PRIMARY + STEM

Teaching Resource

ACTIVITY: Heat transfer

ACTIVITY OVERVIEW

Understanding heat as an energy, what changes it brings about, and how it travels is essential because it underpins so many phenomena that children experience like changes of state, weather, and climate change.

This activity will expose students' common misconceptions about heat and provide opportunities to correct and build upon prior understandings.

SYNOPSIS

Understanding heat as an energy, what changes it brings about, and how it travels is essential because it underpins so many phenomena that children experience like changes of state, weather, and climate change.

There are also innumerable everyday occurrences that we take for granted which are brought about by heat. Making jelly and ice cream, how wet clothes contribute to rain, why puddles disappear, and why ice-cold drinks and hot coffee eventually reach the same temperature all have something to do with heat transfer.

On a much broader scale, concepts from this topic can be directly applied to global warming and climate change, and can be extended to explain natural disasters like cyclones that impact northern Australia annually.

This activity will expose students' common misconceptions about heat and provide opportunities to correct and build upon prior understandings.

Foundation – Year 2

- Objects are made of materials that have observable properties (VCSSU044)
- Observable changes occur in the sky and landscape; daily and seasonal changes affect everyday life (VCSSU046)

Year 3 – 4

- A change of state between solid and liquid can be caused by adding or removing heat (VCSSU059)
- Natural and processed materials have a range of physical properties; these properties can influence their use (VCSSU060)
- Heat can be produced in many ways and can move from one object to another; a change in the temperature of an object is related to the gain or loss of heat by the object (VCSSU063)

Year 5 - 6

- Solids, liquids and gases behave in different ways and have observable properties that help to classify them (VCSSU076)
- Changes to materials can be reversible, including melting, freezing, evaporating, or irreversible, including burning and rusting (VCSSU077)
- Energy from a variety of sources can be used to generate electricity; electric circuits enable this energy to be transferred to another place and then to be transformed into another form of energy (VCSSU081)
- Sudden geological changes or extreme weather conditions can affect Earth's surface (VCSSU079)

ACTIVITY, MATERIALS AND INSTRUCTIONS

An icy drink is most welcomed on a hot summer's day but if left aside long enough, the ice eventually melts, and the once-cold thirst quencher warms to room temperature. But what makes ice melt? And is there a way to slow down the melting process so that icy drinks stay cold for as long as possible (without putting them in the fridge/freezer)?

Materials

(for a class of 30 students)

- 30 x assorted items found around the house or classroom made of different materials, e.g. metal frying pan, ceramic/plastic/wooden/paper plates, tea towel, esky, school jumper
- Ice cubes
- A drinking glass

Optional:

- Aquarium strip thermometers
- Timing device e.g. clock, timer, stopwatch

Instructions

Demonstration

Teacher places some ice cubes into an empty drinking glass and shows this to the students.

1. Can students predict what might happen to the ice cubes? Students know about ice cubes melting in their cold drinks. Have they also noticed how a cold drink, if left aside long enough, eventually reaches whatever the room temperature is?
2. What is making the ice melt? Heat energy going into the ice cube.
3. Where is the heat from? Everything surrounding the ice, e.g. air, table, our bodies, and sunlight.
4. Is there a way to slow down the melting process? Without placing the drinking glass in the fridge/freezer?

Activity

Students investigate if the ice melts fast or slower on different materials.

1. Each group of students selects four to five items made of different materials.
2. Place similar-sized ice cubes on the surfaces of these items.
3. Observe changes to the ice cubes. How do the ice cubes behave on each item? Does the ice melt slowly? Does it melt quickly?
4. Categorise the items by how quickly heat is transferred to the ice. Objects on which ice melts quickly are 'conductors' and those that don't are insulators. Examples of conductors: objects made of metal; examples of insulators: objects made of thick fabrics and wood Discuss the observations. Can students explain their observations? What are some possible theories? Are some items hotter than others? Would that explain how ice cubes melt so quickly on some surfaces, while hardly melting on others?
5. Investigate further. Find the temperature of the items while the ice cubes are still on them. Do this by placing the thermometer strips on the surface of these objects.

Is the metal pan hotter than the school jumper? Use the thermometer to find out. No. In fact, the thermometer will show that the metal pan is cooler than the jumper.

Why is the ice melting on the metal pan a lot quicker than the one on the school jumper? The metal pan/pot is a good conductor that allows heat to move to the ice quickly. The jumper is an insulator and makes it difficult for heat to move quickly to the ice.

HOW TO USE THIS ACTIVITY WITH YOUR STUDENTS

Foundation - Year 2

This lesson can be used to explain why we pay attention to weather forecasts to help us decide how to dress comfortably. Based on the daily high and low temperatures, we decide whether to wear clothes to encourage heat to move away from the body, or wear clothes to keep the heat around the body.

To deepen student understanding of the body as a source of heat and how to keep warm in cooler weather, students can create heat by exercising or by rubbing their hands together and then compare how well materials of different thicknesses can keep the warmth in.

Years 3/4

This lesson is ideal for this year group because the topic of heat is formally introduced at this stage – using a thermometer, how heat is produced, how heat can move, and how well materials can conduct heat. They also learn how changes of state is brought about when heat is either added or removed.

Students can extend their learning from this activity by describing what happens in terms of heat movement in the following scenarios:

A) Holding an ice cube

The ice melts. And the ice feels cold.

Ice gains heat from our bodies and melts as a result. Heat moves from where it is hotter (our bodies) to where it is colder (ice cube). When heat leaves our body through our skin, we perceive the sensation as coldness.

The ice cube will eventually turn into a puddle of water with the same temperature as everything else in the room. This is referred to as room temperature.

B) An icy cold drink and a hot coffee eventually reach the same temperature.

Heat moves from where it is hotter to where it is cooler. In the case of the icy cold drink, heat energy moves into the drink and raises its temperature until it reaches room temperature. Heat energy moves away from the hot coffee into the surroundings until its temperature drops to room temperature.

What is the reason ice cubes melt in our drinks?

It is not because cold has left the ice cubes. It is because heat from the drink is moving into the ice cubes.

Years 5/6

Heat is one type of energy, and like all other forms of energy, can be transformed. Heat can be made from other types of energies, and it can change into other forms of energy. This is the principle by which electricity is generated.

Emphasis can be placed on this important principle by students identifying energy transformation in the following scenarios:

A) How ice cubes melt

Heat energy from the surrounding air and furniture is converted into kinetic energy, making atoms and molecules vibrate and move faster, colliding more and passing on this energy onto particles with less energy. These increased collisions and vibrations eventually reach the ice cubes. The water molecules in ice vibrate with more and more kinetic energy until they can break away from their rigid structure and turn into the liquid form. This change is called melting and it is reversible.

B) Using an electric kettle to boil water

Electrical energy from the wall turns into heat energy in the heating element. This heat energy transforms into kinetic energy of water, allowing water to bubble through the kettle, turning into water vapour that escapes into the air.

Which parts of the kettle are heat conductors? Metal heating element.

Which parts are insulators? The plastic casing.

DISCUSSION SECTION AND KEY THEMES

This activity demonstrates how heat moves from where there is more heat (surrounding air, table) to where there is less heat (ice).

The item that the ice is placed upon either conducts heat to the ice very well (conductors); or not (insulators). The metal pot or frying pan is the best conductor and the school jumper and Esky should be the best insulators.

The ice melts almost instantly on items made of metal. This is because metal is very good at moving heat quickly from the surroundings e.g. table to the ice cube. This makes the ice cube melt almost instantly.

On the other hand, the jumper is not as good as moving heat along to the ice cube. This keeps the ice cube solid for a longer period of time.

KEY THEMES

Heat is an energy

Heat is a form of energy, and like all other types of energy, it is defined as the ability to do work (to move). In simple terms, when an object possesses heat energy, it can MOVE. Even when an object such as a stationary bicycle under the hot sun doesn't appear to be moving, the atoms and molecules that make up the bicycle are. Depending on what state of matter the components of the bicycle are, atoms and molecules could be vibrating in fixed positions, or moving randomly around one another.

All objects possess some amount of energy and the only ones that almost do not are the few atoms and molecules that are kept in the Bose-Einstein condensate state under laboratory conditions.

Heat can be measured

Measuring temperature using a thermometer is one way of getting an indication of how much heat energy is in a material. However, **heat energy and temperature are not the same thing**.

The heat an object contains is the amount of its thermal energy and is measured in Joules (J). Temperature on the other hand represents the average kinetic energy of the atoms and molecules in an object, and is measured in °C.

A swimming pool at 36°C has a lower temperature than a cup of hot coffee at 85°C, but because the swimming pool contains more water, it stores more heat energy than the cup of coffee.

Heat moves: Heat moves from the hotter part of the object, to the cooler part of the object

Heat always moves from hotter objects into colder ones. The bigger the difference in temperature, the faster heat flows.

Heat can be transferred throughout one object, e.g. heat moving through a spoon, or through the air; or it could also move between mediums, e.g. when heat is transferred through a metallic heating kettle into the water within it.

There are three ways in which heat is transferred – conduction, convection, and radiation. These three mechanisms usually occur simultaneously.

Conduction: Heat can move between objects/mediums that are touching one another

This mode of transfer describes how heat moves between objects in direct contact with one another, e.g. pressing our hands onto a mug of hot chocolate.

Heat energy moves along the material, but the material itself does not move. We often associate this form of heat transfer with solids, but it is important to note that conduction also occurs in stationary fluids.

In solids, atoms and molecules vibrate in fixed positions. When heat is applied in one area, the heat energy is converted into kinetic (movement) energy in the particles, making them vibrate faster. These increased vibrations lead to increased collisions with adjoining particles. This is how the energy is transferred.

An everyday example of conduction: We feel the heat in our hands by conduction when holding a mug of hot tea. The faster-moving molecules in the hot water collide with the cooler molecules in the wall of the mug, transferring some of their kinetic energy. The molecules in the mug start vibrating more quickly, and the mug warms up from the inside to the outside. The heat receptors in our skin pick up the heat and we eventually feel the warmth from the hot water.

Conduction and insulators: Some materials transfer heat better than others

When an object transfers heat quickly along, it is a conductor. Metals are great heat conductors and that is why we use them to make cooking pots and pans.

When an object transfers heat slowly, it is an insulator. Materials like wood, plastic, polystyrene and wool are good examples of insulators.

Silver is the best conductor of heat, and a vacuum is the worst. All other materials fall somewhere in between.

Convection: Heat can move throughout a fluid like water or air

This form of heat transfer takes place within fluid mediums such as gases and liquids where atoms and molecules are free to move around one another. In this case, the particles themselves move when heat is applied. When heated, the particles move in such a way that those with higher energy levels move faster and spread further apart. This results in the heated portions of the liquids or gases becoming less dense and rising above the cooler, denser fluids surrounding them. This movement is called a convection current and continues until the entire medium is heated up.

Convection causes predictable movements in water and in air which helps us understand weather patterns. Studying convection in oceans and in the atmosphere helps meteorologists predict the weather and mitigate potential weather-related disasters.

Convection: Hot air rises, cold air sinks

An everyday example of convection

Convection explains why air-conditioning units are placed at the top of a room while heating units are generally found on the floor. This sets up a convection current, which is an efficient method of heating and cooling a room. Convection also explains how a hot air balloon works: Hot air rises; cold air sinks.

Radiation: Everything gives off heat radiation

All objects possess energy and therefore emit heat radiation to the surroundings in the form of electromagnetic waves. This is except for matter kept at absolute (almost) zero temperatures under laboratory conditions. Radiant heat does not require a medium to travel. Heat radiation travels most efficiently in a vacuum when there is no contact between the bodies, and less efficiently in fluids. Without radiation travelling through the vacuum of space, life on Earth would not be possible because this is the only way we get our energy from the Sun. Even when there is a medium such as air, radiation is important. Human bodies lose a lot of heat to the air by radiation through the head and neck – that is why it is important to keep these covered in cooler weather.

Good emitters and absorbers of heat radiation possess matt surfaces and are dark in colour. Poor emitters and absorbers of heat radiation are shiny/reflective and white in colour.

QUESTIONS AND ANSWERS

Why do some objects feel hotter, and others feel cold to us?

When we touch an object with our fingers, heat energy could either leave or enter our fingers. We have nerves in our skin that can detect temperature changes. When heat leaves our fingers into an ice cube, we sense coldness; when heat enters our fingers from a hot potato, we sense hotness.

Is a blanket or jumper really warm? Does it make heat?

It is our bodies that constantly produce heat, which is lost to the air. These insulators both start off at room temperature and they keep us warm by slowing down the movement of heat away from our bodies.

How cold is my fridge/freezer?

According to CSIRO, the best temperature setting for a fridge is below 5°C. For a freezer, it should be between –18 to –20°C. Temperatures between 5 to 60°C are dangerous for storing food because this is the ideal temperature range for bacterial growth that causes food poisoning.

Where are the hottest and coldest places on Earth?

Temperature can be measured by standard instruments found in weather stations; and by satellite imaging which is able to record the surface/ground temperature. Using data from weather stations, Antarctica has recorded temperatures as cold as –89.5°C at the Vostok Station. With satellite data, it's the East Antarctic ice sheet desert (-92.3°C) that is the chilliest place on Earth! With weather station data, the hottest place was recorded at the El Azizia (Libya) weather station at 58°C (1922) but satellite temperature data shows that the hottest part of the Earth is in the Lut Desert in Iran (70.7°C in 2005). The Queensland desert features in the top 3 (69.3°C in 2003)!

What's the difference between warm-blooded and cold-blooded animals?

Warm-blooded animals can regulate heat production and heat loss to maintain a regular body temperature. Cold-blooded animals cannot do this and must depend on external sources such as the Sun or shade to control their body temperatures. When cold-blooded animals move to the shade, they lose their body heat to become cooler. When they rest in a sunny spot, they are absorbing heat they need to keep warm.

How hot is the Sun? Other space temperatures?

The answer depends on which part of the Sun one is referring to. It varies from 15,000,000°C at the core to about 5,500°C at the surface (presumed to be about the same temperature as the core of Earth). One would assume that temperatures would get lower further away from the core of the Sun, but temperatures in the outermost layer of the Sun's atmosphere, called the corona, can get to as high as 1 to 2,000,000°C!

Why do people in America use a weird way to measure temperature?

There are three different temperature scales used by people around the world.

- **Celsius** – is the most common temperature scale and is used in most countries of the world, including Australia. Named after Swedish astronomer Anders Celsius (1701-1744), who designed the scale with the freezing point of water at 0°C and the boiling point of water at 100°C. Very cold temperatures are negative numbers in the Celsius scale.

- **Fahrenheit** – used by people in the United States of America. Named after German physicist Daniel Gabriel Fahrenheit (1686-1736), who designed the scale with a mixture of ice, salt and water at 0°C, the freezing point of water at 32°F, body temperature at 98.6°F, and the boiling point of water at 212°F. Very cold temperatures are negative numbers in the Fahrenheit scale.

- **Kelvin** – used in scientific measurements only. Named after Scottish physicist, Lord William Kelvin (1824-1907), who designed the scale that has no possible negative numbers. 0 K is absolute zero, the theoretical temperature at which all molecular motion stops, and no energy can be detected. Note – we don't use the symbol or word degrees when we refer to temperatures on the Kelvin scale, we just say Kelvins. This scale is useful for really low temperatures, like those measured in science laboratory experiments. On the Kelvin scale water freezes at 273.15 K and water boils at 373.15 K.

I want to live in Queensland where it is warm and tropical, but cyclones occur so regularly over there. Why is that so?

Waters over the north of Australia are warmer and that is why cyclones form more frequently there.

When seawater is warm, evaporation happens at a greater rate, sending lots of water vapour into the air. Immense clouds form overhead and together with forces brought about by convection currents (warm air rises, cold air sinks) and wind, unstable systems could spiral into a high-energy cyclone.

So long as the cyclone is over warm water, it grows in strength and speed. When it is travelling over land, in the absence of warm sea water, the cyclone collapses but can still bring about devastating floods.

How does my body keep cool on a really hot day?

It's important that we maintain our body temperature around 36-37°C.

When we get too hot, heat is sent away from our body by radiation and conduction.

More blood gets sent to our skin which allows the excess heat in our blood to radiate into the air. When we sweat, excess heat enters the sweat to allow it to evaporate. In both cases heat is transferred away from our body.

What's the best way to keep my body warm on a really cold day?

The best way should be both comfortable and delicious. Perhaps being in a warm room, wearing a comfortable beanie, and jumper to reduce heat loss by radiation and conduction away from the head and body. And drinking a mug of hot chocolate.

OUTSIDE OR SUPPLEMENTARY READING

CSIRO – safe food temperatures

Handling food in the home - CSIRO

Guinness World Records – for temperature and weather extremes

https://www.guinnessworldrecords.com/world-records/highest-recorded-temperature

NASA

Where Is the Hottest Place on Earth? (nasa.gov)

Better Health Channel – information about burns

https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/burns-and-scalds

TOPIC WORDS

- crystal
- solid
- liquid
- dissolve
- saturated
- solution
- mixing
- mineral
- chemistry
- reversible
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