UNIT STORYLINE

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

How students will engage with each of the phenomena

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

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

LESSON 1

3 days

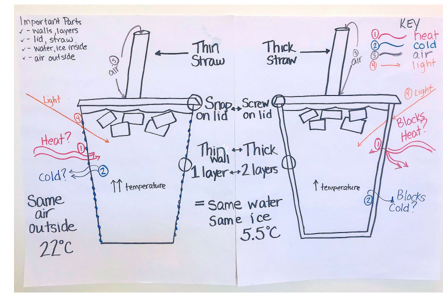
Why does the temperature of the liquid in some cup systems change more than in others?

Anchoring Phenomenon

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

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.



⇓ **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.

LESSON 2

2 days

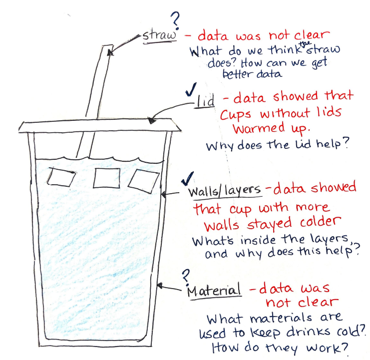
What cup features seem most important for keeping a drink cold?

Investigation

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

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.



⇓ **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.

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<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>
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LESSON 3

2 days

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

Investigation

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

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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.

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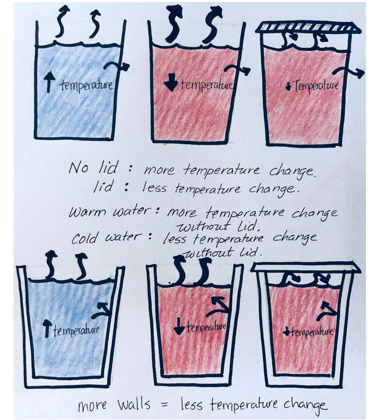

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⇓ **Navigation to Next Lesson:** We saw that one clear difference in the results was apparent when the hot liquid was in containers without lids. We have some initial ideas about why lids matter for hot liquids. We want to test a lid versus no lid (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.

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LESSON 4

3 days

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

Investigation

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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.

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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.

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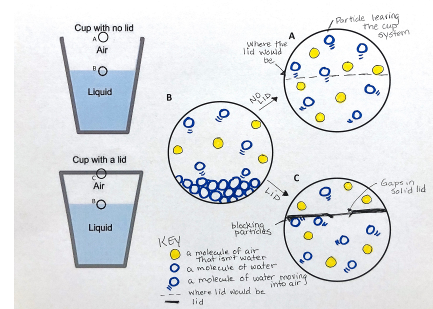

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Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

⇓ **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 5

1 day

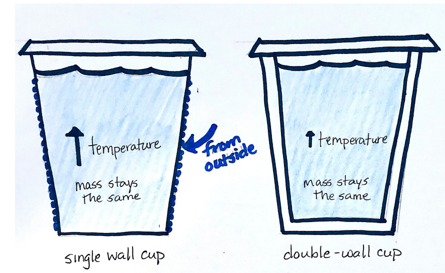
Where does the water on the outside of the cold cup system come from?

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.



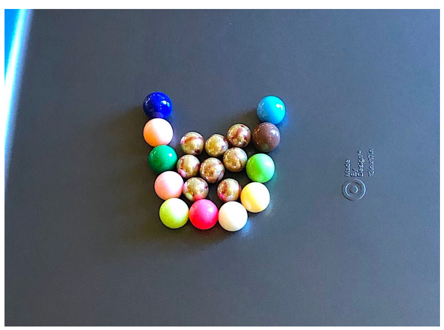
⇓ **Navigation to Next Lesson:** In this lesson, we figured out that matter cannot go through the walls of the cup. When we have a lid, the cup system is mostly closed but not completely closed. We are wondering if a liquid warms up or cools down over time in a completely closed system.

LESSON 6

2 days

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

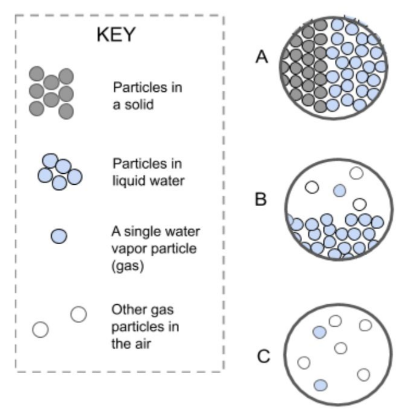
Putting Pieces Together



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.



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

⇓ **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 7

1 day

If matter cannot enter or exit a closed system, how does a liquid in the system change temperature?

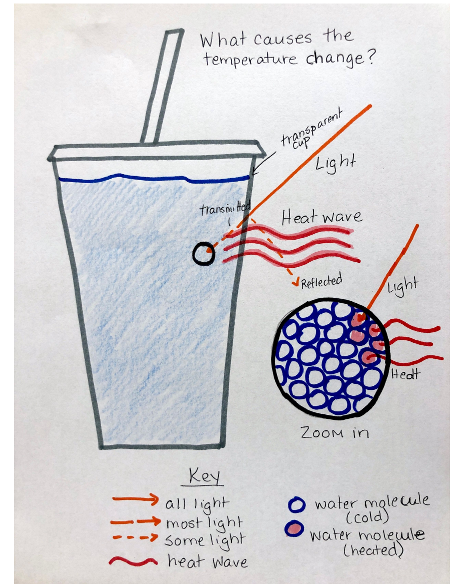
Problematizing

Other possible interactions could cause a temperature change in the liquid inside the closed cup system.

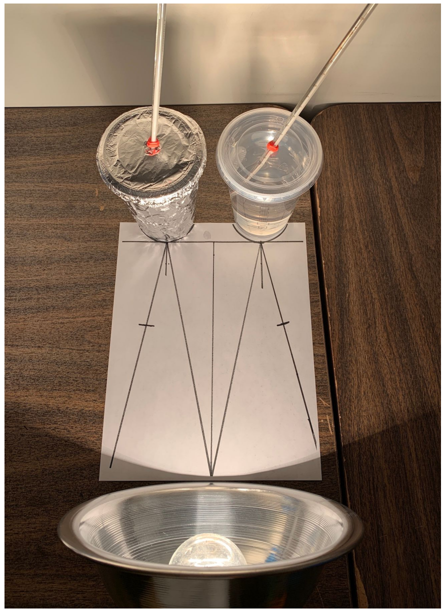
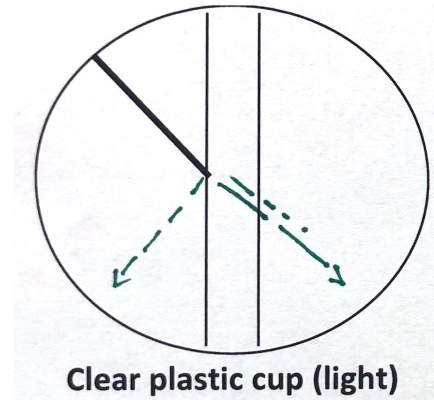
We consider what we know about the components (or structures) of the closed cup system, how they function, and how they interact with one another and with other objects and substances outside of the cup system to determine what else might a temperature change in the liquid inside. We develop models to 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.

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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

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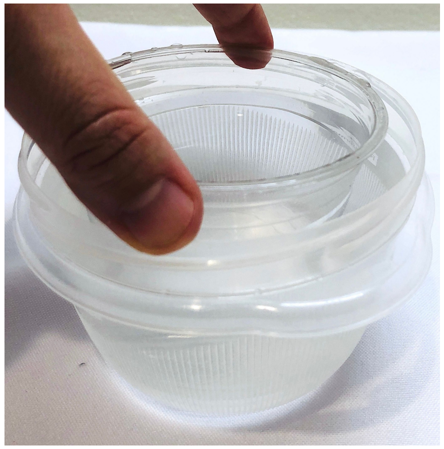

The temperature increases and decreases inside a cup system are correlated with temperature decreases and increases outside the cup system.

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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.

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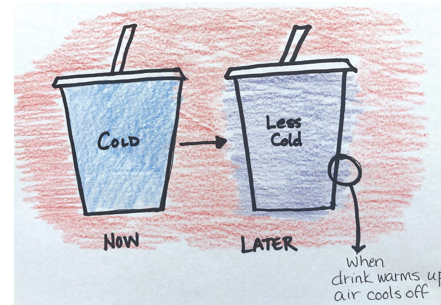

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⇓ **Navigation to Next Lesson:** We gathered evidence that heat and cold can move through the cup wall to change the temperature of water inside and outside the cup. If the temperature difference between the inside and outside is great, more heat or 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.

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LESSON 10

2 days

What is the difference between a hot and a cold liquid?

Investigation

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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.

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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.

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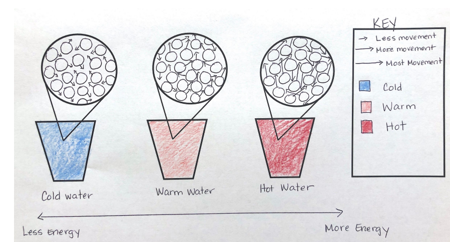

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<tr><td colspan="4">⇓ Navigation to Next Lesson: In this lesson we reviewed that a liquid is made of particles and figure out that the particles move more when the liquid is hotter and less when the liquid is colder. Since we also know that liquids such as water may change temperature over time, we now wonder how and why particle movement changes over time.</td></tr>
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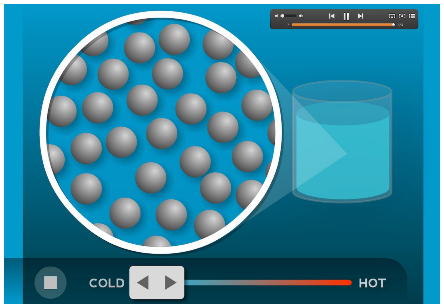
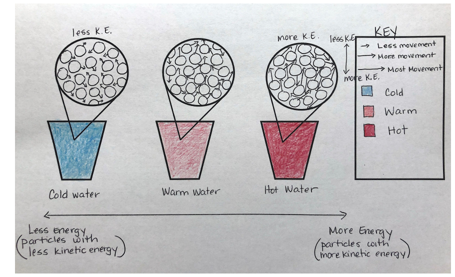
<td>LESSON 11
1 day
Why do particles move more in hot liquids?
Investigation</td>
<td>
A simulation shows that particles move slower when a liquid is cold and faster when a liquid is hot.</td>
<td>We wonder what happened in the Food Coloring Lab at the particle scale and how this relates to energy. We 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.</td>
<td></td>
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<tr><td colspan="4">⇓ 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?</td></tr>
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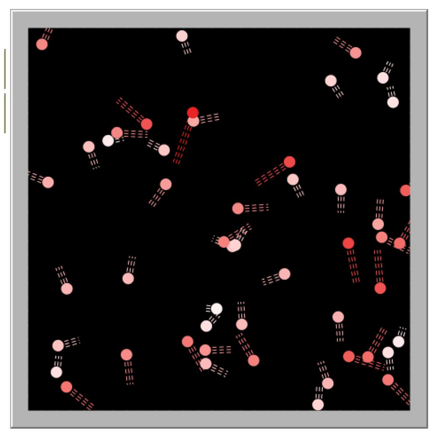
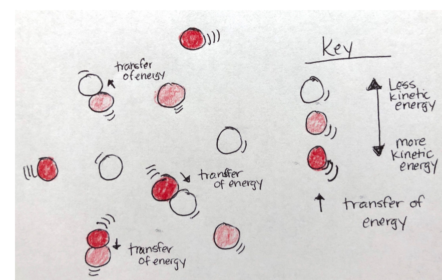
<td>LESSON 12
2 days
How does the motion of particles compare in a sample of matter at a given temperature?
Investigation</td>
<td>
When particles collide, they transfer their kinetic energy to each other, and in a sample of matter at the same temperature, the particles have different speeds.</td>
<td>We 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.</td>
<td></td>
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Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

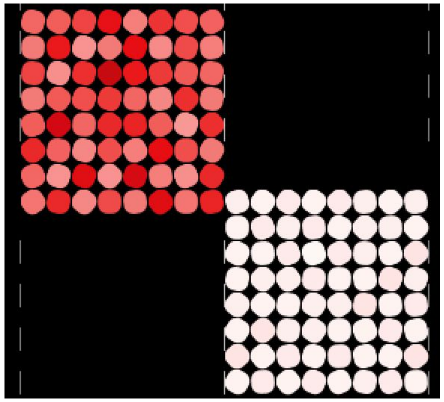
⇓ **Navigation to Next Lesson:** In this lesson, we focus on interactions between the particles in a gas using an online interactive simulation. Next we will investigate how the motion of the particles of the matter on one side of the cup's wall affects the motion of the particles on the other side of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

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



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.

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.

⇓ **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.

LESSON 14

3 days

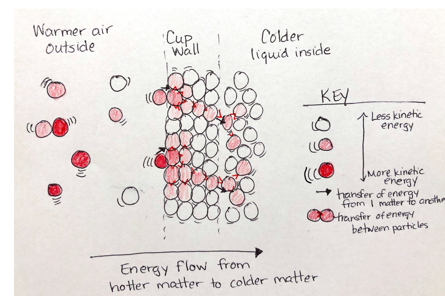
Does our evidence support that cold is leaving the system or that heat is entering the system?

Investigation, Putting Pieces Together

Butter melts when a candle is lit on one side of a strip of aluminum foil.

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.



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

⇓ **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.

LESSON 15

3 days

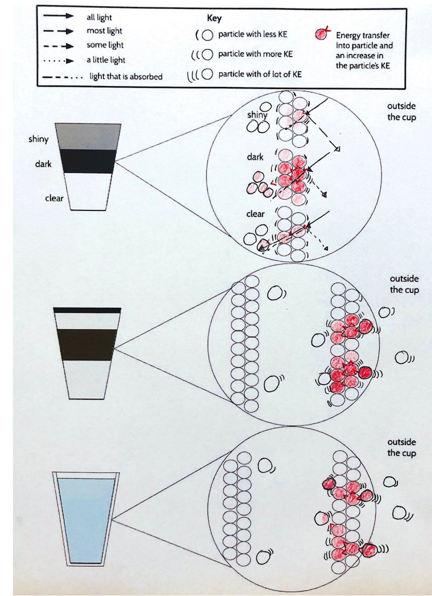
How do certain design features slow down the transfer of energy into a cup?

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 16

2 days

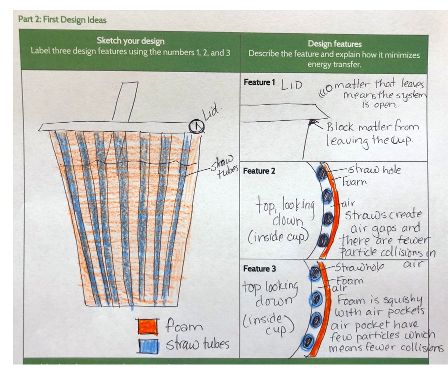
How can we design a cup system to slow energy transfer into the liquid inside it?

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.



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

⇓ **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 17

2 days

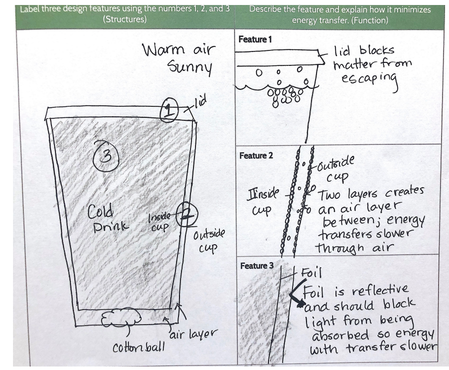
How can we improve our first design to slow energy transfer into the cup system even more?

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

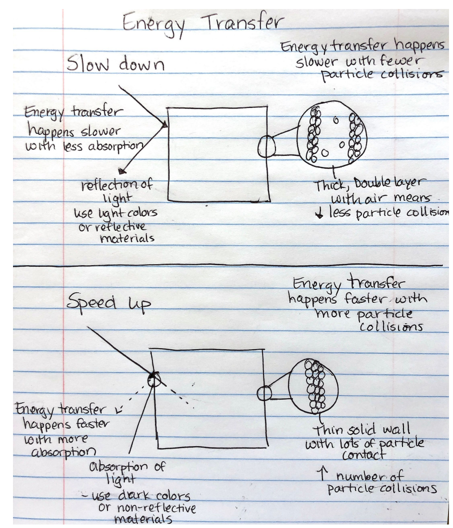
How can containers keep stuff from warming up or cooling down?

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