Creating Science – Heat and Insulation

What is heat? How does it travel? And how do we stop it from moving?

#CreatingScienceInsulatedHouses

Suggested outcomes

(This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Science content Physical sciences - Heat can be produced in many ways and can move from one object to another (ACSSU049).
- Chemical sciences - A change of state between solid and liquid can be caused by adding or removing heat (ACSSU046).

Science inquiry skills

- With guidance, pose clarifying questions and make predictions about scientific investigations (ACSIS231) with the shoebox house.

Science as a human endeavour

As we explored the work and accomplishments of Count Rumford and William Herschel, we saw that;

- Nature and development of science 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE081)
- Use and influence of science 5: Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE083).

Cross curricular outcomes

- Explore art and technology with the insulated shoe boxes.

Science vocabulary words

Tier 1 (Everyday words) – hot, cold

Tier 2 (Dual meaning)

- Energy - the ability to do, or be doing, something. Energy takes many **forms** depending on what we'd like it to do: heat energy, light energy, potential energy etc.
- Energy **sources** are where we get our energy from and it is always made of materials, such as coal, the sun, or radioactive atoms.
- Heat - how much heat energy an object has. Even an ice cube still has heat in it, even if its temperature is less than your body's.

- Frozen - commonly means ‘cold’. Technically, frozen refers to an object in the solid state, not only ice. Technically. a table with metal legs is made of frozen metal.
- Boiling - commonly means ‘really hot’. But technically it means any liquid turning into a gas. While boiling water is hot enough to damage you, liquid nitrogen boils at around -196^{o}C below zero, making it ‘boiling cold’ yet it can freeze your skin solid.

Tier 3 (Specialised vocabulary)

- Particles – the ‘little things’ that make up our world, including us, air, rocks, etc. It is colloquially intended to include such things as atoms, molecules, compounds, etc. I.e. the ‘bits’ that make ‘stuff’.
- Insulation is used to SLOW down the movement of heat from one place to another. It is NOT used to make things hot. Rather, it is used to keep hot things hot, or to keep cool things cool.

Warning

- Hats and sunscreen for all outdoor activities.
- Heat can be hot. Watch for danger in burning people or things, and plan accordingly.

Preparation

- Depending on the activities you choose, you may need some paint (black and white in particular), brushes, drop clothes for messy paint, bottles, shoeboxes, and some balloons.

Suggestions for other year levels

Younger:

Keep it simple, and feel free to avoid the sections on conduction, convection, and radiation. Focus on how heat changes things, changing their state, etc.

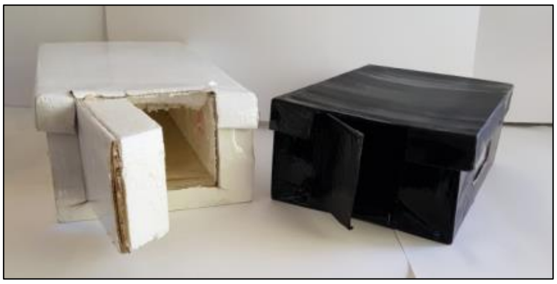
Middle:

This activity is well suited to this age group.

Remember to not give answers immediately, allow students to puzzle out some explanations and experiments on their own.

Teen:

Use mathematics – one of the most powerful means we have of predicting. Require students to suggest how the work will be assessed. What are the criteria for an excellent job?



Engage

- Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

Set up the following demonstration:

- Put a small amount of water in a balloon, enough to fill the uninflated balloon. Inflate the balloon the rest of the way. Allow students to handle and explore the balloon with a small puddle of water in it.
- Set up a lit candle where students cannot touch it.
- Ask students to predict what will happen if you put the balloon into the flame of the candle. Allow them to freak out – perhaps sound sensitive children can leave the room, but it is helpful if they can still see the balloon.
- Place the balloon over the flame so that the puddle is directly over the fire. Under normal circumstances, the balloon will not burst even though the fire is touching it.
- Ask students: what is your theory as to why the balloon didn't burst?

Explore

- Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, 'I don't know' is a valid explanation in science – it is the beginning of learning new things!

Ask:

- What is heat?
- How does heat travel from one object to another?
- What happens to objects when they get hot?

Explain

- Demonstrate how the fire can pop a normal balloon without water in it. Explain that as a balloon is blown up, it stretches. When the fire gets too close to the balloon it melts a hole in the balloon. The hole grows rapidly along the very stretched balloon, making it pop. So why didn't the balloon with water in it melt a hole?

Science as a Human Endeavour – Baron Kelvin and a Theory of Heat

Centuries ago, scientists didn't know what heat was either. The most popular theory was called 'caloric theory', and it was the idea that heat was an invisible goo that flowed away from hot objects through to colder ones. At the time, it made a lot of sense, and quite a bit of very accurate science could be done with this 'caloric theory'.

However, some scientists still doubted it. The debate raged for decades – what was heat?

From as early as the 11th century, some scientists[1] from Iran suggested heat was from motion.

In western society, while working with many scientists over many years, Count Rumford (Aka Benjamin Thompson, an American born British physicist) in 1798, published *An Experimental Enquiry Concerning the Source of the Heat which is Excited by Friction*, where he noted a cannon got hotter as the bore was drilled out, which he thought disagreed with caloric theory – if there was less cannon there should be less space for caloric, but instead of getting colder the cannon always got much, much hotter.

He developed the idea that heat is made out of the invisible jiggling of unbelievably small particles. The hotter they are, the more these particles jiggle and wiggle.

- What do you think?

Elaborate

- Ask students if they can design new ways to test this explanation, is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

Heat theory now

We now think of heat as a kind of **energy** – not a *thing*, but a *concept* we use to describe how things behave.

- The hotter things are, the more their particles are moving about.
- If something has the ability to increase this movement, it is said to contain heat energy. One example is the electromagnetic radiation from the sun – the heat.
- If something can remove this movement, it is said to remove heat energy. One example is magnetocaloric refrigeration effect.

---

[1] From Wikipedia 13 jan 18 - In the 11th century AD, Abū Rayhān Bīrūnī cites movement and friction as causes of heat, which in turn produces the element of fire, and a lack of movement as the cause of cold near the geographical poles:

The earth and the water form one globe, surrounded on all sides by air. Then, since much of the air is in contact with the sphere of the moon, it becomes heated in consequence of the movement and friction of the parts in contact. Thus there is produced fire, which surrounds the air, less in amount in the proximity of the poles owing to the slackening of the movement there.[2]

In the 13th century, the Islamic philosopher and theologian 'Abd Allah Baydawi considered two possibilities for the cause of heat:

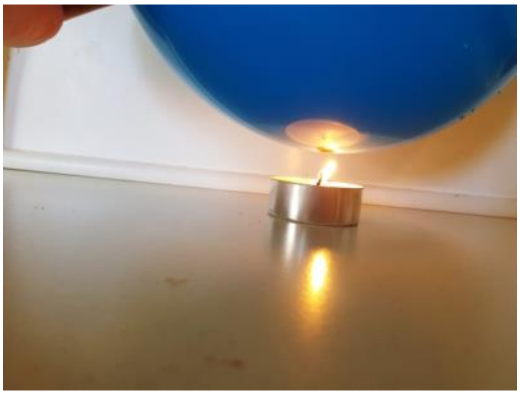
a) that [natural heat] would be the heat of a fiery atom that is broken, and b) that heat may occur through motion-change, the proof of this being through experiment.[3]

In 1253, a Latin text entitled *Speculum Tripartitum* stated:

Avicenna says in his book of heaven and earth, that heat is generated from motion in external things.[4]

Heat travels in three ways

Research ways heat can travel:



Conduction

Conduction requires TOUCH.

When you touch an object with more heat energy than you, the particles bounce along and into the particles that make up your body.

The non-burning balloon at the start of this lesson is a good example, as the fire touches the balloon, allowing the heat to transfer right into the balloon, and then into the water beyond.

Try these:

- **Using tongs and eyewear** – Stick several peas in a line onto a metal knife using margarine to hold them there. Hold the end of the knife in a flame, and watch as the peas melt off one a time. Can you explain what's happening?
- Leave a piece of ice outside and watch it melt as the ground, and the air, directly touches it and warms it up.
- **careful with scalding water!** For this activity, grab several different spoons or sticks, such as a wooden spoon, a metal spoon, a ceramic spoon and a plastic spoon. Predict which material will conduct (heat up) better. Heat (don't boil) some water in a kettle and pour it into a cup. Put all spoons into the water at once, arrange them so they aren't touching. After 2 minutes remove the spoons and feel the difference in temperature in each spoon. The more conductive the material, the hotter it will feel. Remember that fingers have heat as well, and the spoons will cool down naturally over time, so the recording needs to take place right after the spoons are removed.

Convection

Convection requires FLOW.

Hot air rises – and so do hot liquids like magma and porridge.

Demonstrate convection with one or more of the following:

- A clear pot of water on the boil. Add some oat flakes in order to see the convection currents.
- Place a cup of hot water, colour with dye, into a vessel of normal or cool water. You will note the hot water flows out immediately, and can soon feel that the hot water is at the top, and the cooler water is underneath.

- Take something freezing cold out of the freezer, and you can feel the air as it touches the object, cools down, and falls. On humid days you might even see the cool air.
- Open the freezer, and the cool air falls down. BLOW ON THE AIR to increase the humidity, and you might even see the air fall out of the freezer.

People are usually hotter than the air around them, which means there's a gentle convection current around every one of us as air heats up and flows upwards.

Air usually has to fill in the gap left by the air that's rising or falling, often resulting in circles.

⇨ Find other examples of convection in nature. Wherever there are liquids or gasses, there is convection.

Radiation

Radiation requires LIGHT.

- There's nothing in space to carry heat – no matter for convection or conduction. How does the sun heat up the world?

Heat energy can travel without any matter to carry it – using light.

In 1800 William Herschel, British astronomer of German and Czech-Jewish origin, stuck a thermometer in a rainbow he'd made on his desk. He was astonished to find the hottest colour of all was one he could not see, but Herschel figured out he could bounce this light off mirrors and refract it with lenses just like normal light. He took to calling them 'calorific rays', though we now call them infrared light. Infrared light is the way heat usually radiates, and just about all objects with a temperature above 0 degrees Kelvin emit it.

Without infrared light, heat could not get to us from the sun.

Ways to demonstrate heat energy.

- CAUTION!! Feel the heat radiating from a light or fire. Make sure you place your hand beside the glowing object, not above or below it (or you might actually be feeling convection current).

- Place a block of ice on two kinds of paper, black and white. Which will absorb the radiant heat energy from the sun the best?
- Build a solar energy cooker and bake some sausages. Check online for instructions – you'll need loads of aluminium foil!
- Try the bottle activity below:

Bottles for blowing up balloons

- Ask students, which colour heats up and expands the air fastest? (and which cools back down first?)

Place two identical bottles in the sun - one painted dark, the other light. Put 10ml of water in each, and then seal over the top carefully a balloon.

Observe over the day - though on a hot day you will see results in seconds!

This activity works even better if the bottles are cool first. Try bringing them out from an air-conditioned room, or if you are ambitious put them in the freezer overnight first.

After an hour in the sun, the black bottle has gotten so hot the plastic has begun to melt!

BLACK absorbs heat best, but also radiates it out best as well. That's why polar bears have white fur, to keep their heat in.

Other ways to heat things up

There are LOADS of ways to heat things up and cool things down, for example:

- When you compress an object, it heats up. Also, when you decompress an object, it cools down.
  - Refrigerators use this trick to cool their inner liquids down below the freezing point of water.
  - As air rises, it experiences less pressure, so it cools down – helping clouds to form. Likewise, falling air tends to heat up.
- As water goes from a liquid to a gas, it needs extra energy.
  - That's why sweating works, to help carry away heat from your body.
  - Likewise, turning gaseous water into drops releases heat back into the air, making clouds even more humid.

And much, much more! (including friction!)

Extension – how much energy?

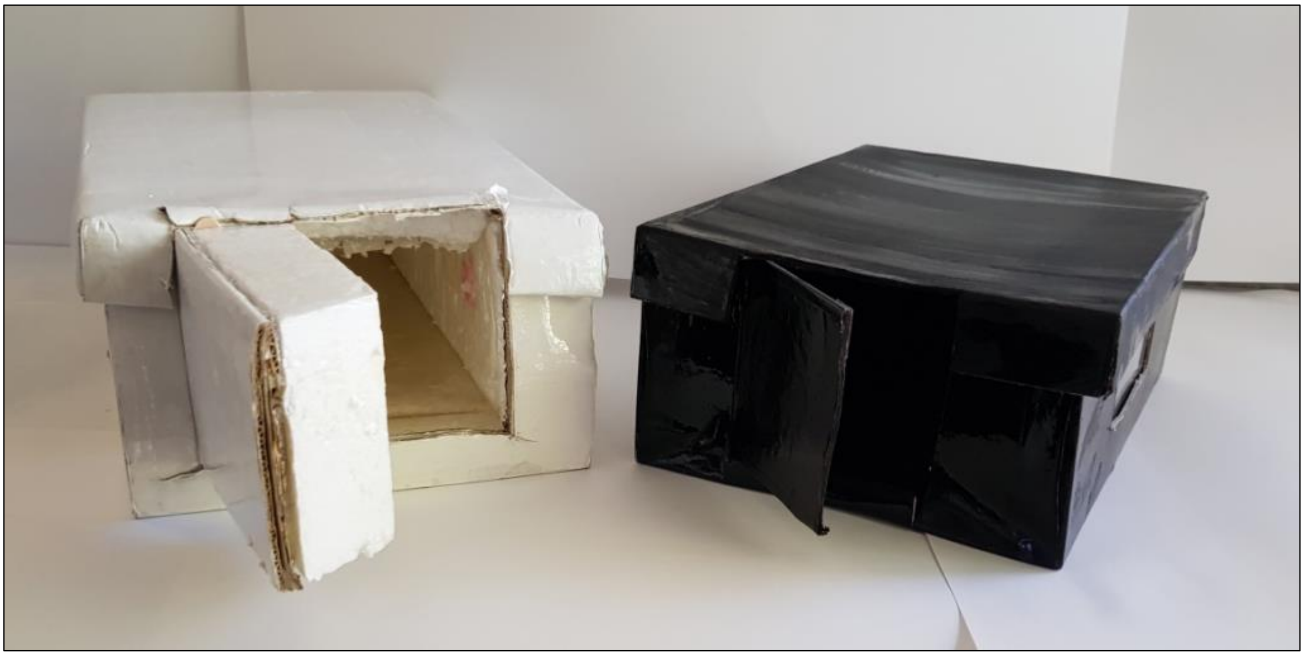
- Different materials require different amounts of heat energy before they will actually get hotter. Water is one of the best compared to other natural materials, and it requires a huge amount of energy before it will actually heat up.

We measure heat with temperature. Develop an experiment to answer one of the following questions – and remember the more students can generate their own questions, the more motivated they tend to be, but keep it real!

- Which cools down fastest, warm water, or hot water? [Two cups, measure and chart temperature every one minute for 20 minutes.]
- If you heat up butter and water the same amount for the same amount of time, which is hotter? [Use a tea light or Bunsen Burner, same setting for 5 minutes each. Measure and graph temperature each minute.]
- Find out what material heats up the most with the least amount of heat energy? [Often metal – but some materials become gases too quickly to be useful for this activity.]

Extension – Insulated houses

Insulation is designed to SLOW the movement of heat down. To keep heat in, or out.



⇨ Which shoe box above will heat up the quickest? [The blackbox. It has thick walls so heat conducts in quickly. It has no double glazing so air convects heat around quickly, and it is painted black to absorb heat energy well.]

⇨ But which one will cool down the fastest? [Again, the black, which can be a bit surprising. But insulation doesn't 'keep heat in'; it keeps heat from going anywhere. So it keeps hot things hot and cold things cold, or it tries to. The black radiates heat out fastest, conducts heat quickly through its thin walls, and convects air around inside easily to transfer heat away.]

Using only repurposed and recycled materials, try building a show box that will keep an ice cube icy the longest.

- Insulation to prevent convection
- Foil to prevent radiation.
- Double glazed windows so you can look at your ice without warm air getting next to it.

Decide if you want to leave room for little people to live inside your cold houses too.

Evaluate

Prior learning:

Take time to focus on planned content material during the engage phase, for example,

- What is heat?
- How does heat get from the sun to us?
- How does heat travel from one object to another?
- How do some materials change when they get hot?
- How can we measure heat?

And ask the following question regarding insulation

- If we put a jacket on a snowman, will he heat up faster or stay cooler longer? [he will stay cool longer, but younger children rarely expect this response!]

Formative:

Interview students on their developing understanding of heat.

Be sure to watch out for common alternative conceptions:

- Heat is a material. [Heat is a concept, not a material.]
- Insulation heats things up. [Insulation only slows the motion of heat down, so it keeps hot things hot, and keeps cold things cold.]

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

- ⇨ Build a shoebox house. Explain how it works by making better suggestions for a better fridge or home.
- ⇨ Have a shoebox house competition. Help students to decide how to measure a winner – perhaps keeping an ice cube icy the longest?
- ⇨ Investigate life that lives in very hot and very cold places. What adaptations make them better suited to deal with radiant, convected and conducted heat energy? Can the same be said for the humans native to these parts of the world?

So what?

- Keeping food the right temperature prevents diseases.
- Knowing how to keep cool can save you money on electricity bills.
- Knowing how heat travels can help keep you safe – 'hot air rises' is why we 'get down low, and go, go, go!' Also, black cars will be hotter on hot days, but will also cool down quicker.
- Convection currents cause the sea breezes, which is good to know if you love the beach.

Creating science

Science understanding

As we learnt about heat and made wonderful, effective shoeboxes, we learnt that;

- Science content Physical sciences - Heat can be produced in many ways and can move from one object to another (ACSSU049).
- Chemical sciences - A change of state between solid and liquid can be caused by adding or removing heat (ACSSU046).

Science inquiry skills

As we built our shoebox house, we were actually learning to;

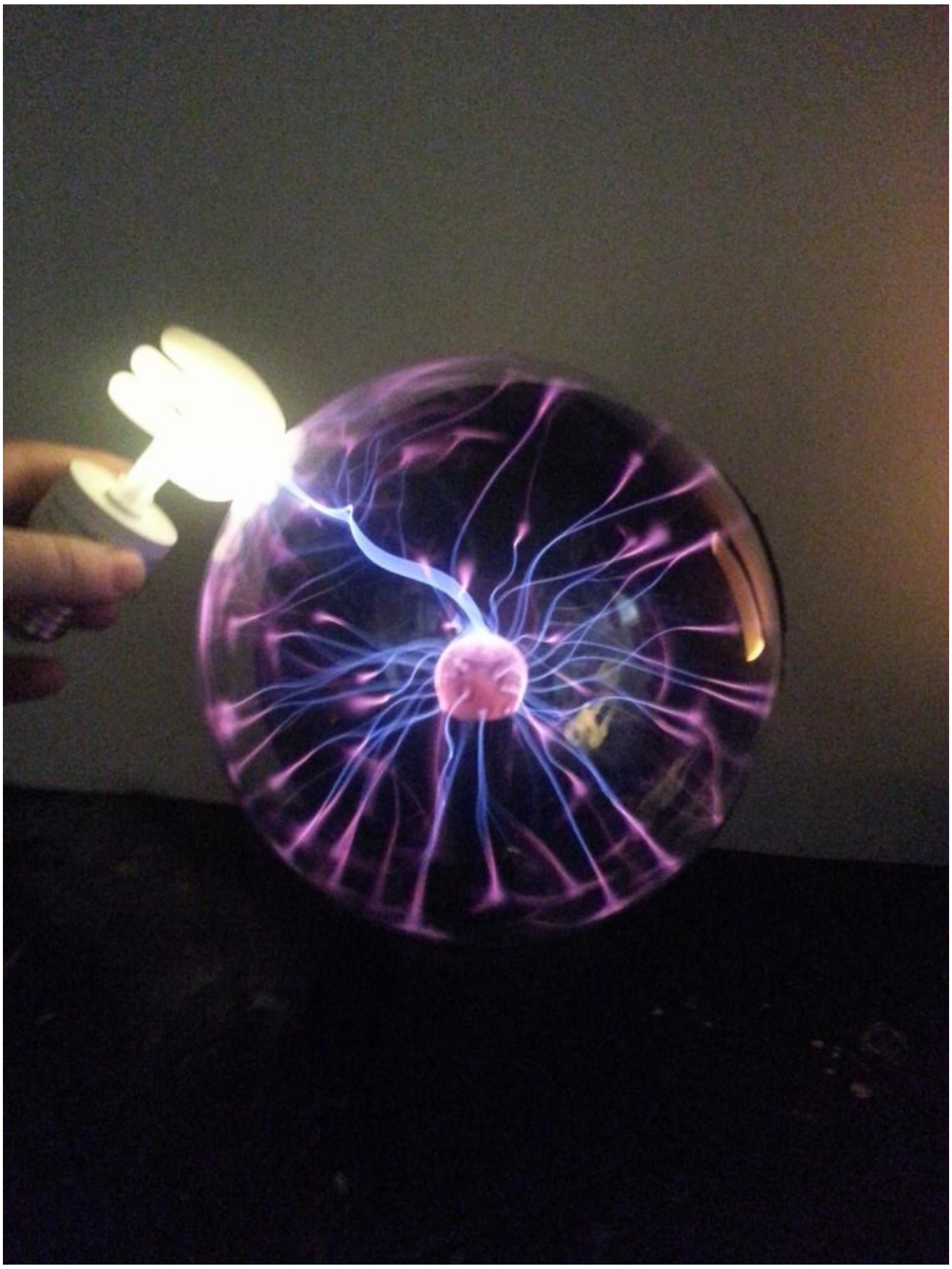
- With guidance, pose clarifying questions and make predictions about scientific investigations (ACSIS231).

Science as a human endeavour

As we explored the work and accomplishments of Count Rumford and William Herschel, we saw that;

- Nature and development of science 5: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE081)
- Use and influence of science 5: Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE083).

Tips from the masters



A plasma ball lights up a fluorescent light bulb using its static electricity.

Plasma is considered the 4th naturally occurring state of matter. Gasses do not conduct electricity well – they're still the best insulators we have! To conduct electricity, gasses must be turned into plasma.

Lightning is plasma, and the sun may be considered a giant ball of plasma. Electricity is invisible, but you can see the gaseous air as it is turning into plasma by the electricity heating it up so much, the electrons break free of the atoms and the resulting plasma glows.

It's easy – with grownup help, to use the radiant energy of the sun to start a fire. A few tips:

- Focus the light just beyond the brightest point, because the hottest light is the invisible infrared light.
- DO NOT use white things – they will reflect your light back around! Try and use brown or black things for best results.
- Midday is best, at evenings or late afternoon the sunlight is so filtered through atmosphere it's not very hot at all!
- DO NOT burn your hands or any living thing. IT WILL HURT!!!