.W.6.1: Write arguments to support claims with clear reasons and relevant evidence.** Working collaboratively as a class, you model for students how to write a evidence-based explanation for how the water in the cup warmed up over time. Then, working individually, students write an evidence-based explanation for a related phenomenon in which they are encouraged to explain how it works to minimize energy transfer, citing relevant evidence and supporting their thinking with scientific reasoning.

Lesson-Specific Teacher Materials

Lesson 14: Teacher Reference 1

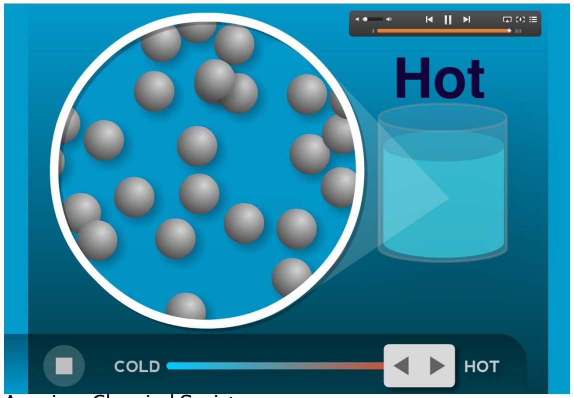
Butter Demonstration

1. Cut a piece of aluminum foil about 8 inches long and 2 inches wide.
2. Fold aluminum foil in half.
3. Lay foil across a block of wood with about 1.5-2 inches hanging off one end of the wood.
4. Line up 4 thermometers, with the first thermometer starting about ½ inch from the edge of the wood block, and the remaining thermometers in a row about ½ inch apart.
5. Wrap the tips of the thermometers inside the folded aluminum foil.
6. Line up the numbers on the thermometers and support the other end of the thermometers with a second piece of wood.
7. Place a small votive candle underneath the 1.5-2 inches of aluminum foil hanging off the end of the wooden block.
8. Fold up the edges of the foil hanging over the block to form a slight cup to catch melted butter before it can drip onto the candle.
9. Cut strips of butter and line up about 2-3 total inches of butter across the top of the foil and on top of the tips of each thermometer.
10. Record initial temperature measurements for each thermometer.
11. Light the candle.
12. Record the temperatures after 1 minute.
13. After 2 minutes, place 2 ice cubes on the side of the foil opposite the candle and record the temperature.
14. Record the temperature for each thermometer every 2 minutes for 8 total minutes.

Time	4th (farthest)	3rd	2nd	1st (closest)
1 minute 	**25.0°C**	**27.2°C**	**33.0°C**	**47.8°C**
Add 2 pieces of ice				
2 minutes	**25.0°C**	**29.0°C**	**38.0°C**	**58.0°C**
4 minutes 	**24.5°C**	**30.0°C**	**41.0°C**	**63.0°C**
6 minutes 	**24.0°C**	**31.0°C**	**44.0°C**	**76.5°C**

Evidence Cards 2

Temperature and KE



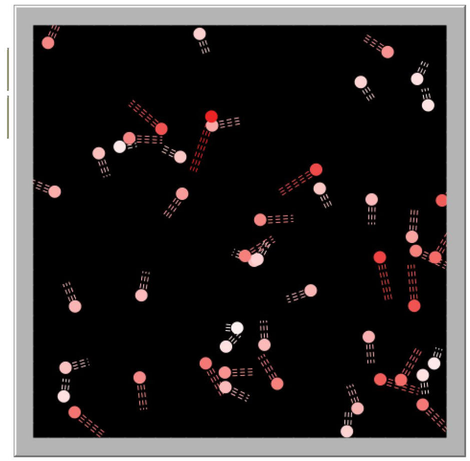
American Chemical Society

Simulations showed that warmer liquids and solids have particles with more KE.

Butter Demonstration

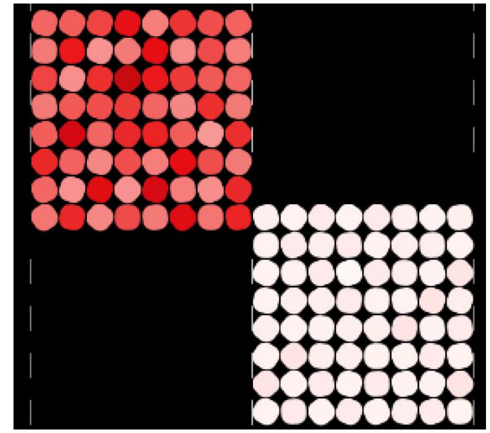
Butter melts first at the candle side and melts in the direction away from the candle.

Particles Colliding



Simulations showed that when particles collide, one slows down and the other speeds up.

Amount of Contact

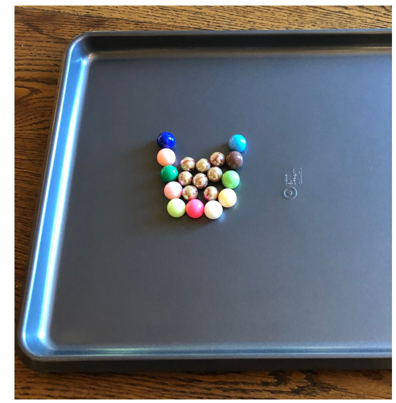


Simulations showed that when solids have more contact, energy transfers faster from the hotter solid to the cooler solid compared to when there is less contact.

Marbles Collide

When you roll a marble into another marble(s), the faster marble slows down and the slower marble (or resting marbles) speeds up.

Marbles into a Solid Wall



When you roll a marble into a wall of marbles, it slows down after the collision, but a marble on the other side of the wall speeds up.

Lesson 14 Assessment Scoring Guide

+1's in red below indicate the important ideas to look for in student responses. They do not indicate a preferred scoring scheme. You can choose how to score or grade the assessment.

To care for and prevent injury, athletes often use plastic wrap to attach bags of ice cubes directly on top of their skin for 20 minutes a day after a practice or a workout. See the image for an example of this.

Part of the way through the 20 minutes, the ice begins to melt and drip. At 20 minutes, doctors recommend removing the ice pack because the skin gets very cold and could become damaged. Two athletic trainers, Steve and Sophie, were wondering, how does the ice work to cool down the skin and muscles? They collected some data, shown in the table below.

Data collected	At 0 min (right when the ice is attached to the skin)	At the end of 20 minutes
Ice pack temperature	0°F	15°F
Skin temperature	98.6°F	55°F
Feeling of skin	Normal	Numb, cold
Ice pack	Not melting	Melting

1. Steve and Sophie argued over what the data showed about how the systems (ice pack and skin) work. Here is what they said:
   - **Steve:** *The cold from the ice pack moves out of the ice pack and enters the skin, causing it to cool down.*
   - **Sophie:** *Heat from the body goes into the ice pack and causes the ice to warm up and melt.*

Complete the table to organize the data.

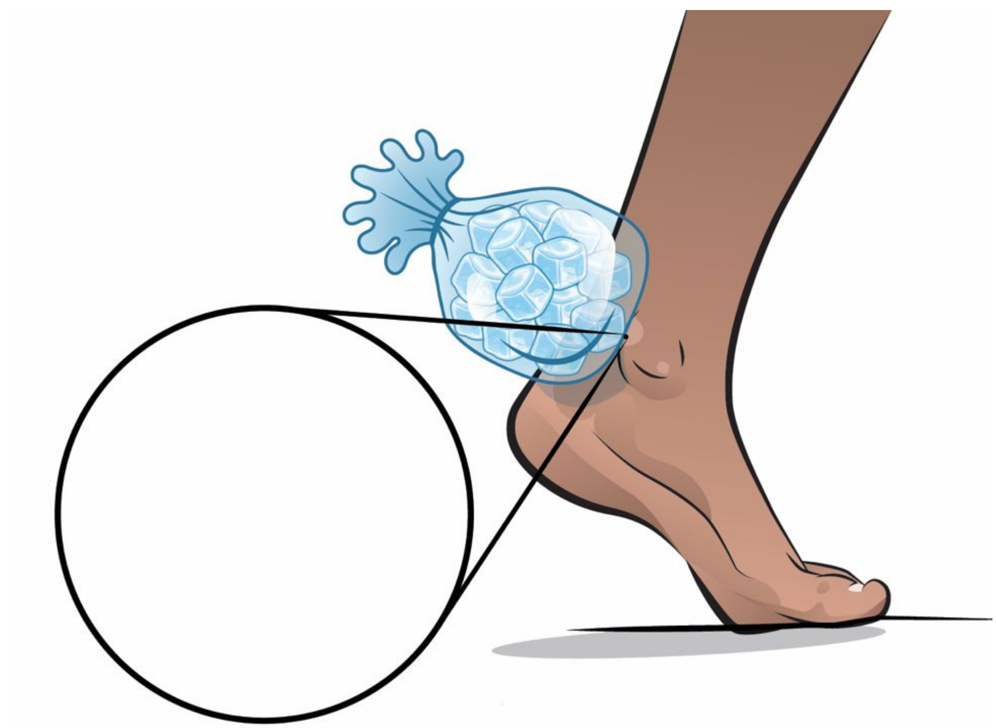
Which pieces of evidence support Steve's claim?	Which pieces of evidence support Sophie's claim?	Which pieces of evidence support both claims?

Students can place the data anywhere in this table and it will begin to tell you how they are thinking about the system and mechanisms of temperature change in the system. Instead of grading, use this question formatively. If students are thinking about cold leaving the system, they will put most of the data into Steve's column. If they are thinking about heat transfer from the body to the ice pack, they will put the data into Sophie's column. Students may also determine that the data does not clearly support a direction of energy transfer, in which case they will place most of the data in the last column. If they do this, look closely at their reasoning on question 3 below.

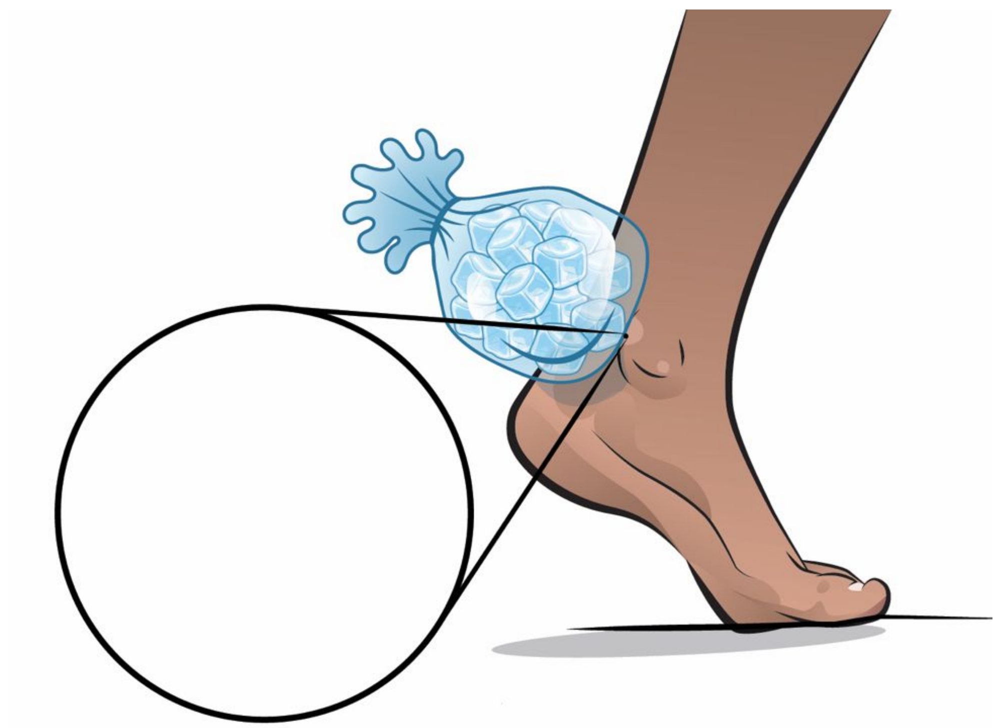
2. Do you think Steve or Sophie is correct? ______________________ +1 Sophie

3. What part of the systems do these data **not show** that would help you decide between Steve and Sophie's claims?
Note: the ice pack is a system and the person's ankle is another system; energy is transferring between these two systems.
+1 Does not show the energy moving between the systems
+1 Does not show the particles moving within the systems
+1 Does not show how the ice pack is interacting with the skin
+1 Does not show a clear direction in which energy is transferring (from the ice pack to the ankle, or from the ankle to the ice pack)

4. Show why you picked Steve or Sophie's claim by **drawing a model zooming in at the point where the ice pack and skin touch** that explains how the contact between the ice pack and skin causes the skin to cool down and/or causes the ice to melt. In your model, make sure to include these components: particles for the ice pack, particles for the skin, how the particles are moving in each system based on their temperatures, and how energy is entering or leaving the systems. You may use words to explain your ideas underneath your models.

At 0 min (right when the ice pack is attached to the skin)


At the end of 20 minutes



Use the *Rubric for Model in Lesson 14 Icing Injuries Assessment* to assess this question.

5. How would your model change if the athlete were standing outside in the sun on a hot (100°F) day?

+1 The system would need to include the absorption of light from the sun on the other side of the ice pack.
+1 This would transfer energy to the ice pack, making the ice melt faster.
+1 The person might have warmer skin and therefore more energy to transfer from their skin to the ice pack.
+1 The air would be warmer, so the air particles surrounding the ice pack would be moving faster and colliding more often with the ice pack.

Name: ______________________________ Date: _______________

Lesson 14: Rubric

Rubric for Model in Lesson 14 Icing Injuries Assessment

Components Clearly represents or describes the system components and must include:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• **Particles** of the ice/water				
• **Particles** of the skin				
• **Particles moving** relative to their state of matter				
• **Particles moving** relative to the temperature of the system				
• **Energy transfer between** the systems				
Interactions between components Clearly represents or describes the following:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• Particle movement in the ice pack increases *energy*.				
• Particle movement in the skin decreases *energy*.				
• The heat is transferred from the skin to the ice pack *energy*.				
Mechanisms Clearly represents or describes the following:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• The energy transfer causes a phase change and temperature change in the ice pack *cause/effect*.				
• When the skin and ice pack are in contact, the energy transfer is caused by particle collisions *energy, cause/effect*.				

LESSON 15: How do certain design features slow down the transfer of energy into a cup?

PREVIOUS LESSON *We sorted previous evidence and collected new evidence to figure out that previously observed temperature changes were due to heat moving into the cup system. We revised our cup system models and used what we learned to explain how and why applying ice to injuries is beneficial.*

THIS LESSON

INVESTIGATION

3 days

We learn about the Cold Cup Challenge and look at some examples of cup designs that we know can keep a drink cold for a long time. We pick out the features of these cups that we think contribute to their effectiveness, and we consider what we still need to explain how they work. These features include vacuum insulation and double walls, porous materials, and preventing light from getting into the cup. We jigsaw the gaps in our knowledge and then conduct a gallery walk to share our findings. Finally, we use what we figured out to reach consensus about mechanisms for energy transfer, which will help us make design decisions to slow down this process.

NEXT LESSON *We will review the criteria and constraints for the design challenge. We will make connections between the tests we will conduct on our cups and how we will use the results to evaluate our designs. We will design and build our first cups and then test them. We will evaluate our results and receive feedback from another group on our design.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Obtain and use information from scientific texts to evaluate the function of certain design features in minimizing energy transfer into a system.

Develop a consensus model for explaining two mechanisms for energy transfer into a system, and design features that minimize energy transfer into a system.

WHAT STUDENTS WILL FIGURE OUT

- Shiny and light-colored materials (feature) reflect light away from a cup wall and prevent light from being absorbed by the wall or the water inside. Absorption of light by particles (mechanism) is one way that energy can transfer into a cup system to cause the water to warm up.
- Porous materials with air pockets (feature) slow down the conduction of energy because there are fewer particles to collide across the air pockets. Conduction of energy from particle collisions (mechanism) is another way that energy can transfer into a cup system to cause the water to warm up.
- A double-walled cup with a vacuum or air between the walls (feature) slows down or minimizes the conduction of energy because there are fewer or no particles to collide between the walls. This is a similar mechanism as in porous materials.

Lesson 15 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**INTRODUCE THE DESIGN CHALLENGE** Introduce the design challenge and brainstorm criteria, constraints, and testing conditions as a class.	A-C	chart paper, markers
2	30 min	**EXAMINE WHAT WORKS** Have students look at examples of cup designs that work well and complete a table to explain features we know work and to reveal gaps in what we know.	D-E	*Features of Cups that Keep Drinks Cool*, assorted cup designs
3	5 min	**NAVIGATION** Help students to take stock of what we still need to figure out before the design challenge.		
				End of day 1
4	5 min	**NAVIGATION** Review the gaps in understanding that were revealed yesterday.	F-H	
5	22 min	**JIGSAW THE GAPS IN WHAT WE KNOW** In small groups, examine new sources of information that will help students make connections to what they have already learned.	I	*How Light Warms Up Matter*, *How Styrene, Neoprene, and Cardboard Sleeves Work*, *How Double Walls Work*
6	15 min	**PREPARE POSTERS OF FEATURES THAT SLOW ENERGY TRANSFER** Support students as they work in groups to revise models for how design features slow down energy transfer by one of two mechanisms: thermal energy transfer via particle collisions, or radiation.	J	chart paper, markers
7	3 min	**NAVIGATION AND EXIT TICKET** Remind students of the upcoming design challenge, and of how filling the gaps in what we know will help us to be successful in that challenge.	K	note card, marker
				End of day 2
8	5 min	**NAVIGATION** Reconvene students in their small groups to add finishing touches to their posters and to prepare for their gallery walk.		posters from day 2, sticky tack or tape, 3 comparison T-charts
9	16 min	**GALLERY WALK OF EFFECTIVE DESIGN FEATURES** Have students observe each poster set in groups. Prompt students to discuss similarities and differences across the models shared on the posters, and to record observations.	L	markers, posters from day 2, 3 comparison T-charts, timer
10	22 min	**CONSENSUS DISCUSSION IN A SCIENTISTS CIRCLE** Facilitate a Class Consensus Discussion to create a class consensus model for each of the three gaps in our knowledge.	M	*Final Cup Consensus Model*, chart paper, markers
11	1 min	**NAVIGATION** Ask your students to begin to apply the new ideas they just learned to the design challenge.	N	
				End of day 3

Lesson 15 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Features of Cups that Keep Drinks Cool* • *How Light Warms Up Matter* • *How Styrene, Neoprene, and Cardboard Sleeves Work* • *How Double Walls Work* • note card • marker • *Final Cup Consensus Model*	• chart paper • markers	• chart paper • markers • assorted cup designs • posters from day 2 • sticky tack or tape • 3 comparison T-charts • timer

Materials preparation (25 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Have an assortment of cup designs available for observation on day 1, including a styrene cup, a paper coffee cup with a cardboard sleeve, a cup or can with a foam koozie, a plastic double-walled cup, and a metal double-walled cup. Have enough for each group to begin with one design and to rotate designs around to each group.

Before the gallery walk on day 3, group the posters that students created on day 2 by topic and hang them in sets around the classroom. For example, the posters of all the groups who investigated double-walled designs should be hung together. Prepare a comparison T-chart for each poster set. The T-charts should have agreements on the left side and disagreements on the right side. Hang one comparison T-chart near each poster set.

Lesson 15 • Where We Are Going and NOT Going

Where We Are Going

Although students have explored double-walled cups and radiation in previous lessons, they have not modeled these sub-phenomena in relation to the anchoring phenomenon of the unit.

In Lesson 8, students investigated various cup materials and colors and the temperature of the water inside. They found that the foil slowed the temperature increase of the water because the light reflected off the foil. They found that the clear plastic cup let light through to transfer energy into the water. They found that a black-painted cup allowed energy to transfer into the water, but a white-painted cup slowed this down. They have not yet figured out the mechanism for light to transfer energy into the water at a particle level. In this lesson, one third of the class will explain how light interacts with particles through reflection, transmission, and absorption. These students will develop a model for how light can interact with the particles that make up the cup and the particles that make up the liquid inside. They will build on their understanding from the light and matter unit about reflection and transmission, and the class will develop their understanding of *absorption*, which describes the way that light interacts with particles when it transfers energy directly into them.

Students have already investigated conduction and used simulations to see how particle collisions transfer energy across matter. They have not yet considered the difference between a regular double-walled cup with air between the walls and a vacuum-sealed double-walled cup, and why the air and the vacuum slow energy transfer. In this lesson, a third of the class will build on their understanding of conduction to explain how air-insulated and vacuum-sealed cups minimize energy transfer into the liquid inside because they have very few particles between the walls to collide and transfer energy.

The last third of the class will build on their understanding of conduction to explain how porous materials like foam can also reduce energy transfer. These students will build a model for the particle structure of materials like cardboard, styrene, and foam, or neoprene, to explain how koozies and coffee cup sleeves can reduce energy transfer into or out of a liquid. Note that students will commonly refer to styrene cups as "styrofoam", though styrofoam is actually used in housing insulation and styrene (or polystyrene) is the material used for cups.

Where We Are NOT Going

Although students will read about absorption in this lesson, they will not be using a particle model for light to understand this process. They will not be learning about electrons or photons to explain what happens when light interacts with a particle of matter. The limit of their model for absorption will be energy transfer into the particle, which ends up as kinetic energy. If this happens to enough particles in a liquid, the liquid will warm up.

LEARNING PLAN for LESSON 15

1 · INTRODUCE THE DESIGN CHALLENGE

10 min

MATERIALS: science notebook, chart paper, markers

Introduce the *Cold Cup Challenge*. Say, *We have figured out so much about how a cup can keep liquids cool by minimizing thermal energy transfer. I think we may know enough to create our own cups and see if they rival the fancy cups you can buy at a store*. Display **slide A** and give students a minute to read the problem and the goal silently to themselves, before reading them aloud.

- **Problem:** Iced drinks bought from coffee shops and restaurants warm up and water down too quickly, especially on warm, sunny days. Stores sell reusable cups that keep a drink colder for longer and reduce environmental impacts, but these cups can be expensive.
- **Goal:** Using everyday materials, design a cup that uses the best design features we know about to keep a drink almost as cold as the store-bought cups do.

Display **slide B**. Say, *Any time we have an engineering challenge, we need to figure out a couple of things beforehand. First, we need to decide what requirements our design needs to meet to be considered successful.✱ This is called our criteria. What are some criteria that you think we might include in the* Cold Cup Challenge? *Turn to a shoulder partner and share your ideas.*

Give partner pairs a minute to talk, and then solicit 3-4 ideas for criteria. Record these ideas at the front of the room on a piece of chart paper labeled "Criteria". Save room at the bottom to create a list of constraints.

Display **slide C**. Say, *We also need to decide on the things that we can and can't do, the limits that we will set on our designs. This is called our constraints. What are some constraints that you think we might include in the* Cold Cup Challenge? *Turn to a partner and share your ideas.*

Give partner pairs another minute to talk, and then solicit 3-4 ideas for constraints. Write "Constraints" underneath the list of criteria and record student ideas on the bottom half of the chart paper.

Tell students that you will use their ideas in creating a list of criteria and constraints for the design challenge that we will start working on in the next lesson, but first we need to do more investigation of what works and why it works.

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLAINING AND DESIGNING SOLUTIONS

The focus of this discussion is to introduce students to criteria and constraints for the design challenge. Over the course of Lessons 15-18, students will undertake a design project, engaging in two design cycles, to construct a solution that meets agreed-upon specific design criteria and constraints. These specific design criteria and constraints will be provided in Lesson 16, but brainstorming them now can help students build their understanding of what it means to be a criteria or a constraint.

2 · EXAMINE WHAT WORKS

30 min

MATERIALS: *Features of Cups that Keep Drinks Cool*, science notebook, assorted cup designs

Look at existing cup designs. Display **slide D**. Say, *Let's start with some cups that we know keep drinks cool. What are some features that we notice on these designs?*

Emphasize to students that looking at existing designs is not cheating. In fact, it is a fundamental part of the engineering design process.✱ Engineers rarely start from scratch; rather, they study what they know works, they learn from it, and then they make it even better.

Display **slide E**. Pass out one copy of *Features of Cups that Keep Drinks Cool* to each student. Have students attach the handout in their science notebooks. Then arrange the class into table groups of 3-4 students. Have enough samples of the existing cup designs that every group can start with one cup; the cups will then be rotated around the room.

You will need several cups, including these:

- a double -walled metal cup (vacuum sealed)
- a double -walled plastic cup (air insulated)
- a styrene cup (commonly called a styrofoam cup)

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLAINING AND DESIGNING SOLUTIONS

Examining existing designs and why they work can help students prioritize which features to include in their cup designs, and keep students' design cycles closely connected to the science of how each feature works to minimize energy transfer.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

- a plastic cup with a neoprene or foam koozie
- a paper coffee cup with a cardboard sleeve

Generate ideas in small groups. Once students are settled into groups, pass out a sample of one existing cup design to each group. Ask groups to examine and discuss the cup to determine at least one feature that they believe can help keep a drink inside the cup cold. In the table in their handout, students need to write that feature, why they think it works, and what they still do not understand about how the feature slows down or minimizes energy (i.e., thermal energy and energy from light) transferring into the cup. Remind students to look back in their Progress Trackers for ideas about why the features work. Circulate among the groups as they work to see what they are including in their tables. After four minutes, rotate the cups to the next table. Repeat this procedure until all groups have examined and written about each existing cup design.

ASSESSMENT OPPORTUNITY

This is an opportunity to assess how well students are making connections between why a feature works and evidence from their previous investigations. Circulate among the groups and ask questions that will challenge students to provide evidence from earlier investigations in the unit. For example, if a student says, "The double-walled cup works because it makes thermal energy transfer into the cup slower," ask, "What evidence do you have for that?" If students are struggling to make these connections, consider using the whole-class discussion that follows for making those connections explicitly. Add a row that is labeled "Evidence from our investigations" to the table that the class makes together, and fill it in as students suggest features of the existing designs.

It is expected that students will have lingering knowledge gaps for all of these features, which is the reason that they will jigsaw learning about different features in the next class period.

Make a class record of what we do and do not know. After approximately 18-20 minutes, bring the class back together. Make a table on chart paper or whiteboard labeled to look like *Features of Cups that Keep Drinks Cool*. Ask each group to share a design feature from their tables. As students share design features, record them in the class table. After each suggested feature, ask students what we already know about why this feature works, and record their ideas. Then ask, *What don't we know about this feature?*✱

Listen for the following ideas to come up for the identified design features:

What works	Why it works	Still need to know
Double wall	Conduction slows down when energy transfers through the space between the walls.	We need to know more about what's in the wall--is it always air?
Something wrapped around the cup	Some materials slow conduction into the cup.	We need to know what is special about styrene, cardboard, and foam.
Shiny surface	Shiny materials reflect light away from the liquid inside, so it doesn't get absorbed.	We need to know more about how light warms up the liquid--what does it mean for light to be absorbed?
Color of the cup	Lighter colors reflect light, so they don't absorb as much energy.	We need to know more about how light warms up the liquid--what does it mean for light to be absorbed?

Support student questioning in engineering tasks so that it leads to investigations of the underlying science ideas. Teachers and curriculum need to support students to shift from thinking "Will this work?" to "Why does this work?" to address the disciplinary core ideas. One way to do this is to focus student thinking on individual features of the design and why those features work, rather than on the product as a whole.

Use questions to challenge students, and push them to explain the mechanisms that they don't yet understand to reveal the gaps in their understanding. For example, if a student suggests that darker colors absorb more energy, you might use the following prompts to challenge that student:

Suggested prompt	Sample student response
What does it mean for something to absorb energy?	*The energy goes into it.*
What happens when energy goes into a liquid?	*The energy turns into kinetic energy and the liquid warms up.*
Why doesn't the light just go right through, like when light transmits through a window?	*I don't know.*

Say, *This sounds like a gap in our understanding, Let's write that down.*

3 · NAVIGATION

5 min

MATERIALS: None

Highlight our knowledge gaps and forecast the next investigations. Say, *It looks like we don't quite understand everything we need yet. What are some of the things we want to learn more about in our next class?*

Listen for students to revoice some of the ideas from the class table. As they make a suggestion, make a checkmark next to that idea on the chart paper. Then say, *Next time, we will investigate some of these questions about the different design features.*

HOME LEARNING OPPORTUNITY

Some students may still have questions about the role of the lid in keeping drinks warm by preventing evaporative cooling. Because the lid does not keep drinks cool in the same way that it keeps drinks warm, we did not include it here as a feature before the design challenge. Consider assigning *Evaporative Cooling* if you think that your students would like to know more about evaporative cooling before the unit is over.

End of day 1

4 · NAVIGATION

5 min

MATERIALS: None

Review our knowledge gaps from the previous class. Say, *The last time we were together, we identified some gaps in what we know. For example, we realized we did not know what was inside the walls of a double-walled cup. Is it just air? Some of you mentioned vacuums, too. Could it be something else? Let's talk about each of these gaps and what we need to learn today.*

Display **slide F**. Have students turn and talk for 1 minute about what they think is between the walls of the cup and how the double wall works. Have them share with each other one thing they need to learn about this design feature to understand why it minimizes thermal energy transfer or energy transfer from light. Repeat this same process with absorption of light (display **slide G**) and certain materials (display **slide H**).

Then say, *Today we will break into groups to fill these gaps in our knowledge. Our goal is to answer some of our lingering questions, and by working together, I believe we can do that.*

5 · JIGSAW THE GAPS IN WHAT WE KNOW

22 min

MATERIALS: *How Light Warms Up Matter*, *How Styrene, Neoprene, and Cardboard Sleeves Work*, *How Double Walls Work*, science notebook

Divide students into groups for further investigation. Begin by dividing the class into small groups of 3-4 students. Once students are settled into their groups, assign each group a number from 1 to 3, representing the 3 gaps that we identified:

- group 1's: absorption of light
- group 2's: materials
- group 3's: double walls

In a class of thirty students, this will mean that 3 groups are assigned to investigate each gap topic. All students assigned to a group 1 should get a copy of the handout *How Light Warms Up Matter*, all students in a group 2 should get a copy of *How Styrene, Neoprene, and Cardboard Sleeves Work*, and all students in a group 3 should get a copy of *How Double Walls Work*.

Display **slide I** and review the close reading protocol with the class. Direct students to read their handout once on their own, and as they read, to annotate the text for important ideas. They can annotate the text following conventions you have established, such as underlining important ideas, circling key words, and writing a question mark next to an idea they do not understand. After 5 minutes or more depending on your students' needs, ask them to read their handout again with their group (silently) and answer the question(s) together.✱

✱ SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

Focus students on critically reading their handout text for new information that can help make connections between ideas they have previously learned and the information in the reading. Many of the ideas included in the reading are not new to students, but the reading integrates these ideas in the context of a design discovery and will help students apply science ideas in new ways to explain the design features of cups.

6 · PREPARE POSTERS OF FEATURES THAT SLOW ENERGY TRANSFER

15 min

MATERIALS: science notebook, chart paper, markers

Represent energy transfer on a poster. Display **slide J**. Say, *Let's make a record of our ideas to share with our classmates next time. Each group will represent the big ideas from their reading on a poster as a way to teach the rest of the class so we can all fill in the gaps in our knowledge.*

Tell students to use the questions on their handouts to get them started, and to include a diagram to illustrate the phenomenon they read about, the mechanisms that cause energy transfer in the cup system, and how the cup design feature would slow down or minimize this transfer.✱

Circulate among the groups and look for those whose posters are sparse or missing either an explanation or a representation. Use this time to challenge students' thinking and encourage them to add more to their posters.

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

As students work, encourage them to develop a diagrammatic model to help them communicate what they learned about to their classrooms. They need to identify if energy is transferring in their

ASSESSMENT OPPORTUNITY

As you move to each group's poster, you need to look for different pieces of information.

Group 1 read a text about the absorption of light. Look to see if students make the connection that absorption of energy from light is related to an increase in particles' kinetic energy. This group's mechanism(s) for energy transfer are radiation and absorption of light by particles. See if students explain how reflective materials block the absorption of light.

Group 2 read a text about types of porous materials with air pockets. Look to see if students make the connection that porous materials are filled with air pockets and that air has fewer particles and therefore fewer opportunities for particle collisions. This group's mechanism for energy transfer is thermal energy transfer via conduction/particle collisions. See if students explain how air pockets slow down or minimize particle collisions.

Group 3 read a text about vacuum-insulated and air-insulated double walls. Look to see if students make the connection that air and a vacuum fill the space between the walls, and that air has fewer particles and therefore fewer opportunities for particle collisions. Vacuums are empty (or mostly empty) of particles. This group's mechanism for energy transfer is thermal energy transfer via conduction (particle collisions). See if students explain how air and a vacuum between the walls slow down or minimize particle collisions.

phenomenon via radiation or conduction, and to show how cup design features slow down or minimize this process. They should include pictures, words, and labels, along with a key that helps the class make sense of their representations. If the class has agreed-upon representations for light, particles, and particle motion, encourage students to use those agreed-upon representations to help others quickly understand what is being explained by their model.

7 · NAVIGATION AND EXIT TICKET

3 min

MATERIALS: note card, marker

Say, *Today you did what engineers do. You gathered scientific information from various sources to make informed decisions about how to design something. Next time, you will share what you learned with the rest of the class so that everyone has the information they need to meet the* Cold Cup Challenge*.*

Display **slide K**. Review the *Cold Cup Challenge*. Then pass out one note card to each student for their exit ticket. Ask students to identify one design feature they would like to include in their design and why they think the feature will work. Collect the posters and exit tickets before students leave class.

End of day 2

8 · NAVIGATION

5 min

MATERIALS: posters from day 2, sticky tack or tape, 3 comparison T-charts

Have the small groups review their own posters. Say, *In our last class, we made posters. Let's spend five minutes reminding ourselves about what we learned. Go stand by your poster in your group. One person in the group should explain one thing on the poster to the rest of the group, and say why it is important. Then the next person will choose something else on the poster to review, and so on until everyone has had a turn.*

ADDITIONAL GUIDANCE	Prior to day 3, arrange students' posters on the walls around the classroom, using tape or sticky tack. Hang posters on the same topic near each other to help students make comparisons between the different big ideas and models presented on the posters.

Tell students to use this time to also make sure that their poster includes everything they want to communicate to other groups. You can use this time to ensure that all the posters are grouped by topic. For example, all of the posters about double-walled designs should be hung close together. You can also use this time to hang a comparison T-chart next to each poster set.

9 · GALLERY WALK OF EFFECTIVE DESIGN FEATURES

16 min

MATERIALS: markers, posters from day 2, 3 comparison T-charts, timer

Set the procedures for the gallery walk. Remind students that the purpose of the gallery walk is to fill the gaps that we identified in our knowledge. Display **slide L** and review the procedures for the gallery walk. Tell students to stay with their group as they move from poster set to poster set. Explain that they will begin by reading each poster in the set on their own, then talking to their group to identify agreements and disagreements across all of the posters in the set. They will then choose one thing that all of the set's posters had in common, an "agreement," and one thing that all of the set's posters had different, a "disagreement," and record them on the comparison T-chart near the poster set.

ASSESSMENT OPPORTUNITY	The gallery walk of different models is an opportunity for you to use a more structured peer feedback protocol. For example, use the sticky note peer review process. In this protocol - shared on *Tools for Ambitious Science Teaching* - students use sticky notes to leave questions and comments on posted student work. There is time built in for students to respond on feedback.

Conduct the gallery walk. Have the groups rotate around the room, moving to the next poster set every 5 minutes. Remind students to first read the posters quietly for 1-2 minutes, then discuss with their groups for 1-2 minutes, and then record one similarity and one difference on the comparison T-chart for that poster set.

Remind students that they should try to come up with something new that has not already been recorded on the T-chart by another group. Note that there may be more than one small group at each poster set at any given time. Remind students that they will need to move from poster to poster in the set to make room for the other groups, and to take turns adding their group's ideas to the T-chart. Step in to manage traffic if necessary. After 15 minutes, have all the students come to a Scientists Circle with their science notebook and a chair.

10 · CONSENSUS DISCUSSION IN A SCIENTISTS CIRCLE

22 min

MATERIALS: science notebook, *Final Cup Consensus Model*, chart paper, markers

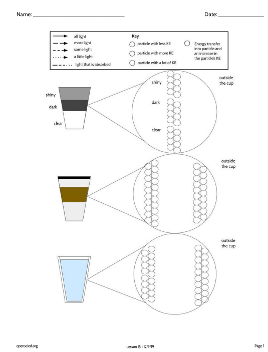
Lead a Class Consensus Discussion around gaps in understanding energy transfer.✱ Pass out one copy of the handout *Final Cup*

✱ ATTENDING TO EQUITY

Consensus Model to each student and have students attach it to their science notebook. The handout is a template for the class to start developing consensus models for each mechanism of energy transfer into the cup system. The key and handout are only partially complete, as the class will need to decide how to represent kinetic energy of particles given the previous decisions made by the class in Lesson 11 or 12. First, update the key with important representations that the class wants to use. Then use the representations in the key to explain how each design feature minimizes energy transfer.

ALTERNATE ACTIVITY

The handout *Final Cup Consensus Model* is a different format for the consensus Progress Tracker and was developed to scaffold students' modeling practice. You can use the original Progress Tracker in lieu of the new handout, which is more of a blank slate for students. If this option is chosen, each student will need at least one copy of the Progress Tracker for this activity. Use *Progress Tracker 2* for composition notebooks, and *Progress Tracker* for spiral notebooks or binders. If using *Progress Tracker 2*, students may need more space to capture their thinking, so provide them with 2-3 copies of the Progress Tracker that they can combine into a booklet attached to their science notebook as shown in the photo.



Record the question at the top of the handout. Display **slide M**. Have students recall the lesson question "Why do certain design features slow down the energy transfer into a cup?" Then have them write the question at the top of their handout or in their Progress Tracker.

Co-develop a list of key ideas figured out from the jigsaw. Focus students on trying to use the model ideas from the posters to fill in gaps in their understanding. About 6-7 minutes is allotted for modeling how each design feature slows energy transfer, so the discussion should be brief and focus on only the most important connections that students need to make.

This Class Consensus Discussion is a prime opportunity to reinforce or introduce new scientific vocabulary to name the processes that students have been learning about. These include *absorption* and *conduction*, both of which may already be on your word wall from earlier in the unit. These are words that students earn because they have engaged with the concepts deeply over the previous days of instruction. If these two words are already on your word wall, revisit them now. If not, take time to add them during this discussion or just after. Additional words to spend time developing during this discussion include: *vacuum*, *air insulated*, and *porous*, which may be new to your students or particularly challenging for emergent multilingual students (e.g., *vacuum* has multiple meanings).

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Throughout this discussion, continue to focus students on design features they may want to test in the design challenge. The purpose of this modeling work is to develop a model that students can use to test their ideas about their cup designs. This model will not only give students a way to represent the energy transfer (or slowing down or minimizing energy transfer) into the cup systems, but it will also give them a way to support their design choices with science ideas.

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLAINING AND DESIGNING SOLUTIONS

To support students in building explanations from evidence, push them to make explicit connections between model ideas and observations. For example, if a student says, "The light transfers energy into the particles," ask, "How does this help us explain our results with the foil-covered cup?"

KEY IDEAS	**Purpose of this discussion:** Summarize what we figured out from the jigsaw investigation. Establish ideas about absorption and conduction. **Listen for these ideas:** • Light model: It is better to reflect light away from the walls of a cup if you want to slow the temperature increase of the liquid inside. This is because when light shines on something, the light interacts with the particles that make up the matter. Light can reflect, or transmit, or transfer energy into the particles (absorption). If the light transfers energy into the particles, the energy may end up as kinetic energy, meaning that the particles will speed up. If this happens to a lot of particles in a liquid, the liquid will warms up. • Air pocket model: It is better to use materials with air pockets because the properties of a material affect how well the material conducts energy. These kinds of materials are called *porous*. For example, if a solid material has a lot of air in it, like styrene, there will be fewer particles for energy to transfer between through particle collisions. If a material is solid all the way through, there will be more particles to collide with one another, so the energy will conduct more easily. • Double-walled model: A cool liquid in a double-walled cup with a vacuum between the walls will have a slower increase in temperature than a liquid in a cup with air between the walls. This is because the vacuum has far fewer particles for energy to transfer through. There will be fewer opportunities for particle collisions in a vacuum, so energy cannot conduct as well. As students share their thinking, press them to support their ideas with evidence from the various investigations we have completed.	Look for students to say something like, "The foil reflects the light away, so it can't shine on the liquid, so the energy won't transfer into the liquid to raise the temperature."

ASSESSMENT OPPORTUNITY	Through this discussion, be mindful of formatively assessing the different dimensions that students are engaging with:
	• Consider whether students are connecting ideas about particle motion and kinetic energy to the different mechanisms of energy transfer via conduction (particle collisions) or radiation (light absorption).
	  ◦ If students are struggling with disciplinary core ideas, focus them on the previous models that they developed, especially from Lessons 6, 11, and 14.
	• Consider whether students are able to use model representations that they've agreed upon to represent their thinking. When students enter the design challenge in the next lesson, they will need to be able to model their design choices and how they minimize energy transfer without the scaffolding you are providing here.
	  ◦ If students are struggling with modeling your thinking, use questioning to elicit their ideas and then brainstorm what kinds of representation they feel would best represent those ideas in a model.
	• Consider whether students are using energy as a way of explaining the flow into the cup system.
	  ◦ Cue students to focus on kinetic energy of particles and energy from light as a way to track the energy flow into the cup systems.

Develop a consensus model for how radiation warms a drink. Move the class to the first set of posters about what happens when light interacts with matter (or move the posters to the Scientists Circle). Say, *One of the things we weren't sure about was why putting something shiny over the outside of the cup slowed the temperature increase in the liquid. We thought it was reflective, which is important, but we weren't sure how light actually warms things up. Let's take a look at these models and your comments and see if we know enough now to explain this.*

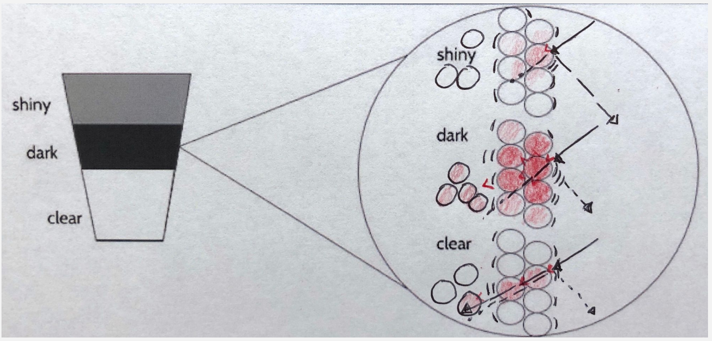
Read the agreement side of the poster set's comparison T-chart out loud, or ask a student to read it out loud to the class. After each idea has been read, revoice the idea to the class and ask if we all agree that this belongs in our consensus model. If the class agrees, have them add the idea to their handouts using the agreed-upon representations. You may want to project a version of the handout on document camera, or sketch one on a whiteboard or chart paper, as the class agrees on what to include in the consensus model.✱

Then move on to the disagreements. After each disagreement, ask the class if this disagreement needs to be resolved to explain how preventing light from getting in slows down or minimizes energy transfer into the cup. If the majority of the class says yes, ask the groups who disagreed to share their reasoning. Use questions to clarify their ideas. Ask other students whose reasoning they find more convincing, and add those ideas to the chart paper at the front of the room.

After all the ideas have been read, ask someone to summarize why something shiny slows the temperature increase in a cool liquid. Ask the class if they agree, and if anybody would like to add to this explanation.✱

At this point, the list of things we figured out should include:

- When light shines on something, it might reflect off particles, transmit between particles, or transfer energy into particles (absorption).
- If the light transfers energy into the particles, the energy may end up as kinetic energy, meaning that the particles will speed up. If this happens to a lot of particles in a liquid, the liquid will warm up.



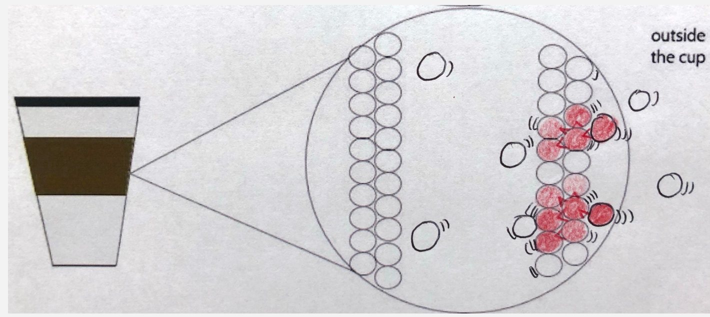
You may choose to model these ideas on a piece of chart paper. Have students add these to their Progress Tracker before moving on, telling them to leave more than half the remaining space in it to add some other key ideas.

Repeat the process for a consensus model for why air pockets keep a drink cooler for longer. Move to the second set of posters about conduction in materials with air pockets. Say, *One of the things we weren't sure about was why using materials like styrene, koozies, or coffee cup sleeves is able to minimize the temperature change in a liquid. Let's take a look at this model and see if we know enough now to explain this.*

- Review the T-chart for agreements.
- Discuss and resolve areas of disagreement.
- As you discuss, develop a model that incorporates the important ideas.

At this point, the list of things we figured out should include:

- If a solid material has air pockets, there are fewer particles in the air pockets for energy to transfer between through particle collisions. If a material is solid all the way through, there are more particles to collide with one another, so the energy will conduct more easily.

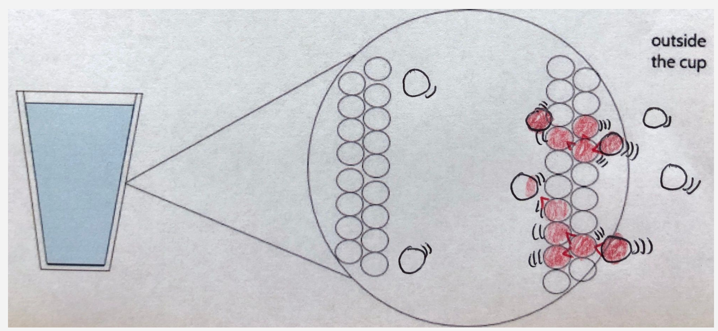


Repeat the process for a consensus model for why double walls keep a drink cooler for longer. Move to the third set of posters about how double-walled containers work. Say, *One of the things we weren't sure about was what is inside the double wall and why this helped keep a drink cooler for longer. We found out that there are two kinds of double-walled containers: ones with air and ones with a vacuum, and the ones with a vacuum work better. Let's take a look at this model and see if we know enough now to explain this.*

- Review the T-chart for agreements.
- Discuss and resolve areas of disagreement.
- As you discuss, develop a model that incorporates the important ideas.

At this point, the list of things we figured out should include:

- A vacuum has far fewer particles than air does. This means there are fewer particles in a vacuum for energy to transfer between through particle collisions.
- Solid walls have the most particle collisions, an air layer has fewer particle collisions, and a vacuum has very few particle collisions.



11 · NAVIGATION

1 min

MATERIALS: None

Motivate the need to figure out how we will test our new cups. Display **slide N**. Say, *Next time, we will begin the Cold Cup Challenge. Start thinking about one feature you want to include in your cup design and how you think it will work. For every design choice you make, you need to explain whether it will help energy to transfer or will slow down that transfer.*

ADDITIONAL GUIDANCE	Think ahead to the design challenge and the materials you want to provide to your students, such as aluminum foil, plastic wrap, cotton balls, foam or felt, or other insulative materials. Ask parents if they can help supply any of these design challenge materials, with unused materials being returned home at the completion of the challenge.

Additional Lesson 15 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.** **CCSS.ELA-Literacy.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).** Help students construct a model to explain how energy transfers in the system given the design feature they read about (reflective or transmissive materials, double walls, or air pockets). Students should first summarize important ideas from the reading that they want to include in their model. They will then develop a model that includes these important ideas and share it with their classmates for comparison across models.

LESSON 16: How can we design a cup system to slow energy transfer into the liquid inside it?

PREVIOUS LESSON *We learned about the Cold Cup Challenge and considered what we still needed to figure out about how cups keep drinks cold for a long time. We jigsawed the gaps in our knowledge and then conducted a gallery walk to share our findings. We used what we figured out to reach consensus about mechanisms for energy transfer and design features that slow down this process.*

THIS LESSON

INVESTIGATION

2 days

We review the Cold Cup Challenge and discuss the purpose of the different criteria and constraints for the design challenge. We make connections to the tests we will carry out on our cup designs and how results from those tests will help us evaluate our designs. We design our cups, pointing out at least 3 features we have evidence for that will slow energy transfer. We then build our first cup designs. We carry out 5 tests on the cups, and then evaluate our results compared to the criteria and constraints. Each design group then provides feedback to each other to offer additional suggestions for improving the cup designs.

NEXT LESSON *We will review our test results and feedback on our first cup design. We will use this information to redesign, build, and test a 2nd cup design, modifying features of the cup to slow energy transfer even more. We will add our test results to a class chart and make observations from the chart looking for patterns in design features that seemed to slow energy transfer the most.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Design a solution for a cup system with features (structures) to slow energy transfer into the liquid inside the cup (function).

Carry out investigations to collect data to evaluate the performance of cup systems that slow energy transfer given the criteria and constraints of the problem, and to modify design features (structures) based on test results (functions).

WHAT STUDENTS WILL FIGURE OUT

- The more clearly a design task is defined, the more likely the solution (cup system) will meet the criteria and constraints.
- A designed cup needs to be tested and then modified on the basis of the test results that will help evaluate the solution to how well it meets the criteria and constraints of a problem.

Lesson 16 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Have students turn and talk about their initial ideas for design features they want to include in their first cup design.	A	
2	15 min	**REVIEW THE DESIGN CHALLENGE** Pass out a copy of the design challenge packet. As a class, review the criteria, constraints, and tests that will be carried out on the first cup designs.	B-H	*Cold Cup Design Challenge*
3	25 min	**DESIGN AND BUILD CUP DESIGN 1** Arrange students in their design groups and give them time to design their cups using *Part 2* of their design packet. Then, give students time to build their cups.	I	*Cold Cup Design Challenge*, Cup Design Round 1 Build
				End of day 1
4	30 min	**TEST FIRST CUP DESIGNS** Have the students work through part 3 of their design packet to carry out 5 tests on their cups. Students can complete some of the tests concurrently.	J	*Cold Cup Design Challenge*, Cup Design Round 1 Tests
5	15 min	**EVALUATE THE RESULTS OF THE FIRST DESIGN** Have students first review their own design, then conduct a peer evaluation on another group's design to provide feedback.	K-L	*Cold Cup Design Challenge*, *Design Evaluation: Peer Feedback*
				End of day 2

Lesson 16 • Materials List

	per student	per group	per class
Cup Design Round 1 Build materials		• 1 16 oz single wall plastic cup	• 10 16 oz single wall plastic cups • 10 plastic lids • aluminum foil • plastic wrap • sheets of foam and/or felt • plastic straws • cotton balls • paper towels • cardboard wrap • paper cups • paint and paint brushes • rubberbands • tape • glue and/or hot glue.
Cup Design Round 1 Tests materials		• Cup design 1 • 1 thermometer • 1 ruler • 1 lamp with 100-watt bulb • 1 500-mL beaker • *Regular light and temperature test* • *Bright light and temperature test* • *Environmental Impact Test* • *Price check test* • *Diameter test*	• Ice cold water (6°C) (800mL/group)
Lesson materials	• science notebook • *Cold Cup Design Challenge*	• *Design Evaluation: Peer Feedback*	

Materials preparation (35 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1: *Cup Design Round 1 Build*
- **Group size:** 2-3
- **Setup:** Arrange cup design materials in a central location accessible to all students. These materials should include: 10 - 16 oz single wall plastic cups, 10 plastic lids, aluminum foil, plastic wrap, sheets of foam and/or felt, plastic straws, cotton balls, paper towels, cardboard wrap, paper cups, paint and paint brushes, rubberbands, tape, glue and/or hot glue. Students may add materials they bring from home.
- **Safety:** If hot glue is used, warn students not to touch the tip of the glue gun and to be careful when they handle it. They should carefully return the glue gun to the table top when finished. Students need to be careful when handling parts of the cup until the hot glue has cooled.

Day 2: *Cup Design Round 1 Tests*
- **Group size:** 2-3

- **Setup:** Prior to day 2, make ice to chill water. You will need to chill at least 800 mL of water for each group of students (400mL for each temperature test), so make the appropriate amount of ice. Prepare design testing bins for each group that include: 1 500-mL graduated cylinder or beaker, 1 thermometer, 1 timer or stopwatch, 1 12-inch ruler, and 1 lamp with 100-watt bulb.
- **Notes for during the lab:** Students will need access to 800-mL of cold water (400-mL for the regular light test and 400-mL for the bright light test).
- **Safety:** Warn students not to touch or handle the lamps during the bright light test. Lamp shields can become very hot during the investigation and the light bulbs are also breakable. Lamps should not be removed until they have cooled completely.

Lesson 16 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will apply their energy transfer models to design a solution for keeping a drink cold for as long as possible. They will consider a range of materials that they could use to slow down the transfer of energy. To prevent students from simply layering materials to maximize thickness of the insulation around the cup, students are given design constraints to help them be more strategic about the types of materials they choose and how they might apply the features of insulative materials to their designs. If you see overly complex designs or ones that use a lot of materials, do not correct these designs. This is part of learning how to pay attention to constraints, while still meeting the criteria for the design challenge.

Students will need to transition in this lesson from thinking about the components of the cup system to thinking about these components as design variables that can be changed and manipulated to achieve certain accounts. For this reason, make Structure and Function an explicit focus as students identify design features for their cups and explain how they expect them to function when the cups are tested.

Where We Are NOT Going

The focus of the design challenge is on minimizing energy transfer in a situation in which the cold drink is inside the system. Alternative approaches, such as including a hot drink inside the system as another test, or even modifying cups to maximize energy transfer should be avoided at this moment. These two options are great additions to the design challenge, but most appropriate after the class has completed at least 2 design cycles within the specified Cold Cup Challenge.

LEARNING PLAN for LESSON 16

1 · NAVIGATION

5 min

MATERIALS: None

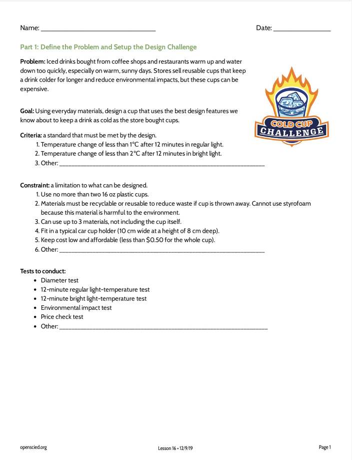
Have students share their initial design ideas with a partner. Display **slide A**. Ask students to find a partner and to spend 2 minutes talking to each other about initial design features they believe will help their cup slows energy transfer into the cup. Students should 1) identify the design feature, and 2) explain how it works (in terms of particle collisions and/or light's interaction with matter in the system) to slow energy transfer.

2 · REVIEW THE DESIGN CHALLENGE

15 min

MATERIALS: science notebook, *Cold Cup Design Challenge*

Review the problem and goal of the design challenge. Display **slide B** and pass out one copy of *Cold Cup Design Challenge* to each student. Students will use this design packet handout in this lesson and in Lessons 17 and 18. Students should keep their design packet with their science notebooks. In Lesson 18, students will fold the pages and attach the packet to their notebook, but have students keep the packet unattached from their notebook right now.



Name: ______________ Date: ______________

Part 1: Define the Problem and Setup the Design Challenge

Problem: Iced drinks bought from coffee shops and restaurants warm up and water down too quickly, especially on warm, sunny days. Stores sell reusable cups that keep a drink colder for longer and reduce environmental impacts, but these cups can be expensive.

Goal: Using everyday materials, design a cup that uses the best design features we know about to keep a drink as cold as the store bought cups.

Criteria: a standard that must be met by the design.

1. Temperature change of less than 1°C after 12 minutes in regular light.
2. Temperature change of less than 2°C after 12 minutes in bright light.
3. Other: ______________

Constraint: a limitation to what can be designed.

1. Use no more than two 16 oz plastic cups.
2. Materials must be recyclable or reusable to reduce waste if cup is thrown away. Cannot use styrofoam because this material is harmful to the environment.
3. Can use up to 3 materials, not including the cup itself.
4. Fit in a typical car cup holder (10 cm wide at a height of 8 cm deep).
5. Keep cost low and affordable (less than $0.50 for the whole cup).
6. Other: ______________

Tests to conduct:

- Diameter test
- 12-minute regular light-temperature test
- 12-minute bright light-temperature test
- Environmental impact test
- Price check test
- Other: ______________

Read the design problem and goal from **slide B,** which is also included in *Part 1* of the students' design packet. Ask students, *What are some initial things we need to think about with our designs*?

Listen for:

- Reducing contact between the materials, like having air pockets,
- Creating an air layer,
- Using light-colored materials,
- Using reflective materials.

With each sharing of an idea, probe students on how this design feature helps to slow down energy transfer into the cup. Listen for the use of mechanisms that refer to particle collisions and/or light's interaction with the matter in the system

Review the criteria and constraints for the cup design challenge.
Display **slide C** and continue to read *Part 1* of the design packet. Remind students that in the previous lesson they generated a few ideas about criteria and constraints. Review what the words criteria and constraints mean to your students.

- Criteria- standards that must be met by the design.
- Constraints- limitations to what can be designed.

Add these words to your word wall today or in Lesson 17 when students revisit them.

Read together each criterion and constraint. Ask students if these make sense given the problem and the goal for the design challenge.✱ Ask students if they want to add any criteria and/or constraints they felt were important from their discussions in Lesson 15 that they do not see included here. For example, students may want to add the constraint of not using straws to design more environmentally-friendly cups. There is space in students' design packet to make additions.

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLAINING AND DESIGNING SOLUTIONS

The purpose for reviewing criteria and constraints with students is to support students in making connections between the list being provided to them and the design problem and goal. This will help students understand how the criteria and constraints are related to the larger design challenge and are not arbitrarily selected.

✱ SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

As students talk about the tests, emphasize to students that these tests will help them collect data to serve as the basis for testing and evaluating their cup designs and also, to compare their designs to other groups because everyone tested their cups under a similar range of conditions.

Review the tests that students will conduct on their cup designs. Display **slides D** and continue reading *Part 1* of the design packet. Review the diameter test. Ask students how the diameter test will help them evaluate whether it meets the criteria and constraints for the design challenge.✱

Listen for students to say:

- *It will help us know if we are following constraint 4 that the cup fits in a typical car cup holder.*
- *It will help us decide if the cup is user-friendly.*

Display **slide E-H**. Review the other 4 tests. Each time you discuss a test, ask students to identify how the test is related to the criteria, constraints, or overall design problem.

Suggested prompt	Sample student response
How will the regular light and temperature test help you evaluate whether the cup meets the criteria and/or constraints for the design challenge?	*It will help us know if it meets criterion for temperature change of less than 1 °C after 12 minutes in regular light.* *It will help us know if the cup can keep a drink cold on a warm day.*
How will the bright light and temperature test help you evaluate whether the cup meets the criteria and/or constraints for the design challenge?	*It will help us know if it meets criterion 2 for temperature change of less than 2 °C after 12 minutes in bright light.* *It will help us know if the cup can keep a drink cold on a very warm and sunny day.*
How will the environmental impact test help you evaluate whether the cup meets the criteria and/or constraints for the design challenge?	*It will help us know if it meets constraint 2 and that materials must be recyclable or reusable to reduce waste if cup is thrown away.* *It will help us know if we are following constraint 2 and not using styrofoam.* *It will help us know if the cup can reduce environmental impacts.*
How will the price check test help you evaluate whether the cup meets the criteria and/or constraints for the design challenge?	*It will help us know if it meets constraint 5 and keeping the cup affordable.* *It will help us know if we are following constraint 3 and not using more than 3 materials.*

If students added criteria and constraints to the list in *Part 1*, give students time to brainstorm how they want to test their cups to evaluate whether they meet the new criteria or constraints.

ALTERNATE ACTIVITY

This design challenge is written as if it were students' first engineering design task of middle school. The task is well-specified, providing students with a list of criteria and constraints. There is some flexibility for students to co-construct new ideas too, to add to this list. If your students have more familiarity with engineering design, you will want to involve them more in defining the design problem and goal, and generating criteria to meet and constraints to follow.

3 · DESIGN AND BUILD CUP DESIGN 1

25 min

MATERIALS: Cup Design Round 1 Build, science notebook, *Cold Cup Design Challenge*

Preview expectations for designing and building the cups and arrange students in groups. Display **slide I** and have students look at *Part 2* of their design packet. Tell students that first they need to make a sketch of their cup designs with their design group, and label at least 3 features of the cup that should slow energy transfer and explain how they would.✱ Once they have a cup design, they should revisit the criteria and constraints to see if they think they will likely meet them given the design. They should note this in *Part 2.*

ASSESSMENT OPPORTUNITY

Prompt students to work with their group members to design a cup with at least 3 design features they believe will slow energy transfer into the cup system. They need to think about each design feature as a structure that serves a particular function in the system. As students work in their groups circulate among the groups to examine the emerging cup designs.

Look for students to share examples, such as:

- The use of metallic and other reflective colors or materials that will reflect light and minimize its absorption.
- The use of foam that contains air pockets that will slow down conduction.
- The use of two cups stacked within each other to create a double wall to slow down conduction.

Aim to provide written feedback to each group about their initial cup design. This feedback should target the design features specifically and not necessarily focus on the cup design as a whole. You can provide one set of written feedback per group and should ideally give it to students toward the end of day 2 when they also receive peer feedback.

Ask students to voice any questions they have about the design process.

Then, preview your expectations for their work together in groups, prompting students to think about the classroom norms as they work. Also, explain how you want students to gather materials for building their cups and cleaning up at the end of class. Once students are clear on these expectations, arrange students in groups of 2-3 for the design challenge. Group size can vary depending on the number of supplies you have available and your class size.

Design and build the first cup. Allow students the remainder of the class period to design and build the first cup. Circulate around the room to probe student thinking about design features and to monitor students as they gather and use materials. Remind students that if they waste materials, the unused materials should be added into their price check test.

Save at least 5 minutes at the end of class to return supplies to their proper place. Have each group write a group name on the bottom of their cup and place their cup where you want them.

Tell students that in the next class they will test their cups to see how their first design compares to the criteria and constraints.

End of day 1

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STRUCTURE AND FUNCTION

Students work with their group members to select at least three design features (structures) for their cup systems that they believe will minimize energy transfer. Prompt students to explain, as much as possible, how each feature minimizes energy transfer (function) by reducing particle collisions or blocking absorption of light .

4 · TEST FIRST CUP DESIGNS

30 min

MATERIALS: Cup Design Round 1 Tests, science notebook, *Cold Cup Design Challenge*

Preview instructions for the first round of testing. Arrange students in their design groups. Display **slide J** and direct students to find *Part 3: Test 1* in their design packet. Explain to students each of the tests they will carry out and your expectations for their work together in small groups. Also explain how to gather the materials they need and clean up. Revisit **slides D-H** as needed as you review each test.

Pass out one copy of *Regular light and temperature test*, *Bright light and temperature test*, *Environmental Impact Test*, *Price check test*, *Diameter test* to each group, unless these are pre-sorted into the group's lab bins. There is space on the *Environmental Impact Test* and *Price check test* to add materials. If you provided other materials than what is listed on those handouts, add the materials to the handouts now, if not done prior to the start of the lesson.

Explain to students that they will first carry out the *Regular light and temperature test* and while they wait for the results, they can complete the *Price check test*. Once the *Regular light and temperature test* is complete, one student from each group should discard the water, while another student retrieves another 400 mL of cold water for the *Bright light and temperature test*.

Explain to students that they will then carry out the *Bright light and temperature test*. While they wait for results they should complete the *Diameter test* and *Environmental Impact Test*.

SAFETY PRECAUTIONS

Remind students not to touch the lamp or lamp shield at all during this investigation. The shield can become very hot after 12 minutes. Students can leave their lamps in place to cool down at the conclusion of the investigation.

Review with students your expectations for the clean up of materials and ask students if they have any questions before they begin.

Carry out the first round of tests. Have students begin the *Regular light and temperature test* and the *Price check test* while they wait 12 minutes for results. Circulate among the groups to help students as needed.✱

After the first 12 minutes *Regular light and temperature test*, give groups about 2 minutes to clean up and transition to the next set of tests. Explain to students where to discard their water and retrieve 400mL of cold water for the next test.

Get students started on the *Bright light and temperature test*. While they wait for results, circulate among the groups to assist students as they complete the *Diameter test* and *Environmental Impact Test*.

After 12 minutes, have students carefully turn off their lamps and return all supplies (except lamps) to the appropriate place. Keep Cup Design 1 available through the end of the unit. Students may want to revisit Cup Design 1 in Lessons 17 and 18 as they evaluate the best designs.

✱ ATTENDING TO EQUITY

The price check test involves addition with decimals. Make calculators available to students who need the extra support or if a student uses a calculator as part of their individualized education plan.

5 · EVALUATE THE RESULTS OF THE FIRST DESIGN

15 min

MATERIALS: science notebook, *Cold Cup Design Challenge*, *Design Evaluation: Peer Feedback*

Work in design groups to evaluate the design. Have students remain in their design groups, now sitting back at their desks. Display **slide K** and direct students to read the first two questions on *Part 4: Evaluate your design*.

- What worked and why did it work?
- What is not working and why?

Give students about 5 minutes to examine their test results in comparison to the criteria and constraints in *Part 1* and to think about where their first design did well and where it could be improved.

ADDITIONAL GUIDANCE	For the environmental impact test, you may want to note to students that there areno traditional adhesives (tape, glue, rubber bands) that are reusable or recyclable, so many of their first cup designs likely included this as a landfill item. Make a connection to companies that have recently shifted their packaging to require no adhesives, like Apple. Challenge students to get creative in thinking about how to design their cups to avoid these adhesives if they can do it.

Explain the peer feedback process to students. Bring the groups back together as a whole class. Display **slide L**. Describe the purpose of getting peer feedback (e.g., getting fresh and new ideas from others, their peers may see an area for improvement that they themselves missed) and how to use the *Design Evaluation: Peer Feedback* to provide feedback to each other.

Carry out the peer feedback. Assign each group to provide feedback on another group's cup. Pass out 1 copy of *Design Evaluation: Peer Feedback* to each group. Each group only needs to complete 1 form for 1 other group. The peer feedback group will need access to Cup Design 1 and 1 copy of *Part 3: Test 1* test results from the design group. Give groups about 6 minutes to evaluate the cup and make suggestions for improvement. Then, have the feedback group share their completed feedback form with the design group.

Generate initial plans for the redesign. Ask each group to review their peer feedback. This is a prime opportunity to share your feedback on each group's first design. Ask design groups to complete the third question on *Part 4: Evaluate your design*.

ASSESSMENT OPPORTUNITY	Remind students that the purpose of each test was to help them evaluate whether their cup met the criteria and followed the constraints. Prompt students to look at each test result individually with respect to the criteria or constraints. Listen for students to consider the following: • High temperature change in the bright light condition may mean they need a different outside surface material to reflect light. • High temperature change in the regular light condition may mean they need to re-evaluate the cup wall material, the thickness, and the amount of contact between materials. • High cost or high waste means they need to rethink the type and numbers of materials used. • Too large of a diameter means they need to rethink the thickness of their cup. Encourage students to use their test results, peer feedback and feedback from you to help them determine how to modify their cups in the 2nd design cycle.

Close the lesson saying, *This first round of cup designs was impressive and I'm hearing some good ideas about how you want to improve your cups even more. Think about one feature you want to modify with your cup and why you think the change will help. Be prepared to share this with your group tomorrow, and make sure you have evidence to support your suggestion to help your group decide this more easily.*

LESSON 17: How can we improve our first design to slow energy transfer into the cup system even more?

PREVIOUS LESSON *We reviewed the criteria and constraints for the design challenge. We made connections between the tests we were conducting on our cups and how to use the results to evaluate our designs. We designed and built our first cups and carried out 5 tests on the cups. We evaluated our results and received feedback from another group on our design.*

THIS LESSON

INVESTIGATION

2 days

We review our test results and peer and teacher feedback from our first design. We discuss the design criteria and constraints and clarify them as a class. We then redesign our cup, making modifications to features we believe will slow energy transfer. We build, test, and evaluate the 2nd cup design. We add our results in a class chart and make initial observations from this data with respect to the best performing cups and what features helped them perform so well.

NEXT LESSON *We will review test results across our best cup designs and discuss why certain cups slow energy transfer the way that they did. We will propose a final design and participate in a Consensus Discussion to design the Ultimate Cold Cup together. We will develop a generalized model for energy transfer and apply this to several scenarios. We will demonstrate our understanding by individually taking an assessment. Finally, we will revisit the Driving Question Board and discuss all of the questions that we have answered and then reflect upon our experiences in the unit.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Design a solution that is modified based on test results to improve the features (structures) to better slow energy transfer (effect) by reducing the absorption of light or opportunity for particle collisions (function/cause).

Carry out investigations to collect data to evaluate the performance of cup systems that slow energy transfer given the criteria and constraints of the problem, and to propose ways to optimize design features (structures) based on the test results (functions).

WHAT STUDENTS WILL FIGURE OUT

- Surface materials that reflect more light help cups perform better on the bright light and temperature test.
- Materials used on the cup walls that reduce the amount of contact between layers help cups perform better on the regular light and temperature test.
- The use of fewer materials can still be effective on the two temperature tests, while also reducing costs, diameter, and environmental impact.

Lesson 17 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Compare and discuss the cups that met the two criteria of the Cold Cup Challenge, looking for patterns in design features.	A	*Cold Cup Design Challenge*, Cup Design 1, chart paper or whiteboard, markers
2	10 min	**CLARIFY CRITERIA AND CONSTRAINTS AND TESTS TO CARRY OUT** Facilitate a reflection on the criteria, constraints, and tests to help improve students' understanding of how these work together in a design cycle.	B	*Cold Cup Design Challenge*
3	25 min	**DESIGN AND BUILD CUP DESIGN 2** Arrange students in their design groups and give them time to design their second cups using *Part 4* of their design packet. Then, give students time to build their cups.	C	*Cold Cup Design Challenge*, Cup Design Round 2 Build
				End of day 1
4	30 min	**TEST SECOND CUP DESIGNS** Have the students work through *Part 6* of their design packet to carry out 5 tests on their second cup design. Students can complete some of the tests concurrently.	D	*Cold Cup Design Challenge*, Cup Design Round 2 Tests
5	10 min	**ADD THE RESULTS TO A CLASS CHART** Have students first evaluate their second design in comparison to their first design. Groups then choose which of their designs best met the criteria and followed the constraints, and they share their design and test results with the class.	E	*Cold Cup Design Challenge*, Cup Design 1, Cup Design 2, Cold Cup Challenge: Class Test Results chart
6	5 min	**NAVIGATION** Give students time to work on their own to explain how they would design a 3rd cup to minimize energy transfer. Collect students' design packet to formatively assess student thinking before the last lesson of the unit.	F	*Cold Cup Design Challenge*
				End of day 2

Lesson 17 • Materials List

	per student	per group	per class
Cup Design Round 2 Build materials		• 1 16 oz single wall plastic cup	• 10 16 oz single wall plastic cups • 10 plastic lids • aluminum foil • plastic wrap • sheets of foam and/or felt • plastic straws • cotton balls • paper towels • cardboard wrap • paper cups • paint and paint brushes • rubberbands • tape • glue and/or hot glue.
Cup Design Round 2 Tests materials		• Cup Design 2 • 1 thermometer • 1 ruler • 1 lamp with 100-watt bulb • 1 500-mL beaker • *Regular light and temperature test* • *Bright light and temperature test* • *Environmental Impact Test* • *Price check test* • *Diameter test*	• Ice cold water (6°C) (800mL/group)
Lesson materials	• science notebook • *Cold Cup Design Challenge*	• Cup Design 1 • Cup Design 2	• chart paper or whiteboard • markers • Cold Cup Challenge: Class Test Results chart

Materials preparation (35 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

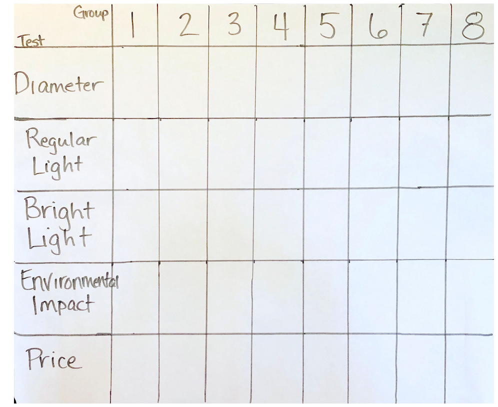
Prepare a class data chart for students to share the test results from their best performing cup from either round 1 or round 2 tests. Title the chart, *Cold Cup Challenge: Class Test Results*.

Day 1: *Cup Design Round 2 Build*

- **Group size:** 2-3
- **Setup:** Arrange cup design materials in a central location accessible to all students. These materials should include: 10 16 oz single wall plastic cups, 10 plastic lids, aluminum foil, plastic wrap, sheets of foam and/or felt, plastic straws, cotton balls, paper towels, cardboard wrap, paper cups, paint and paint brushes, rubberbands, tape, glue and/or hot glue. Students may add materials they bring from home.
- **Safety:** If hot glue is used, warn students not to touch the tip of the glue gun and to be careful when they handle it. They should carefully return the glue gun to the table top when finished. Students need to be careful when handling parts of the cup until the hot glue has cooled.

Day 2: ***Cup Design Round 2 Tests***

- **Group size:** 2-3
- **Setup:** Prior to day 2, make ice to chill water. You will need to chill at least 800 mL of water for each group of students (400mL for each temperature test), so make the appropriate amount of ice. Prepare design testing bins for each group that includes: 1 500-mL graduated cylinder or beaker, 1 thermometer, 1 timer or stopwatch, 1 12-inch ruler, and 1 lamp with 100-watt bulb.
- **Notes for during the lab:** Students will need access to 800-mL of cold water (400-mL for the regular light test and 400-mL for the bright light test).
- **Safety:** Warn students not to touch or handle the lamps during the bright light test. Lamp shields become very hot during the investigation and the light bulbs are also breakable. Lamps should not be removed until they have cooled completely.



Lesson 17 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will apply their energy transfer models that include energy transfer through radiation and conduction to redesign a solution for keeping a drink cold for as long as possible. Students need to account for how energy transfers through both mechanisms (radiation and conduction) to design a cup that performs well in regular and bright light.

Students now have test results from their first cup design and they have feedback from their peers and you. The purpose of this lesson is to help students use test results to make informed choices about the redesign of their cup. Encourage students to use this redesign opportunity to make iterative improvements to their design where they think a change could improve performance on any of the 5 tests.

Where We Are NOT Going

The second design cycle is not meant to give students an opportunity to try a cup design that is completely different from their first design. Instead, it is intended for students to work with their first design to modify certain design features they believe will help them better meet the criteria and constraints. If students make too drastic of changes to their cups, it will make it challenging to compare results across both design cycles.

LEARNING PLAN for LESSON 17

1 · NAVIGATION

10 min

MATERIALS: science notebook, *Cold Cup Design Challenge*, Cup Design 1, chart paper or whiteboard, markers

Examine patterns across the first set of cups. Arrange students in their design groups though most of this discussion will happen through whole group. Direct students to open their design packets to *Part 4: Evaluate your design*. Display **slide A**. Say, *In the last class period, you had a chance to consider how your first design performed on the different tests and whether it met the criteria and constraints. For the most part, you have only seen your cup and you have evaluated another group's cup. But let's see if we can find some patterns across all our cups that we think are working well.*

Look for patterns in the regular light and temperature test. Tell students we will focus on cups who met the two criteria. Ask groups to share whether their cup met the first criteria: Temperature change of less than 1°C after 12 minutes in regular light. If their cup met this criteria, have them bring it to the front of the room and line up the cups on a table top for others to see.

Ask students to discuss in their design group what pattern, if any, they notice about the cup designs. Give groups 1 minute to identify a pattern and then elicit suggestions from each group. Record students' ideas on chart paper or a whiteboard space. Record the pattern and then probe students to suggest why this pattern across the cup designs is effective.

Suggested prompt	Sample student response
What pattern do you notice about these designs?	*They all have an air layer or use air pockets.* *They use light colors or shiny materials.* *They have a couple layers.*
Why would an air layer help?	*Energy cannot transfer fast across the air.* *There are fewer particles that can collide with each other.* *If the layers aren't touching then the particles in the air are the only way to transfer energy and it happens slowly because there are only a few air particles.*
Does having more layers help?	*Only if the layers are touching completely. If solid layers touch each other then energy can transfer faster.*

Direct students to record some of these ideas in their design packet, in the last prompt under *Part 4: Evaluate your design*. They do not need to copy verbatim what you write on the chart paper or white board, but should put it in their own words.

Look for patterns in the bright light and temperature test. Repeat this same process for the second criterion. Have groups bring their cups to the front of the room if their cup met this criterion: Temperature change of less than 2°C after 12 minutes in bright light.

Ask students to discuss in their design group what pattern, if any, they notice about the cup designs. Give groups 1 minute to identify a pattern and then elicit suggestions from each group. Add students' ideas to the chart paper or a whiteboard space. Record the pattern and then probe students to suggest why this pattern across the cup designs is effective.

Suggested prompt	Sample student response
What pattern do you notice about these designs?	*They all use shiny materials or light colored materials.* *They also use air layers or air pockets.*
Why would the shiny or light-colored material help?	*Light colors and shiny materials can reflect light, so that means less light is absorbed.*
So, what if I keep these cups the same and simply painted a navy blue color into them to make them look better. How would that change things?	*If you color the outside to look nice, it could cause the cup surface to absorb more light and the drink may warm up faster.*

Direct students to record some of these ideas into their design packet, in the last prompt under *Part 4: Evaluate your design*. They do not need to copy verbatim what you write on the chart paper or whiteboard, but should put it in their own words.

If time permits, you can continue this same process for the constraints, or if time is short move onto the next activity now.

Have students place their Cup Design 1 in a designated location that they can access later if they want to examine their cup design.

2 · CLARIFY CRITERIA AND CONSTRAINTS AND TESTS TO CARRY OUT

10 min

MATERIALS: science notebook, *Cold Cup Design Challenge*

Reflect on the first design cycle to clarify any students' questions. Use this opportunity to reflect as a class on the first engineering design cycle. Ask students to think about what went well and where they can improve in terms of the process. Say, *We just completed our first engineering design cycle. A design cycle is where you plan, build and test a solution. We did that and we're about to modify our designs for a second design cycle. But first, let's think about what we need to improve upon as we do this engineering work.*✱

Customize this discussion for your students given what you observed in different classrooms during the first design cycle. This discussion could take a number of forms and **slide B** should be modified accordingly. For example, the discussion could focus on:

- clarifying what is the difference between a criterion and a constraint
- upping the challenge if all students' cup met the criteria in the first round. For example, the challenge could be to make the cheapest, most environmentally friendly cup that still meets the criteria
- prioritizing criteria and constraints if none of the cups met the criteria in the first round. For example, prioritize the regular light and temperature criterion and prioritize the diameter test constraint
- clarifying how to conduct each test carefully so that data can be compared across groups and compared to the first cup designs

Display **slide B** and facilitate a reflection discussion with students. Use the prompts on the slide to reflect upon the first design cycle and to plan for the second design cycle. Alternatively, consider using this time to add in a light sensor test if students want to measure how much reflection occurs with certain materials. See the alternate activity option below.

ALTERNATE ACTIVITY

Students may want to use light sensors to test different materials with respect to reflectivity. If so, set up a light sensor station using materials and procedures either from OpenSciEd Unit 6.1, Lesson 4 or from this unit, Lesson 8. You will need 1 lamp, 1 copy of *Light Measurement Template*, and 1 light sensor. Use this discussion time to introduce students to the light sensor station and how to use it to measure reflectivity of materials. Encourage students to measure reflectivity of materials prior to placing them on their cups. In this way, they can determine which material they want to use without wasting materials they decide not to use.

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLAINING AND DESIGNING SOLUTIONS

The focus of this discussion should be around the optimization of the performance of a design by prioritizing criteria, considering tradeoffs, and reflecting on the way the designs were tested. As engineers undertake their design challenges, they often need to rethink the process in which they are designing and evaluating solution. Use this moment to pause students to reflect on their own process and whether it still makes sense given the goal of the design challenge, and where they can improve the process, if at all, to better meet the goal.

3 · DESIGN AND BUILD CUP DESIGN 2

25 min

MATERIALS: Cup Design Round 2 Build, science notebook, *Cold Cup Design Challenge*

Preview expectations for redesigning and building the cups. Display **slide C** and have students look at *Part 5: Redesign ideas* of their design packet. Tell students that they need to make a sketch of their revised cup designs with their design group and label at least 3 features of the cup that should slow energy transfer. Once they have a cup design, they should revisit the criteria and constraints to see if they think they will likely meet them, given the design. They should note 1-2 changes they plan to make to their design, identify the test where they expect their cup to perform better, and explain how the change to their design should improve performance.

ASSESSMENT OPPORTUNITY

In *Part 5: Redesign Ideas*, students work with their design group to propose modifications to their first cup design. They must identify at least 3 design features they believe will slow energy transfer into the cup system. They are prompted to describe which feature they are modifying, where this modification will improve the cup's performance (which test), and how they believe it will help.

Look for students to share examples, such as:

- changing the outside surface material to reflect more light,
- using fewer materials to lower costs, reduce thickness, and reduce environmental impact, and
- creating more air gaps or air layers between materials to try to better use air insulation with fewer resources.

As students work with their groups, circulate around to groups to provide oral feedback to each group. At this time, use probing questions to learn about the modifications each group has decided to make, and what they expect the modification will do with respect to the tests. Make certain to provide written feedback on each group's redesign using the *Design Evaluation: Peer Feedback* modified for teacher feedback as opposed to peer feedback.

Ask students to voice any questions they have about the design process.

Then, preview your expectations for their work together in groups, and how you want students to gather materials for building their cups and cleaning up at the end of class. Once students are clear on these expectations, they can begin their redesign work in groups.

Design and build the second cup. Allow students the remainder of the class period to design and build the second cup. Circulate around the room to probe student thinking about design features they are considering changing and why they want to make a change. Monitor students as they gather and use materials. Remind students that if they waste materials, the unused materials should be added into their price check test.

If the light sensor test is added, have students take light sensor measurements prior to their build. They can record this information in *Part 6: Test 2* at the bottom of the test results page.

Save at least 5 minutes at the end of class to return supplies to their proper place. Have each group write a group name on the bottom of their cup and place their cup in a designated location.

Tell students that in the next class they will test their cups to see how their second design compares to the criteria and constraints and improves in performance to their first design.

End of day 1

4 · TEST SECOND CUP DESIGNS

30 min

MATERIALS: Cup Design Round 2 Tests, science notebook, *Cold Cup Design Challenge*

Preview instructions for the second round of testing. Arrange students in their design groups. Display **slide D** and direct students to find *Part 6: Test 2* in their design packet. Review each of the tests they will carry out and clarify any issues that came up during the first round of tests. Explain how to gather the materials they need for the investigations. Note that students may add light sensor data to the bottom of this page should they test reflectivity of their cups (either now or in the prior class period when they designed their cups).

Pass out one copy of *Regular light and temperature test*, *Bright light and temperature test*, *Environmental Impact Test*, *Price check test*, *Diameter test* to each group, unless these are pre-sorted into the group's lab bins. There is space on the *Environmental Impact Test* and *Price check test* to add materials, if necessary. If you provided other materials than what is listed on those handouts, add the materials to the handouts now, if not done prior to the first design cycle.

Remind students that they will first carry out the *Regular light and temperature test* and while they wait for the results, they will complete the *Price check test*. Once the *Regular light and temperature test* is complete, one student from each group should discard of the water while another student retrieves another 400 mL of cold water for the *Bright light and temperature test*.

Remind students that they will then carry out the *Bright light and temperature test*. While they wait for results they should complete the *Diameter test* and *Environmental Impact Test*.

SAFETY PRECAUTIONS

Remind students not to touch the lamp or lamp shield at all during this investigation. The shield can become very hot after 12 minutes. Students can leave their lamps in place to cool down at the conclusion of the investigation.

Review with students your expectations for the clean up of materials, and ask students if they have any questions before they begin.

Carry out the second round of tests. Have students begin the *Regular light and temperature test* and the *Price check test* while they wait 12 minutes for results. Circulate among the groups to help students as they calculate the costs of their cups.✱

After the first 12 minute *Regular light and temperature test*, give groups about 2 minutes to clean up and transition to the next set of tests. Explain to students where to discard their water and retrieve 400mL of cold water for the next test.

Get students started on the *Bright light and temperature test*. While they wait for results, circulate among the groups to assist students as they complete the *Diameter test* and *Environmental Impact Test*.

After 12 minutes, have students carefully turn off their lamps and return all supplies (except lamps) to the appropriate place.

✱ ATTENDING TO EQUITY

The price check test involves addition with decimals. Make calculators available to students who need the extra support or if a student uses a calculator as part of their individualized education plan.

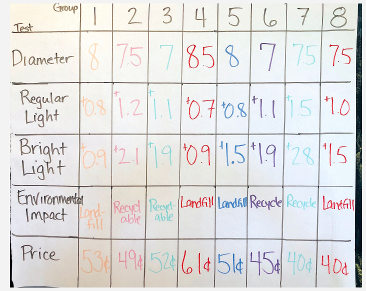
5 · ADD THE RESULTS TO A CLASS CHART

10 min

MATERIALS: science notebook, *Cold Cup Design Challenge*, Cup Design 1, Cup Design 2, Cold Cup Challenge: Class Test Results chart

Work in design groups to compare the performance of design 2 to design 1. Display **slide E** and direct students to read the top part of *Part 7: Evaluate your 2nd design.* Tell students to work with their groups for 8 minutes to evaluate their second design compared to their first design for each test. Explain that students will use this information to determine which one performed the best.

They will share the results for their best design with the class. After 8 minutes, have each group decide which cup to share, and send one group member to add their group's data to the class chart. Each group will need to share the cup too, lining the cups up with cups from other groups.



ASSESSMENT OPPORTUNITY

Students will compare test results from design cycle 1 and 2 to decide which cup design best met the criteria and constraints. They will record their ideas on *Part 7: Evaluate your 2nd design.*

Look for students to explain why certain changes to their cup helped it perform better or caused it to perform worse on the second set of tests:

- Use of too many materials in the first round caused problems with costs, environmental impacts, or thickness (diameter). Fewer materials reduce these issues.
- Use of too many materials in the first round caused problems with too much contact that helped energy to transfer. Reducing points of contact and making more air gaps slowed energy transfer.
- Use of certain colors or materials on the surface caused too much absorption of light and changing the surface color or material to reflect more light slowed down energy transfer.

If students struggle with interpreting their results and evaluating the performance of their cup, help them focus on one test result at a time. Breaking complex tasks down into discrete steps can help students who may be overwhelmed with evaluating their cup as a whole with results from multiple tests.

6 · NAVIGATION

5 min

MATERIALS: science notebook, *Cold Cup Design Challenge*

Have students share their ideas about features of the best and worst performers. Ask students to return to their regular seats with their science notebook and design packet. Display **slide F** and direct students to read the bottom half of *Part 7: Evaluate your 2nd design.* Say, *We have a lot of test results from each group and it's going to take more discussion to decide which of these met the criteria and constraints the best. We will have that discussion in the next class. First, I want to give you a chance to examine the results on your own and to share some ideas you have if your were going to redesign a 3rd cup on your own.*

Tell students to take 1-2 minutes to quietly examine the class data chart and the best performing cups. Then direct students to complete the bottom half of *Part 7: Evaluate your 2nd design* on their own. Use students' ideas to help you craft the Consensus Discussion you will facilitate in the final lesson. Ask students leave their science notebooks and design packets in the classroom for you to examine before the final lesson.

ASSESSMENT OPPORTUNITY

Collect students design packets and examine their ideas on *Part 7: Evaluate your 2nd design.* Focus on the bottom half of the page where students wrote individual explanations to justify their ideas for a 3rd design. Write feedback to each student on their design ideas. Students can incorporate feedback from you in the very next lesson as they propose a new design in *Part 8* of their design packet.

LESSON 18: How can containers keep stuff from warming up or cooling down?

PREVIOUS LESSON *We reviewed our test results and feedback on our first cup design. We used the information to redesign, build, and test a 2nd cup design, and modified the features to slow energy transfer even more. We added our test results from the second round of tests to a class chart and made observations from the chart looking for patterns in design features that seemed to slow energy transfer the most.*

THIS LESSON

PUTTING PIECES TOGETHER

3 days

We review test results across our best cup designs and discuss how certain cups slow energy transfer. We work individually to redesign the cup and offer suggestions during a Consensus Discussion where we develop a design for the Ultimate Cold Cup together. We then generalize our model to explain patterns in the way to minimize or maximize energy transfer. We use our model to predict how energy transfer could be maximized or minimized in a variety of examples that we bring from home. We demonstrate our understanding by individually taking an assessment. Finally, we revisit the Driving Question Board and discuss all of the questions that we have answered and reflect upon our experiences in the unit.

NEXT LESSON *There is no next lesson.*

BUILDING TOWARD NGSS

MS-PS1-4, MS-PS3-3, MS-PS3-4, MS-PS3-5, MS-PS4-2, MS-ETS1-4

WHAT STUDENTS WILL DO

Develop a model based on patterns in performance that can be used to predict ways to minimize or maximize energy transfer into or out of a variety of systems.

Evaluate a design solution for a disaster blanket that includes several design features (structure) to minimize energy transfer (function) that could result in body heat loss.

WHAT STUDENTS WILL FIGURE OUT

- The rate of energy transfer between two substances speeds up or slows down depending on the number of particle collisions.
- The rate of energy transfer between a substance and light speeds up or slows down depending on how much light is absorbed by the substance.
- The amount of matter in a substance affects the rate of energy transfer and how much energy is needed to increase the substance's temperature.

Lesson 18 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Have students turn and talk with a partner to identify patterns they see in the Cold Cup Challenge class data.	A	Cold Cup Challenge Class Data chart, each group's best performing cup
2	10 min	**ANALYSIS OF COLD CUP CHALLENGE DATA** Ask students to identify which cup they believe performed the best and to give their rationale for their choice. Tally up students' votes to select 2-3 high performing cups to consider further.	B	Cold Cup Challenge Class Data chart, each group's best performing cup
3	20 min	**REDESIGN THE ULTIMATE COLD CUP AND UPDATE PROGRESS TRACKER** Give students time to work on their own to propose a redesign to the Cold Cup. Then, ask students to gather in a Scientists Circle to engage in a Consensus Discussion to create a generalized consensus model for maximizing and minimizing energy transfer.	C	*Cold Cup Design Challenge*, chart paper or whiteboard, markers
4	8 min	**MODIFY THE MODEL TO MAXIMIZE ENERGY TRANSFER** Have students consider how they would model ways to maximize energy transfer between systems.	D	chart paper or whiteboard, markers
5	2 min	**ASSIGN HOME LEARNING** Assign students home learning to identify a device or object at home for which they want to slow down or speed up energy transfer.	E	
				End of day 1
6	17 min	**APPLY MODELS TO EXPLAIN RELATED PHENOMENA** Have students work in small groups to test models on related phenomena. Then bring students together for a final Consensus Discussion to develop a generalized model for energy transfer.	F	chart paper or whiteboard, markers
7	25 min	**DEMONSTRATE UNDERSTANDING ON AN ASSESSMENT TASK** Students individually demonstrate understanding on an assessment to evaluate design solutions for disaster relief blankets.	G	*Disaster Blanket Design Assessment*
8	3 min	**NAVIGATION AND HOME LEARNING** Assign students home learning to review and annotate the questions for the Driving Question Board, which they will revisit in the next class period.	H	*Let's Answer Questions from Our Driving Question Board!*
				End of day 2
9	5 min	**NAVIGATION** Prepare to gather around the DQB by having students share with a partner which questions they've marked from their home learning. Then students place sticky dots on the questions that they think we have made progress on and move into their Scientists Circle.	I	*Let's Answer Questions from Our Driving Question Board!*
10	25 min	**REVISIT OUR DRIVING QUESTION BOARD (DQB)** Students revisit the DQB and take stock of all the questions we've now answered with the whole class.	J	*Let's Answer Questions from Our Driving Question Board!*, Driving Question Board, 3 colors of sticky dots
11	15 min	**QUICK WRITE: REFLECT ON OUR EXPERIENCES** Students discuss what was challenging and rewarding about this unit and complete a quick write about their learning experience.	K	
				End of day 3

Lesson 18 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Cold Cup Design Challenge* • *Disaster Blanket Design Assessment* • *Let's Answer Questions from Our Driving Question Board!*		• Cold Cup Challenge Class Data chart • each group's best performing cup • chart paper or whiteboard • markers • Driving Question Board • 3 colors of sticky dots

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

On day 1, have the Cold Cup Challenge Class Data chart posted near the front of the room for analysis.

Before day 2, type up or take a high resolution photograph of all the questions on the DQB and modify handout, *Let's Answer Questions from Our Driving Question Board!*, with these questions. If you take a photograph, insert the photograph in place of the table. Add as many rows as needed to the table.

Display all previous classroom consensus models around the room.

Make sure the Driving Question Board is displayed.

Lesson 18 • Where We Are Going and NOT Going

Where We Are Going

This lesson provides a final opportunity for students to explain how energy transfers into and out of systems that result in a temperature change to the systems. Students will explain these transfers mostly in terms of conduction but also in terms of radiation. This lesson also highlights that the energy transfer model that students have developed in the context of the cup designs is applicable, with slight modifications, to many other systems.

Where We Are NOT Going

This unit does not include energy transfer via convection, as that will become an important focus in OpenSciEd Unit 6.3 on Water Cycling, Weather, and Climate. Students have also developed limited understanding of how the amount and type of matter affects energy transfer in the context of the cup systems; though, these same concepts will become a focus in Unit 6.3 as well when students learn about uneven heating of land and water across time.

LEARNING PLAN for LESSON 18

1 · NAVIGATION

5 min

MATERIALS: Cold Cup Challenge Class Data chart, each group's best performing cup

Preliminary analysis of Cold Cup Challenge class data. Display **slide A** and direct students' attention to the class data chart that is prominently displayed for the class. Make certain that the corresponding cup designs are also on display near the class data chart and in the same order as the data. Prompt students to discuss the data with a shoulder partner, looking for patterns in cups that performed well on both criteria.

After two minutes, have students return to a whole-class discussion. Elicit 3-4 ideas from them for what they observed. Students may note the following:

- cups that performed well in bright light also performed well in regular light,
- cups that performed well in bright light used reflective or light colored materials, and
- cups that performed well in regular light used air layers or materials with air pockets.

2 · ANALYSIS OF COLD CUP CHALLENGE DATA

10 min

MATERIALS: Cold Cup Challenge Class Data chart, each group's best performing cup

Identify the best performing cups. Display **slide B**. Prompt students to consider all the criteria and constraints. Then ask them, *If you had to select only one cup to build to sell to other people, which cup would you choose and why?*

Give students a minute to turn and talk to a shoulder partner. Then bring students back to share their thoughts. Ask each partner group to share their choice(s). Keep a tally as students share. After tallying the choice, probe students to explain how they made their choice and whether they were prioritizing a criterion or constraint over another when they made their choice.

At the end add up the tallies to see which cup designs had the most "votes." Place 2-3 designs with the most votes at the front of the room. Tell students, *Let's see if we can identify what makes these cups so effective. Maybe if we find certain features on one cup, we can combine them with features from the other cups and then design an even better cup using ideas from all of them.*

3 · REDESIGN THE ULTIMATE COLD CUP AND UPDATE PROGRESS TRACKER

20 min

MATERIALS: science notebook, *Cold Cup Design Challenge*, chart paper or whiteboard, markers

Redesign the Ultimate Cold Cup using features from the best performing cups. Keep the 2-3 best performing cups on display. Direct students to their design packet, *Part 8: The best performing design features.* Display **slide C**. Give students time to quietly work on a third cup design using what they have learned from looking at other cups. This should take about 5 minutes.

ASSESSMENT OPPORTUNITY	Collect students' design packets after today's class. Use *Part 8: The best performing design features* to formatively assess each student's progress on supporting design decisions with scientific principles. While the goal is to work toward a consensus design as a class, this section of the design packet provides an artifact of students' individual work and a glimpse at their current thinking.

Gather in a Scientists Circle to create the Ultimate Cold Cup. Ask students to gather in a Scientists Circle, bringing their science notebooks and design packets with them. Students should gather near the class data chart and corresponding cup designs.

✱ STRATEGIES FOR THIS CONSENSUS DISCUSSION

- It is important that, as you write the ideas that are suggested on chart paper or a white board, you ask everyone to weigh in on each proposed idea—e.g., they should consider if they had a similar idea.
- It is also important for students to work on restating and re-phrasing the ideas that you write down and to make sure each idea captures

Facilitate a Consensus Discussion about features to include in the Ultimate Cold Cup. Ask students to offer up features they believe to be highly effective in slowing energy transfer. As each student offers up an idea, write the idea on a whiteboard or chart paper. Ask if other students had a similar idea and keep a tally of students who shared similar features in their design.✱ Continue adding design ideas until all ideas are shared. Have students look at the tally for the different features shared to see which features were most common across students' third design plans. These features may include:

- a lid
- reflective or light-colored exterior
- air layers or air pockets
- thick, foam material

KEY IDEAS

Purpose of the discussion: to come to consensus on key design features and the scientific principles that support them in the design of a cup. This represents students' conclusions to the anchoring phenomenon.

Listen for students to suggest design features, such as:

- a lid
- reflective or light-colored exterior
- air layers or air pockets
- thick, foam material

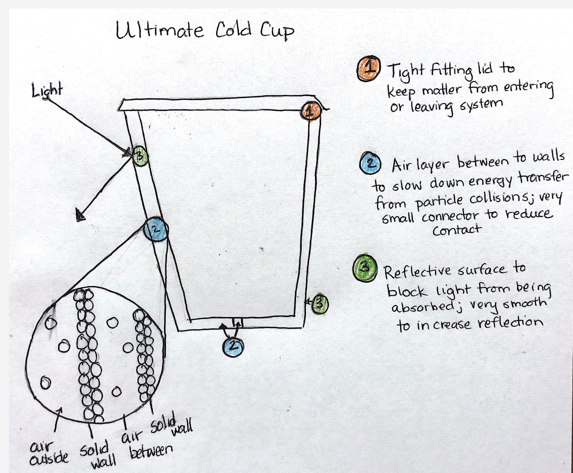
Listen for students to support these design features with scientific principles, such as:

- The energy transfer between two substances slows down depending on the number of particle collisions.
- The energy transfer between a substance and light slows down depending on how much light is absorbed by the substance.

Emphasize in this moment that students figured out something really important that can help them slow down energy transfer in a lot of situations. Next, students will broaden beyond the cup system and slowing energy transfer to explain other contexts in which energy is moving between substances or systems.

Transition to a design for the Ultimate Cold Cup. Work with students to create a visual representation using the top 3-4 features offered by the class. Record this representation on chart paper. As the class agrees on a design features, such as a material or other structural feature, ask students to explain exactly how it would function in the cup system. When the class has an agreed-upon design, take a moment to celebrate their work.

Post the Ultimate Cold Cup design near the class's initial model from Lesson 1.



what everyone thinks are the essential pieces of the design feature. Revise the ideas as students make suggestions that others in class agree with to help clarify the proposed design feature.

- Do not have students write these features down at this time. Have them work on listening and linking to the ideas that other people share.

4 · MODIFY THE MODEL TO MAXIMIZE ENERGY TRANSFER

8 min

MATERIALS: science notebook, chart paper or whiteboard, markers

Use the model ideas for slowing energy transfer to develop a model for speeding up energy transfer. Stay in a Scientists Circle. Display **slide D**. Tell students to imagine a new situation (other than a cup) in which they want to speed up energy transfer between systems. On chart paper or a whiteboard, draw 2 generic square boxes. The top box represents a system designed to slow energy transfer, while the bottom box represents a system designed to speed up energy transfer. Have students make a copy of this diagram in their notebook and title the page, "Energy Transfer Models."

Give students 3 minutes to work with a partner to identify and represent 2-3 things they know slows energy transfer in the top box. Then, have students use another 3 minutes to identify and represent how to speed up energy transfer on the bottom box. Students can include their ideas in drawings, symbols, or writing.

ASSESSMENT OPPORTUNITY

Circulate around the room as students construct their generalized models. Use the following question prompts to help students in their thinking:

- What type of matter is the object made of, and does this facilitate particle collisions?
- How much matter (thickness) does the energy need to transfer through to get into or out of the system?
- How reflective, transmissive, or absorptive is the material?
- How much matter is needed to stay warm or cold? Or how much matter do we need to warm up or cool down?

5 · ASSIGN HOME LEARNING

2 min

MATERIALS: None

Assign students a home learning assignment. Display **slide E**. Say, *We've just begun to explore how our model would change if we wanted to speed up energy transfer. We're going to continue with this in the next class, but for us to make sure our model can explain a lot of phenomena, I want you to go home tonight and identify one object, device, or situation for which you would want to slow down or speed up energy transfer. We'll use these to test our models in the next class.*

If students need help, revisit the related phenomena poster from Lesson 1 to get ideas about which devices on the list could have features that maximize energy transfer.

End of day 1

6 · APPLY MODELS TO EXPLAIN RELATED PHENOMENA

17 min

MATERIALS: science notebook, chart paper or whiteboard, markers

Facilitate small-group work to explain related phenomena. Display **slide F**. Arrange students in groups of 3 to share their related phenomena. Then, tell students to locate in their science notebooks their "Energy Transfer Models." Groups will have 5 minutes to share and discuss their related phenomena. As students share, they need to decide (1) if it is a situation in which we want to slow down or speed up energy transfer and (2) whether their model accounts for how it works. Encourage students to edit their models should they realize their models are incomplete.✱

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Brings students together for a final Consensus Discussion on energy transfer. Return to the two boxes drawn on the previous day (either on chart paper or a whiteboard). The box on top should represent a generic system in which we want to slow down energy transfer. The box on the bottom should represent a generic system in which we want to speed up energy transfer.

KEY IDEAS

Purpose of this discussion: to develop an agreed-upon generalized model that can help students explain how multiple devices, objects, and situations work to speed up or slow down energy transfer.

Listen for key ideas that relate to the following science principles.

As students share, help them to extrapolate key underlying ideas that apply across situations and devices:

- The rate of energy transfer between two substances speeds up or slows down depending on the number of particle collisions.
- The rate of energy transfer between a substance and light speeds up or slows down depending on how much light is absorbed by the substance.

Depending on students' related phenomenon, another important idea that may emerge from students' sharing of their models includes:

- The amount of matter in a substance affects the rate of energy transfer and how much energy is needed to increase the substance's temperature.

Elicit 2-3 examples from the class of systems for which we want to slow energy transfer. You will not have time to elicit all examples from your students. Focus on creating a more generalized consensus model for slowing down energy transfer that could apply to systems beyond the cup:

- Reduce contact and thus, the opportunity for particle collisions.
- Make something multi-layered so that there are more particles for energy to pass through.
- Reduce absorption of light.

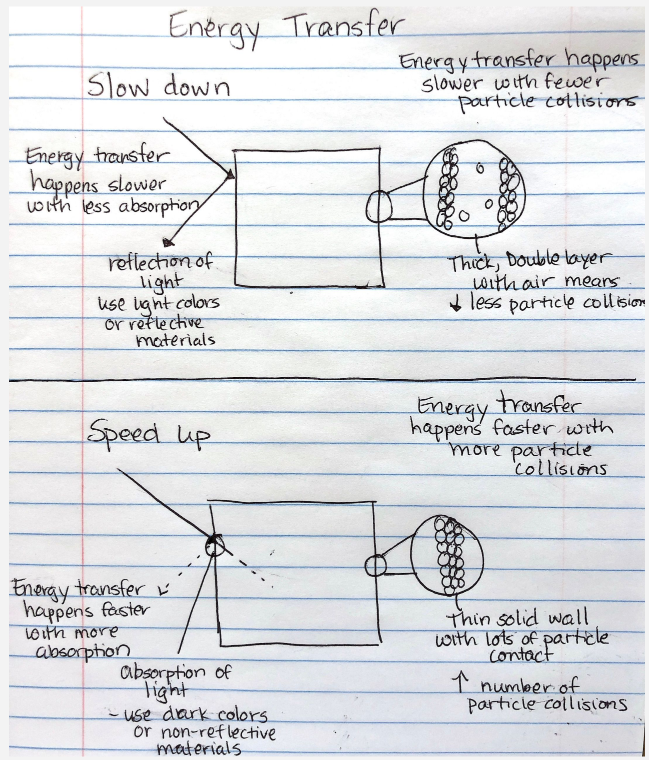
Using these science ideas, develop a general model that explains how the 2-3 systems work to slow energy transfer.

Then elicit 2-3 examples from the class of systems for which we want to speed up energy transfer. Create a generalized model for speeding up energy transfer that could apply to these systems:

- Increase contact with solids to increase the number of particle collisions.
- Make something thin so that there are fewer particles for energy to pass through.
- Increase absorption from light.

Using these science ideas, develop a general model that explains how the 2-3 systems work to slow energy transfer.

Celebrate the fact that their models can be used to explain a lot of their experiences in life and encourage students to test these models at home when they encounter new situations in which they know energy is transferring between systems.



The focus of this activity is to give students the opportunity to apply their models to explain multiple phenomena. While most of the model and explanation development in this unit has been centered on an anchoring phenomenon of the cups, the model ideas students have developed are applicable to a wide variety of phenomena. Use this opportunity to create an explicit conversation about generalizing their models to account for a class of phenomena.

ALTERNATE ACTIVITY

This phenomena space is still rich with possibilities and students may have unanswered questions about energy transfer. If time permits, consider follow-up investigations to further cement scientific principles about energy transfer for your students. These suggestions can also be used if your students move quickly through the previous content.

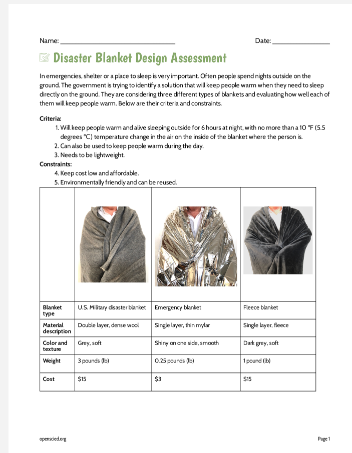
- Test the best performing design cups to see if they work equally well with hot water. Note that evaporative cooling becomes more of a factor with keeping drinks hot, thus the need to modify the model to emphasize this mechanism.
- Change the amount of water in the cup to see how this affects the amount of energy needed to change the water's temperature.
- Design a device to maximize energy transfer into water and then see if this device works equally well if you change the amount of water or change from water to sand.

7 · DEMONSTRATE UNDERSTANDING ON AN ASSESSMENT TASK

25 min

MATERIALS: *Disaster Blanket Design Assessment*

Administer *Disaster Blanket Design Assessment* individually to students. Have students return to their regular seats and prepare for the assessment. Pass out one copy of the assessment to each student. Display **slide G** if students want to see larger images of the three blankets under consideration. This assessment will take students the remainder of the class period to complete. Once completed, students should turn in their assessment to you for feedback.



Name: ______________ Date: ______________

Disaster Blanket Design Assessment

In emergencies, shelter or a place to sleep is very important. Often people spend nights outside on the ground. The government is trying to identify a solution that will keep people warm when they need to sleep directly on the ground. They are considering three different types of blankets and evaluating how well each of them will keep people warm. Below are their criteria and constraints.

Criteria:

1. Will keep people warm and alive sleeping outside for 6 hours at night, with no more than a 10 °F (5.5 degrees °C) temperature change in the air on the inside of the blanket where the person is.
2. Can also be used to keep people warm during the day.
3. Needs to be lightweight.

Constraints:

4. Keep cost low and affordable.
5. Environmentally friendly and can be reused.

Blanket type	U.S. Military disaster blanket	Emergency blanket	Fleece blanket
Material description	Double layer, dense wool	Single layer, thin mylar	Single layer, fleece
Color and texture	Grey, soft	Shiny on one side, smooth	Dark grey, soft
Weight	3 pounds (lb)	0.25 pounds (lb)	1 pound (lb)
Cost	$15	$3	$15

openscied.org Page 1

ASSESSMENT OPPORTUNITY

This lesson includes a transfer task to give students an opportunity to use the 3 dimensions to make sense of a different phenomenon. This is meant to be a summative assessment task for the unit, and it gives you a grading opportunity. The task includes a teacher reference, *Reference for Disaster Blanket Design Assessment*, with a scoring guide. Scoring guides are meant to highlight important ideas that students should be including in their responses. If students share these ideas elsewhere in the assessment, it is up to you to decide if that understanding is sufficiently demonstrated.

Student responses will vary because the task is designed as a structured engineering design challenge; however, students must use science ideas and information from the task to support their responses.

8 · NAVIGATION AND HOME LEARNING

3 min

MATERIALS: science notebook, *Let's Answer Questions from Our Driving Question Board!*

Say, We've figured out so much! I bet we can answer many of our questions on the Driving Question Board.

Assign reviewing the DQB questions for home learning. Present **slide H**. Tell students that they will revisit their Driving Question Board and celebrate all that they have figured out in the next class. Hand out a copy of *Let's Answer Questions from Our Driving Question Board!*, which you created to contain all of the student questions from the DQB, and have students tape it into their science notebooks.

Have students evaluate which questions the class has answered from the DQB for home learning. Have students mark questions that they think the class has answered by putting different symbols next to each question:

- We did not answer this question or any parts of it yet: **?**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓✓

End of day 2

9 · NAVIGATION

5 min

MATERIALS: science notebook, *Let's Answer Questions from Our Driving Question Board!*

Have students work in pairs to evaluate which questions the class has answered from the DQB.✱ Project **slide I**. Ask students to take out their home learning, *Let's Answer Questions from Our Driving Question Board!*, which you created to contain all of the student questions from the DQB, and have students tape it into their science notebook. Have students work with a shoulder partner to compare which questions they marked to indicate what they think the class has answered:

- We did not answer this question or any parts of it yet: **?**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓✓

✱ ATTENDING TO EQUITY

Revisiting the Driving Question Board is important for students to feel as though their questions are valued and recognized. While not all questions will have been addressed (it's more likely that 50–75 percent will be at least partially answered), this helps students see the hard work that they have done to answer many of their own questions.

10 · REVISIT OUR DRIVING QUESTION BOARD (DQB)

25 min

MATERIALS: science notebook, *Let's Answer Questions from Our Driving Question Board!*, Driving Question Board, 3 colors of sticky dots

Mark patterns in questions answered using the sticky dots. Have students move into their Scientists Circle, bringing with them their science notebooks and *Let's Answer Questions from Our Driving Question Board!* . Once in the Scientists Circle, students will focus the discussion on the questions they agree we can answer, answer parts of the question, or not answer at all. Choose one color of sticky dots to mark each of these categories.

Discuss the questions the class can now answer.✱ Present **slide J** if needed. Have the class discuss the answers to those questions as a group. If you have space, you might make a "Take Aways" board that has a record of the answers with which the class comes up.

ASSESSMENT OPPORTUNITY While students are answering questions from the Driving Question Board, this is an excellent formative assessment opportunity to address partial understandings and see if any pieces need to be revisited.

Celebrate the class's accomplishments.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering questions that are important to them at the onset of the unit. Students were tasked with asking questions "that required sufficient and appropriate evidence to answer." Through the investigations in the unit and individual and whole-group sensemaking, they can now answer many of the questions. This final visit to the DQB also allows students to see how their hard work toward a shared learning goal helps them figure out the phenomenon and can also explain a lot of other phenomena in the world.

11 · QUICK WRITE: REFLECT ON OUR EXPERIENCES

15 min

MATERIALS: science notebook

Have students reflect upon their experiences with the unit. Have students return to their regular seats. Prompt students to find a new page in their science notebook and title the page: "Reflection." Display **slide K**. Give students about 5 minutes to write a personal reflection on their learning based on the following prompts:

- What was most challenging in this unit?
- What was most rewarding?
- Think about how you engaged in sensemaking discussions with classmates. How would you want to engage with those experiences the next time you are part of a classroom community that is working to try to figure out answers to the questions the class formed together, by investigating different sources of data and phenomena?
    - What would you do the same?
    - What would you do differently?

Then bring students together in a whole-group discussion to share one part of their reflection on the unit.

ADDITIONAL GUIDANCE This unit asks students to do meaning-making that is difficult, but potentially rewarding. Taking time to reflect upon the process of this unit can allow students to think about what works well for them as learners. Consider giving more time to answer these questions if needed.

Lesson-Specific Teacher Materials

Name: ______________________ Date: ______________

Lesson 18: Teacher Reference

Reference for Disaster Blanket Design Assessment

In emergencies, shelter or a place to sleep is very important. Often people spend nights outside on the ground. The government is trying to identify a solution that will keep people warm when they need to sleep directly on the ground. They are considering three different types of blankets and evaluating how well each of them will keep people warm. Below are their criteria and constraints.

Criteria:

1. Will keep people warm and alive sleeping outside for 6 hours at night, with no more than a 10 °F (5.5 degrees °C) temperature change in the air on the inside of the blanket where the person is.
2. Can also be used to keep people warm during the day.
3. Needs to be lightweight.

Constraints:

4. Keep cost low and affordable.
5. Environmentally friendly and can be reused.

			
Blanket type	U.S. Military disaster blanket	Emergency blanket	Fleece blanket
Material description	Double layer, dense wool	Single layer, thin mylar	Single layer, fleece
Color and texture	Grey, soft	Shiny on one side, smooth	Dark grey, soft
Weight	3 pounds (lb)	0.25 pounds (lb)	1 pound (lb)
Cost	$15	$3	$15

Additional Data to Consider:

Average nightly conditions in September on the East Coast Average High: 84°F (29°C) Average Low: 64°F (18°C) Dry without rain	**Human Body Temperature** 98.6°F (37°C)

Results of Initial Tests:

Blanket	Density Test (amount of matter)	Daytime core body temperature test (2 hours)	Nighttime core body temperature test (2 hours)	Environmental Impact Test

U.S. Military Wool Blanket	Double layer, thick, somewhat porous	Δ temp: -0.5 °C	Δ temp: -3.5 °C	Reusable, not washable
Emergency Blanket	Single layer, thin, not porous	Δ temp: -1.5°C	Δ temp: -2.8 °C	Reusable, then landfill
Black Fleece Blanket	Single layer, very porous	Δ temp: -2.5°C	Δ temp: -8.5 °C	Reusable, washable

1. Why is the government so concerned about people getting too cold if they sleep directly on the ground?
+1 People have a higher body temperature than the ground.
+1 When a person is in direct contact with the ground, energy transfers from the person to the ground.
+1 The person is relatively small in comparison to Earth; therefore, the ground will remain cold, and the person will also be cold with no way to regain the heat energy.

2. Use the information and data from the tests to make a recommendation for which blanket the government should choose. In your response include scientific reasoning to support your recommendation.

Choice: ___________________________________

Reasoning: Explain using scientific principles and connect the test results to the criteria and constraints.

Student responses can vary; however, well argued responses should include:
+1 Consideration of each of the criteria and constraints.
+1 Use of the scientific idea that the rate of energy transfer in the system is related to the material of the blanket to support their recommendation.

- Type of matter—for example, the shiny emergency blanket is not porous, and the data shows a 2.8°C core body temperature change in 2 hours at night. The nonporous material of the blanket slows energy transfer because the air particles will not hit other air particles within the blanket.
- Amount of matter—for example, wool is the thickest of the blanket options, and the data shows a 3.5°C core body temperature change in 2 hours at night. The amount of wool material means that the energy transfer from the person will slow because the amount of energy needed from the person to increase the temperature on the ground is more as the energy moves through the wool.
- How light interacts with matter—for example, the emergency blanket may reflect light, while the dark-colored wool and fleece may absorb light, transferring energy into the person during the daytime hours. This seems to be partly supported by the data, since the fleece blanket performed slightly worse during the daytime test, but a lot worse at night.

+1 A counterclaim or consideration of another solution with evidence to support why the solution was not chosen.

3. In many environments, the temperature of the ground and the air right above the ground are both very similar in the middle of the night. Engineers have proposed developing a portable pop-up hammock that would allow people to sleep suspended in the air above the ground in emergencies. It will take time and money to develop a really lightweight, easy to collapse, low cost design. Before they invest the resources to do this, explain whether what you learned about energy transfer makes this an idea worth pursuing. Would suspending a person in a hammock, wrapped in one of the blankets you chose above, decrease the amount of temperature change compared to sleeping directly on the ground with one of these blankets? Explain.

+1 Yes, suspending a person in a hammock would decrease the amount of temperature change compared to sleeping on the ground.
+1 This occurs because with the hammock there is space/air between the person and the ground, so energy must transfer from the person to the air. Some energy will transfer to the ground, and some will move throughout the air.
+1 Particles in the air are moving quickly (gas) and are less dense/compact than on the ground (solid), so there will be a smaller chance of particle collisions and, therefore, a lower rate of energy transfer than with a person directly on the ground.