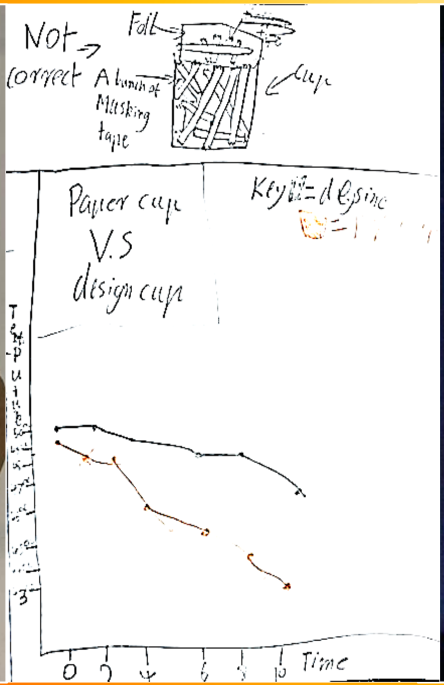
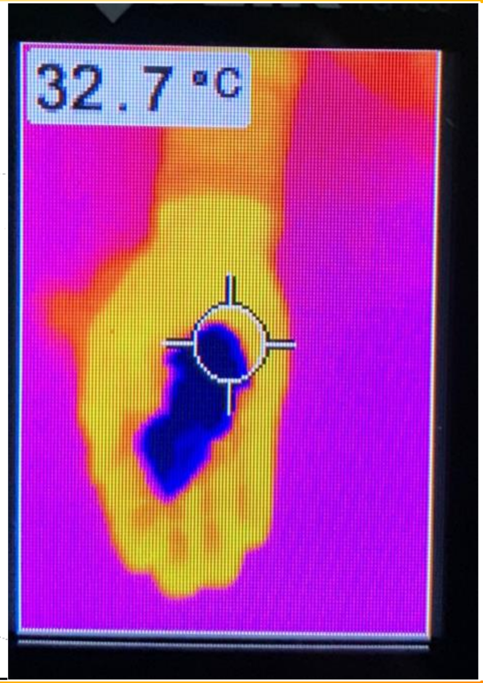
Heat and Temperature

Year 3





This learning sequence focuses on the concept of heat, heat transfer, insulators and conductors. Students design ways of keeping things warm and construct informal and then formal measures of temperature. They use tables to organise data during investigations, and devise ways of showing the data and representing change over time. This may include constructing line graphs, to demonstrate change in temperatures.

INTERDISCIPLINARY MATHEMATICS AND SCIENCE (IMS) LEARNING

Deakin University · Macquarie University · Vanderbilt University · Australian Government · Australian Research Council

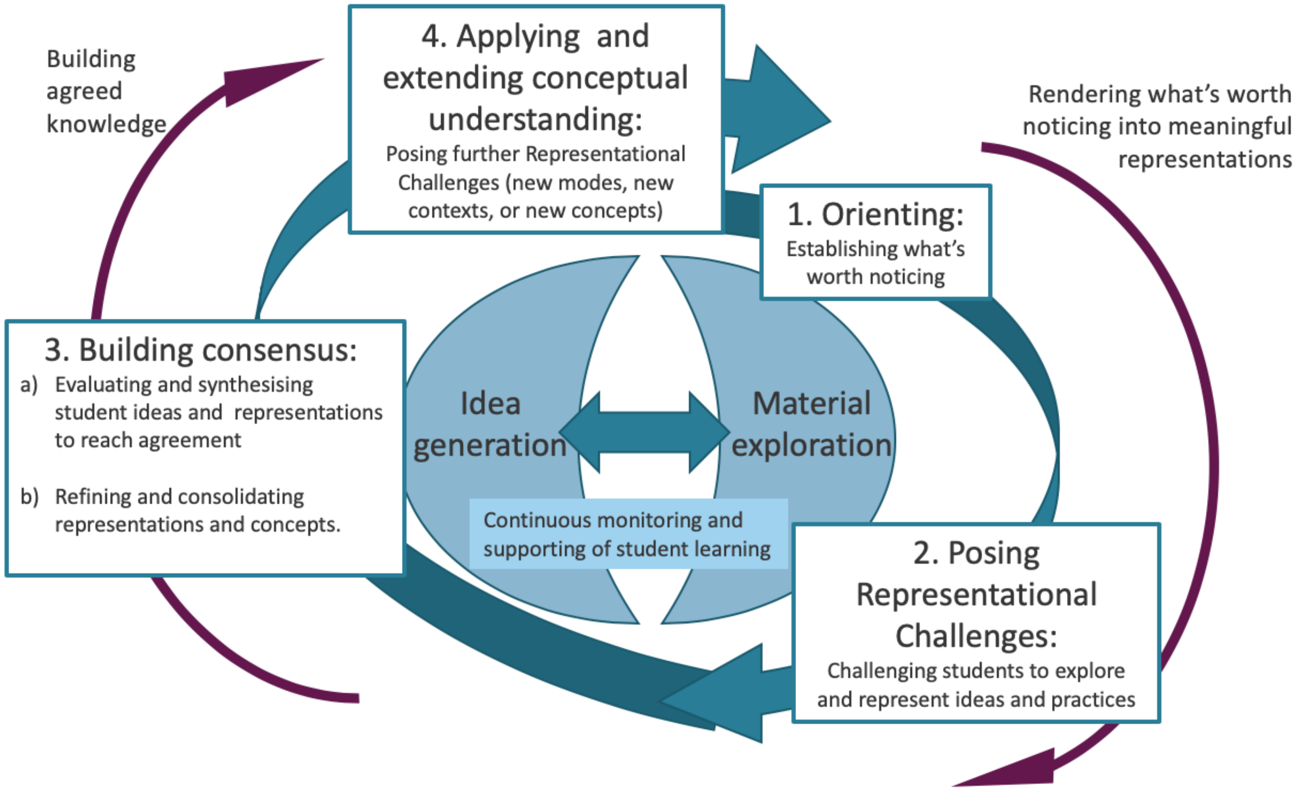
This learning sequence is one of a number that are designed to productively integrate mathematics with science, using a guided inquiry approach in which students construct, share, evaluate and revise multimodal representations to establish conceptual understanding. Developed as part of the Australian Research Council Project: Enhancing Mathematics and Science Learning: An Interdisciplinary Approach https://imslearning.org Deakin, Macquarie, and Vanderbilt Universities.

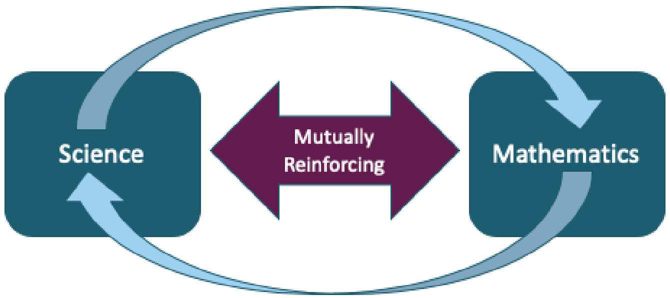
Interdisciplinary Mathematics and Science (IMS) Learning

IMS aims to enrich learning through two interconnected principles, which are key to the nature of the unit design and the pedagogy. The first principle concerns a focus on students constructing, evaluating, and refining multimodal representations, enacted through a four-stage IMS pedagogical model. The second principle concerns interdisciplinarity: the relation between science and mathematics. The project can be found at https://imslearning.org/
Below we describe the key features of the approach.

Student constructed representations

The teaching and learning sequences follow a guided inquiry pedagogy that focuses on students constructing, evaluating, refining, and extending multimodal representations. This is a literacy focus built on the insight that learning in both science and mathematics involves students being inducted into the representational practices that underpin explanation and problem solving. Representations diagrams, models, equations, graphs and tables, and symbols as well as written text. The approach involves a number of stages through which the teacher guides student learning. These stages, although distinct, often cycle and repeat within and across lessons. The model (to the right) showing these stages has been developed as an outcome of the IMS research.





Interdisciplinarity

In the teaching and learning sequences, the mathematics and science activities are built around interrelated concepts, with the principle that the learning in each subject enriches learning in the other. For instance, measuring, graphical work and data modeling generally are freshly developed in science contexts in ways that raise questions and promote deeper knowledge in science, and the science context raises questions that can be further explored mathematically.

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Stages of the IMS Pedagogical Model

Orienting: Teachers pose questions, explore students' ideas and orient them to the learning focus by a variety of means such as asking for predictions, questioning what they have noticed, asking for ideas about what could be measured, and eliciting prior knowledge. This provides a way to focus students' attention on what is worth noticing about the school environment, or about data sets for instance, and could be interesting to explore.

Posing representational challenges: Students are challenged to explore and represent their ideas and practices, for instance they may be challenged to represent the movement of their shadow over a day, involving decisions about what to measure and how to represent patterns in length, and angle, or to use particle representations to predict, investigate and explain why a saucer of water evaporates more quickly in warm, or windy places.

Building consensus: This involves two stages. First, using the student ideas and representations to compare, evaluate and then synthesise these to reach agreement about which aspects of these effectively show patterns in data, or suggest explanations. Second, these ideas are refined by students, and consolidated to establish a shared understanding of the concept and associated representations. In this process students develop knowledge of the role of representational work in learning.

Applying and extending conceptual understanding: Students are given new representational challenges to extend their new knowledge and practices in related situations, or further concepts are introduced through representational tasks, to repeat the cycle.

In these stages the teacher is constantly monitoring and responding to students' representations and ideas. The approach can be seen as 'assessment as learning'. The focus on student production has been found to allow the teacher significant insights into student thinking. The art of teaching in this way involves setting appropriate tasks, preparing students strategically through questioning and challenges, and guiding their work to reach consensus about the key ideas and their representations. The sequences all involve a close association of material exploration, and the generation of ideas.

These stages have much in common with the 5Es that underpin Primary Connections (PC). The stages line up as Orienting = Engage, Posing Representational Challenges = Explore, Building Consensus = Explain; and Applying and Extending Conceptual Understanding = Elaborate. The 'Evaluate' stage appears in the IMS pedagogy as a continuous process of monitoring and formative assessment (assessment 'for' and 'as' learning) throughout the stages. Most sequences have a summative evaluative task, but this sits outside the cycle. Distinct from the 5Es, the IMS stages are explicitly focused on representations as central to learning (consistent with the PC focus on literacy), and structured to lead from noticing what is of interest to investigate, through the generation of representations, to generating class agreement on key concepts as systems of representations and representational practices.

The teaching and learning sequences follow these stages explicitly, but they cycle in different ways, in different lessons and in different topics. In some lessons there are more than one cycle, or even interweaving cycles for science and mathematics. In other cases, a cycle is spread over a number of lessons. Sometimes, activities have more than one role, such as an extension representational challenge acting as an orientation into a further concept. Nevertheless, we believe the movement from opening up what is noticed, to exploration and representation construction, to evaluating and building consensus, is a fundamental and powerful aspect of effective teaching and learning. Tasks in the sequences are designed to be approachable at a range of levels. This, together with teacher open questioning and targeted scaffolding, enables differentiation of the learning.

Supporting differentiation of learning in the IMS learning design

In the IMS learning sequences the student- guided inquiry design enables diverse student learning needs to be responded to within the regular classroom. The open learning tasks are designed flexibly to enable students to work at their own level, and at their own pace, to develop their understanding and skills in a variety of ways. Variation in student responses offers a resource for promoting, encouraging and refining learning as students demonstrate, in different ways, what they know and understand. With teacher support, students learn from each others' ideas and productions. The focus on student-constructed representations, and open questioning and discussion, enables the teacher to monitor individual students' understandings and cater for their learning needs over time.

Features of the learning sequences that enable embedded and teacher-supported differentiation

There are three distinct aspects of the IMS pedagogy that enable differentiation.

Open questioning, guided inquiry and open tasks provide the teacher with insight into individual student learning and understanding that:

a) enables teacher decisions for on-the-spot feedback, and individualised monitoring and support of student learning through targeted learning adjustments, scaffolding, and extension challenges.

   "Giving them (students) more freedom is a good approach because they're more capable than I thought they would be, but they still needed the support as well. So, giving students the initial freedom to do whatever they thought they could do and then helping them from that… "

b) enables support for students to navigate tasks with multiple entry points, solution pathways and outcome possibilities, whilst negating possible student stigmatisation from the withdrawal from their peer group, or students assigned a different task.

   "the fact that they are open-ended so they (the students) can come to a solution in a variety of different ways. There was not one student where I had to really modify an activity for, they could participate in the activity, they could all have success in the activity but they all got something from it and because it was open-ended…"

c) enables the development of creative and critical thinking skills, and higher-order thinking, as student responses are not limited

   "…I always found everything was just deeper level thinking"

Peer learning, collaborative learning and student voice increases student engagement as students learn from and with their peer group.

Students learn collaboratively as a whole class and in mixed ability peer groups. Student are encouraged to share ideas, co-construct investigations, designs, data and representations. Through purposeful guided reflection, targeted scaffolding, prompts and extension challenges, students engage in comparative discussions and review of peer representations (e.g. graphical representations) to build their understandings.

> *"…we were able to cater for everyone without making it obvious to them that we had to modify the activities, which I think is really important for their confidence and self-esteem and learning too"*.
>
> "*…coming from their peers and it's quite interesting because when they actually get feedback from their peers as well I find that they really do put it into practice a lot quicker, it's quite interesting, as opposed to coming from the teacher all the time, it's coming from someone different. That has been a really interesting pick up that we have found..."*

Multimodal representational challenges cater for diverse learner needs and provide differentiated insight into students' conceptions.

Teachers have identified that a focus on multimodal representation enhances learning for students with language difficulties, who are English Second Language (ESL), and/or have literacy support needs, since they are not so constrained by their language skills. Access to multiple modes reduces the effects of language demands as barriers to learning. Students' multimodal representations provide teachers with insight into individual students' knowledge, skills and learning needs.

> *"…this has been really interesting, seeing children that don't speak up as often really come up with some really insightful representations. I mean, they're a lot further ahead than what I thought".*

"'show me what you know through your drawings' and often that speaks volumes because children find it difficult to articulate at the time. They might understand more than what they are conveying… But they are actually showing me so much of their knowledge through their diagrams.

Science and Mathematics Learning and Curriculum Focus

Learning Focus	Key Curriculum Outcomes (Victoria Curriculum)
Science ideas and practices Concepts and practices and associated representations attended to in sequence • What causes things to be hot? – distinction between heat sources and things externally heated. • How should we think about how things are heated? • What is the relationship between heat and temperature? • How do we measure temperature and what range of temperatures exist in our everyday life? • How do we keep warm? • What is the effect of heat on different materials (conduction).	**Science** *A change of state between solid and liquid can be caused by adding or removing heat investigating how liquids and solids respond to changes in temperature* (VCSSU059) ***Science Inquiry Skills*** ***Questioning and predicting:*** With guidance, identify questions in familiar contexts that can be investigated scientifically and predict what might happen based on prior knowledge (VCSIS065) ***Planning and conducting:*** Suggest ways to plan and conduct investigations to find answers to questions including consideration of the elements of fair tests (VCSIS066) Safely use appropriate materials, tools, equipment and technologies (VCSIS067) ***Recording and processing:*** Use formal measurements in the collection and recording of observations (VCSIS068) Use a range of methods including tables and column graphs to represent data and to identify patterns and trends (VCSIS069) ***Analysing and evaluating:*** Compare results with predictions, suggesting possible reasons for findings (VCSIS070) Reflect on an investigation, including whether a test was fair or not (VCSIS071) ***Communicating:*** *Represent and communicate observations, ideas and findings to show patterns and relationships using formal and informal scientific language* (VCSIS072)
Mathematical ideas and practices Concepts and practices and associated representations attended to in sequence • Measuring temperature and constructing a scale that translates between informal and formal measurement. • Structuring and interpreting data in controlled experiments – involving spatial patterns and time. • Constructing visual and tabular representations of temperature and melting point patterns.	**Mathematics** ***Fractions and decimals:*** Model and represent unit fractions including 1/2, 1/4, 1/3, 1/5 and their multiples to a complete whole (VCMNA136) ***Using units of measurement:*** Measure, order and compare objects using familiar metric units of length, area, mass and capacity (VCMMG140) ***Statistics and Probability*** ***Chance:*** Conduct chance experiments, identify and describe possible outcomes and recognise variation in results (VCMSP147) ***Data representation and interpretation:*** Identify questions or issues for categorical variables. Identify data sources and plan methods of data collection and recording (VCMSP148) Collect data, organise into categories and create displays using lists, tables, picture graphs and simple column graphs, with and without the use of digital technologies (VCMSP149) Interpret and compare data displays (VCMSP150)

Heat and Temperature (Year 3): Sequence Overview

Sequence Overview: This learning sequence focuses on the concept of heat, heat transfer, insulators and conductors. Students construct informal and then formal measures of temperature. They use tables to organise data in investigations, and construct line graphs to track temperature over time.

Sequence Outline

Lesson 1 Keeping warm: In this lesson students consider different ways of keeping warm, and what these say about heat and heat exchange. They classify different hot objects into heat sources and receivers, and consider the three major types of energy that produces heat: chemical, electrical, and friction. They learn to represent heat exchange with arrows.

Lesson 2 How hot is it? In this lesson students investigate different temperature and variation using infrared images and explain these using heat exchange ideas. They construct a temperature scale, and produce data and represent and explain variations in temperature related to the body.

Lesson 3: How does heat travel through different spoons? In this lesson students investigate heat transfer through metal compared to wood or plastic. They construct and use an informal temperature scale, and develop and use tables to organise and investigation, and line graphs to compare temperature vs. time. They develop a particle model of heat transfer.

Lesson 4 Keeping the heat in: In this lesson students re-design a paper cup using insulating materials, to keep a cup of hot chocolate hot for as long as possible. They devise line graphs to track the cooling of hot water in the design cup compared to a control cup. They explain their findings using heat transfer representations.

Lesson 5 The iceblock challenge: Students learn about the insulation characteristics of different materials and construct representations of heat transfer to melt a block of ice. They measure the amount of melt over time, construct data tables and line graphs to compare two conditions.

Post Sequence Assessment Task

Note: This sequence draws on the Primary Connections unit "Heating up" for some activities.

Heat and Temperature: Equipment/Resources Required

Lesson		Equipment/Resources
All Lessons		**Students:** student workbooks (unlined), pencils, coloured markers and rulers **Teachers:** Board (IWB/whiteboard) and or butchers' paper for shared recording, pens and computer
1	Keeping warm	Internet connection www.bbc.co.uk/learningzone/clips/penguin-huddle/12886.html [Opens new Window]
2	How hot is it?	Class set (one per small group) of thermometers. If possible – one or more infrared cameras; 2 sets of five plastic cups with water: cold water from fridge, ice water, warm water, cold water from tap, water left out on the bench, hot water from tap. (*NB: kettle and ice needed prior to get the water to varied temperatures)* 6 or so warming clothing pieces - - gloves, or scarves Infrared images (PPT)
3	How does heat travel through different spoons?	(based on 6 groups) Thermometers – 6 per class 6 plastic cup, 6 metal teaspoons, 6 wooden spoons, 6 plastic spoons Source of hot water (i.e. kettle prior to lesson – beware of temperature and student safety)
4	Keeping the heat in	(based on 6 groups) 6 thermometers (12 is better); 12 paper cups (2 for each of 6 groups); material for insulating a cup: aluminum foil, cardboard flexible foam, sticky tape and scissors (one each per group) Source of hot water (i.e. kettle prior to lesson – beware of temperature and student safety)
5	The iceblock challenge	(based on 7 groups) 2 iceblocks for each group (14); 7 saucers for the iceblocks; 7 measuring cups (measuring medicine); 7 plastic pipettes; Materials: alfoil, paper, woolen cloth, rubber glove material, sponge, polystyrene , metal and plastic sheets, scissors, sticky tape,

Appendices

1 Pre-post sequence assessment task: student example and master

LESSON 1: Keeping warm

(Approximate duration: 120 minute, or 2 x 60 minute sessions)

Learning focus:

Science concepts and practices

Heat production and transfer
Different ways of keeping warm

Mathematics concepts and practices

Classification of heat phenomena – representing patterns

Learning Intention:

Students will experience and understand:

- The different ways we keep warm
- Different heat sources and the distinction between heat producers and heat receivers
- Heat production mechanisms and heat transfer

Equipment/Resources

Videos from BBC- internet connected monitor

www.bbc.co.uk/learningzone/clips/penguin-huddle/12886.html [Opens new Window]

Equipment required for all lessons

Students: student workbooks (unlined), pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers' paper for shared recording and pens

The lesson at a glance:

In this lesson students consider different ways of keeping warm, and what these say about heat and heat exchange. They classify different hot objects into heat sources and receivers, and consider the three major types of energy that produces heat: chemical, electrical, and friction. They learn to represent heat exchange with arrows.

LESSON 1: Keeping warm

(Approximate duration: 120 minutes, or 2 x 60 minute sessions + 20 minute Pre-Sequence Assessment Task)

Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
		PRE-ASSESSMENT OF KNOWLEDGE AND SKILLS *(20 minutes)* Pre-sequence assessment for all students. Read the questions as a literacy support. Students answer independently. Answers can be shown through text or drawings with labels.	Establishing student understanding
Science: Heat transfer and exchange Insulation to control heat exchange	***Orienting*** Students are led to notice a variety of ways we keep warm, and raise questions of how these work	**Ways that animals and humans keep warm (Whole Class)** *(15 minutes)* Show the Primary Connections multimedia resource showing animals warming themselves through different strategies. BBC Learning zone clip 12886, 'Penguin Huddle': www.bbc.co.uk/learningzone/clips/penguin-huddle/12886.html [Opens new Window] Also: Video on snow monkeys. **Probing question** ❖ *What strategy is the animal using? How does it work to keep them warm?* (NB: for the penguins in the middle, their body heat warms the penguins near them. Those on the outside or alone lose heat to the air especially if there is wind) Challenge and organise students to: • role-play the way they feel when they are hot or cold • role play the penguins' strategy to see how it feels • discuss the ways they would warm up if they felt cold • explain the reasons they think different things help them to warm up **Questions to guide ideas:** ❖ *Why do you think a heater is hot?* ❖ *How do you think a blanket keeps you warm?* ❖ *Why do people need heat?*	Can students identify the distinctive ways the penguins are keeping warm? Can students identify how this might work in terms of heat loss, heat retention? What range of ideas do students have about heat? Can students think about blankets in terms of trapping heat or keeping it in, rather than actively warming?

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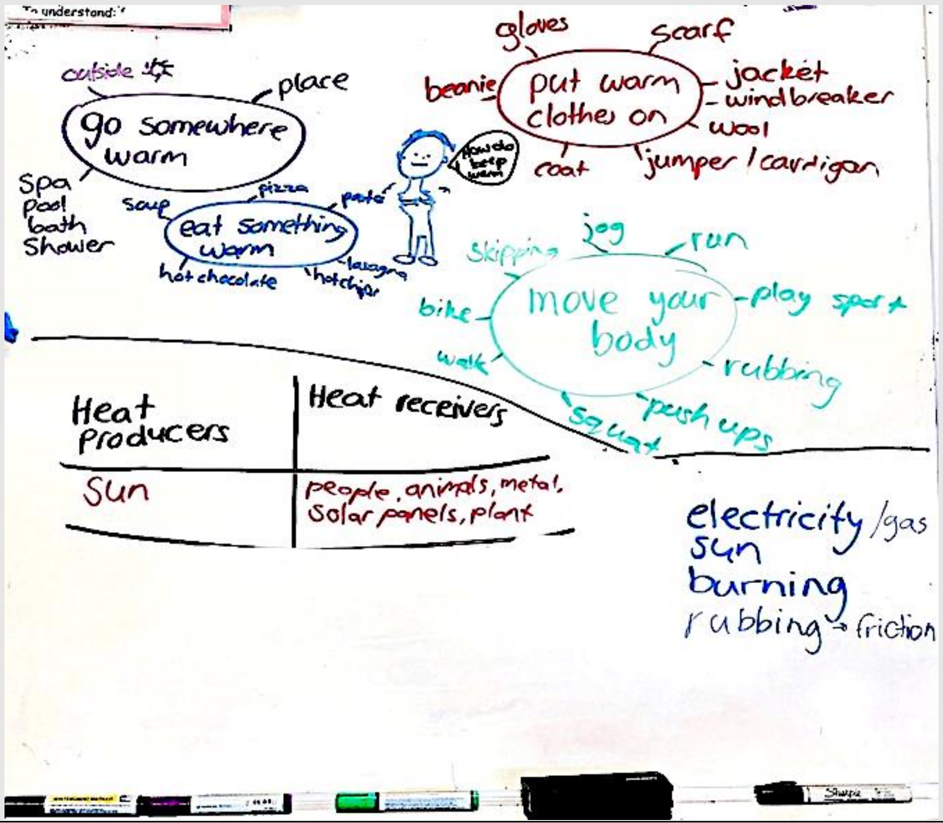
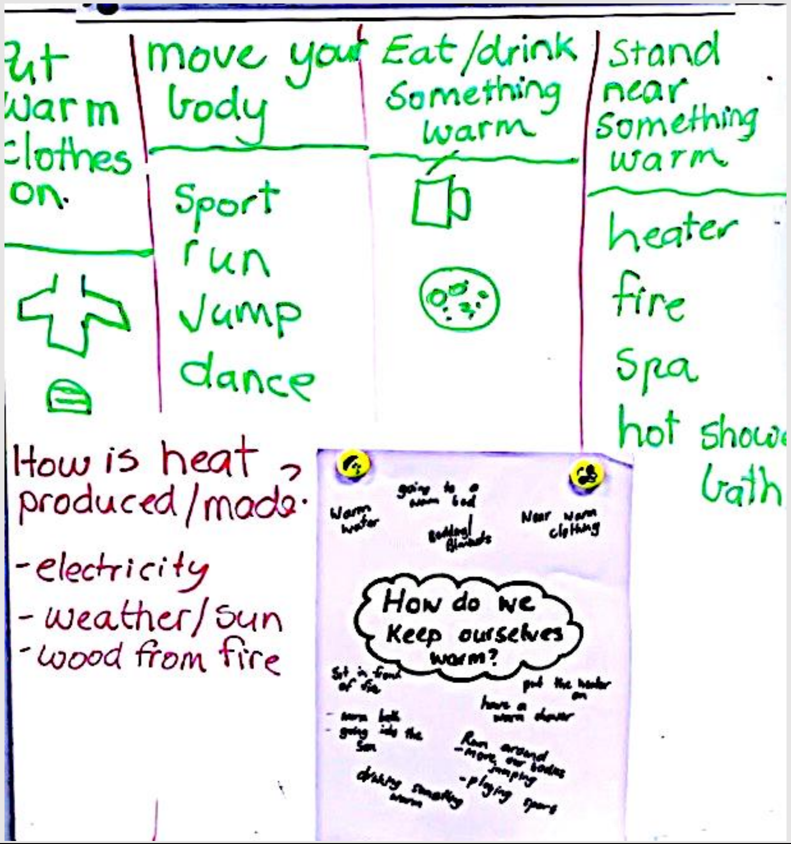
Science: Different energy sources that and energy exchange related to heat and temperature	***Orienting*** Students identify a variety of ways we keep warm and begin discussions about how these might work	**Organising ways of keeping warm** *(10 minutes)* Note on the whiteboard the different suggestions students make. With students' help, organise these into categories, such as (from Primary Connections) See samples of class derived ideas below (note that this activity, and others in the sequence, draws inspiration from the Primary Connections unit 'Heating Up').	Can students nominate a variety of ways of keeping warm? Can they make links and distinctions between the different ways? Do students have detailed stories that can be drawn on, about how and why we keep warm?

Samples of class board work

Ways of keeping warm





Science: The distinction between heat producers and heat receivers **Mathematics** Organising patterns of phenomena	***Orienting*** Students learn to notice that some things produce heat and others get hot from external sources ***Posing representational challenges*** Students are challenged to organise hot things into categories ***Building consensus*** Students share, compare, evaluate each other's ideas and the teacher synthesises these	**Whole class: Heat producers and heat receivers** *(20 minutes)* **Overall questions** ❖ *How can heat be produced/made in different ways?* ❖ *How can heat move from one object to another?* **Probing question** ❖ *What things around the house can you think of that are hot or can get hot?* ❖ *How does that happen?* Construct a list on the board. ❖ *How might we best organise our information?* (Enter student ideas on board) Move the discussion toward the distinction between heat producers (things that produce heat themselves- a fire, or toaster), and heat receivers (that are warmed by something else-e.g. a pot of water on a stove, something in the sun). Jointly, on the board, *classify some different objects* in the examples. **Student book task** *(15 minutes)* Ask students to complete the task of classification in their workbooks. Organise in your student workbook these ways to warm up into things that are similar and things that are different. ❖ *What differences can you see? Which are similar?* **Class sharing/discussion of bookwork & student ideas**	Can students distinguish between different categories of hot things, from their experience? Can students talk about heat as something that flows to an object, or something that an object can create? Can students articulate distinctions between objects creating heat, and receiving heat from outside? Can they justify their responses?
The lesson could be broken at this point if only 60 minute time slots are available			

Science: Representing and interpreting heat transfer	***Posing representational challenges*** Students are challenged to represent heat transfer for different examples	**Student Representation: Representing heat flow** *(20 minutes)* Choose three examples from the previous list that include at least one external heat source (look for examples of the 3 heat sources; electricity, burning (chemical energy) & rubbing (friction) and at least one heat receiver. **Probing question for student book task (single students or groups)**: ❖ *How might we represent how these are warmed, or how they warm?* NB: Circulate and talk to students, and select some to draw out productive examples, OR conduct a student gallery walk **Representation Review & Discussion (whole class)** **Move** students towards an **arrow convention** to represent heat flowing into or from or between objects. Raise the question of what is causing the heat.	Can students represent, in different ways, the movement of heat between objects? Can students identify heat sources in different contexts? Can students agree on a convention for describing heat flow?
Science: Initial ideas about links between energy and heat and the transfer of heat	***Building consensus*** Consolidating understanding about different sources of heat through students generating examples	**Whole class discussion: Different ways of producing heat** *(15 minutes)* **Probing question (whole class)** ❖ *What causes the heat in these different situations we have on the board?* Discuss selected student examples of heat sources and establish the three ways in which heating occurs.ie. Electricity, burning (chemical energy), rubbing (Friction). Label the different heat sources appropriately. **Book Representation: Three ways of heating** *(15 minutes)* Challenge students to represent different things that use each of these three ways of heating in their books. e.g. Radiators, heating systems, toasters (electric), Fires, gas burners, a person exercising (chemical); Friction (rubbing hands, bike brakes, Kitchen appliance motors) **Class sharing and evaluation** *(10 minutes)* Share examples of what students have done… **Review questions** ❖ *What have we learned about heat?* ❖ *How do we keep warm?* ❖ *How is heat produced?* ❖ *How do we represent heat moving from one place to another?* **Next lesson:** inform the class what will be done in the second lesson.	Can students suggest and justify their accounts of different heat sources? Are students able to appropriately classify the different heat sources? Can students identify different situations where heat is controlled? Can students describe and classify the creation and transfer of heat with reasonable justifications?

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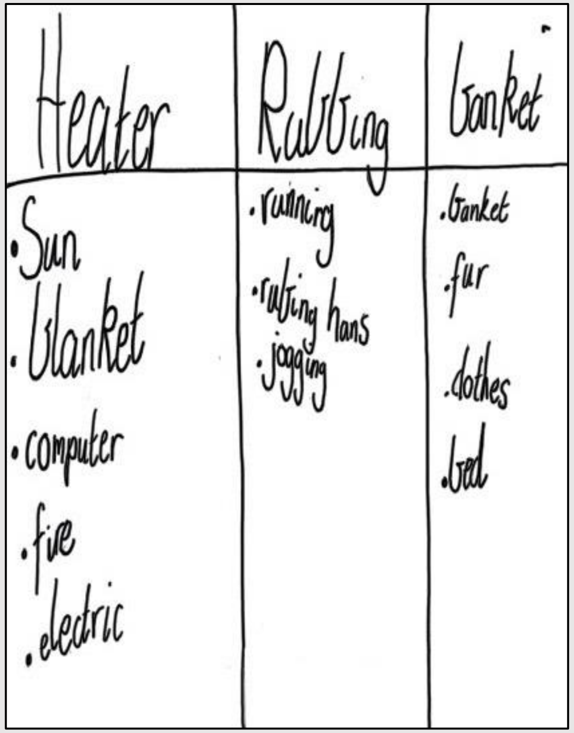
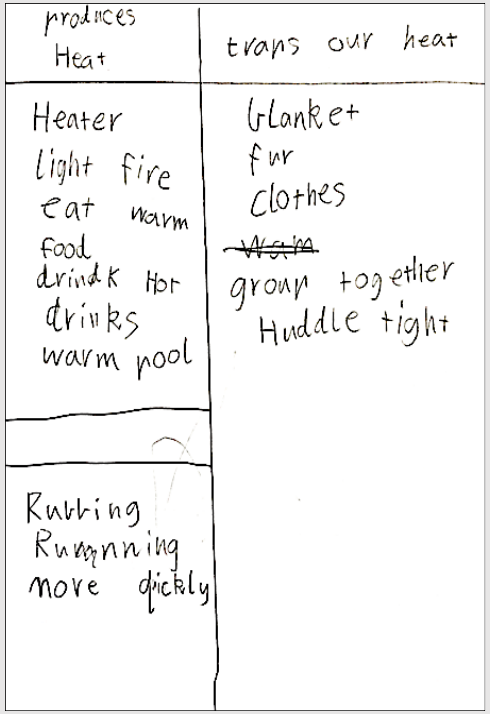
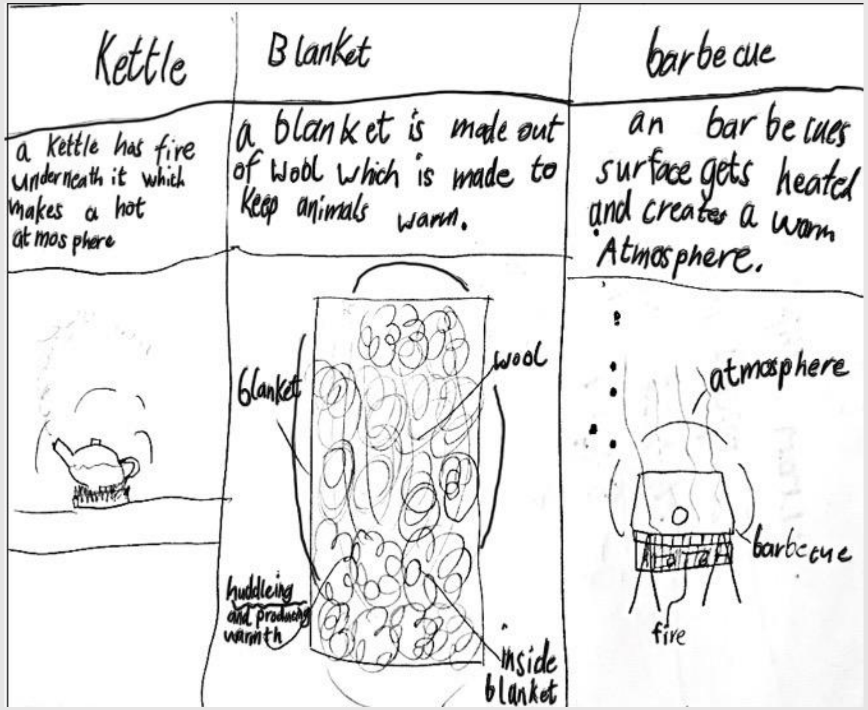
Samples of student work: bookwork

Tabulated examples and drawings







LESSON 2: How hot is it?

(Approximate duration: 120 minutes or 2 x 60 minute sessions)

Learning focus:

Science ideas and practices:

Temperature and temperature variation
Informal and formal temperature measures

Mathematics ideas and practices:

Inventing an informal measure of temperature
Mapping patterns of temperature

Learning Intention:

Students will experience and understand:

- How temperature varies in different places and on different parts of objects
- How to set up and represent an informal temperature scale
- Measuring temperature with a thermometer and mapping body temperatures

The lesson at a glance:

In this lesson students investigate different temperatures and variation using infrared images and explain these using heat exchange ideas. They construct a temperature scale, and produce data and represent and explain variations in temperature related to the body.

Equipment/Resources

Class set (one per small group) of thermometers.
If possible – one or more infrared cameras
2 sets of five plastic cups with water:
Cold water from fridge, ice water, warm water, cold water from tap, water left out on the bench, hot water from tap
6 or so warming clothing bits- gloves, or scarves

Infrared images (PPT)

Equipment required for all lessons
Students: student workbooks (unlined), pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

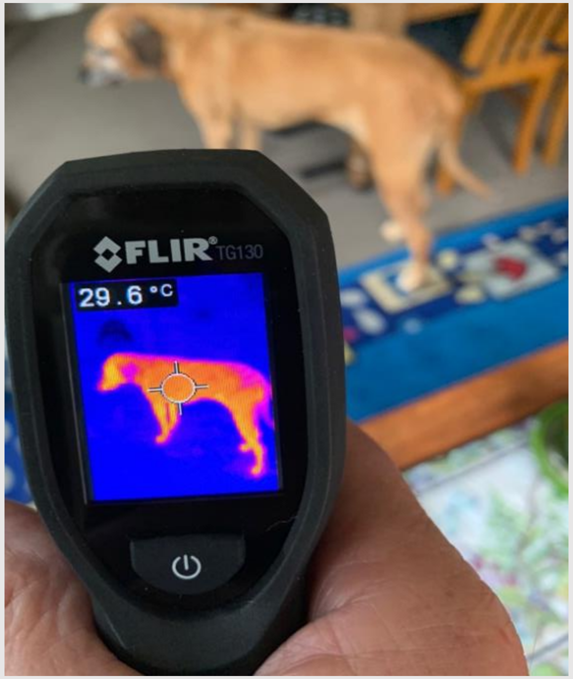
LESSON 2: How hot is it?

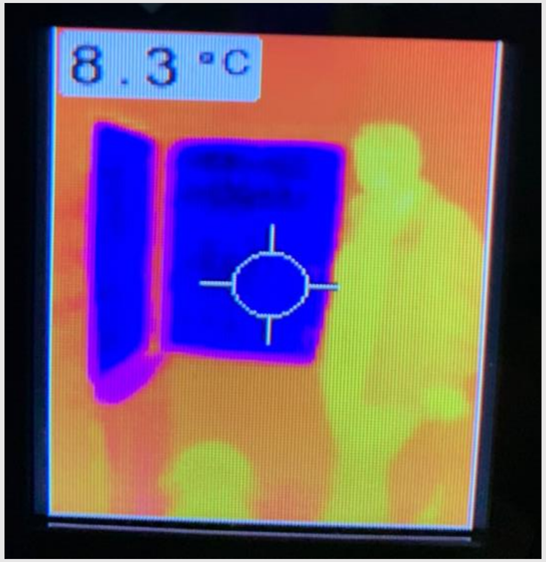
(Approximate duration: 120 minutes or 2 x 60 minute sessions)

Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
Science: Variation in temperature. Heat movement and exchange and its relation to temperature	***Orienting*** Establishing students' experience of temperature variation	**Class Discussion: Identifying hot and cold things and places** *(10 minutes)* Discuss the hot and cold things and places students are aware of (e.g. fridge, cold windy day, oven, sauna, bath, ocean, a person all rugged up, a hot day with the sun coming through glass) **Probing Question** ❖ *How do we measure how hot or cold things are? "* NB: Establish 'temperature' and 'degrees' as words that are important.	What experiences of hot and cold temperatures have children had to allow a focus on temperature scale and associated words? Do children have any sense of the temperature variation in places they are familiar with?
Science: Variation in temperature of different parts of objects Creating and interpreting infrared images	***Orienting*** Students notice consistent variations in temperature in images and recognise the use of a temperature scale	**Measuring temperature: hot and cold places** *(10 minutes max)* Show an infrared image of different objects (See PowerPoint). Explain the nature of the infrared camera (see the image). Explain how the different colours represent different temperatures. How does the dog's temperature vary? Where is it warmest? Why? Challenge students to interpret each image: ❖ *Which parts are hot or cold?* ❖ *What does the ^{0}C mean?* ❖ *Which are the hottest parts of the dog? Why is that?* ❖ *Why is the temperature varying on this image of a person?* ❖ *What variation in temperature can you see in the fridge image, and the block of ice in the hand?* NB: Establish the link with heat sources, such as a heater in the room, compared to a fridge which takes heat out of things, or that body extremities such as fingers, or a nose, are cooler because they are more exposed to the air.	Can students recognise the temperature variation in different objects. Can students come up with valid reasons why there is variation? – For instance: • The fridge and ice block are colder • Exposed parts of a body, such as ears, lose heat and are at a lower temperature • The clothes we wear are not hot in themselves – they stop heat escaping.

Sample infrared images

Possible Stimuli images





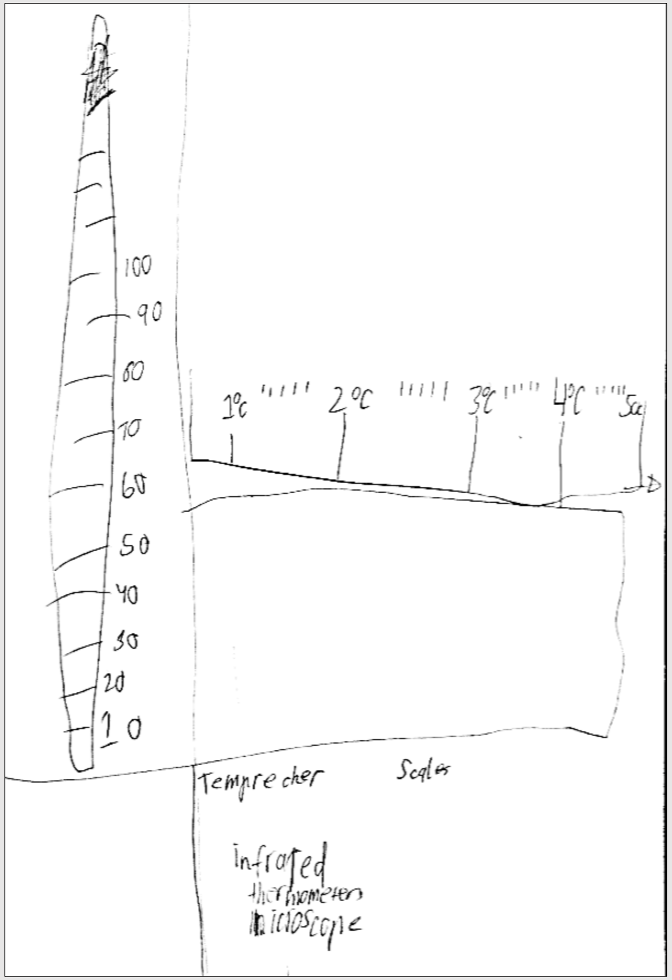
	Orienting Students consider the effect of clothing on temperature, raising questions about temperature measures	**Class Discussion (modelling infrared temperature)** *(10 minutes)* ***Our body temperatures – Blanket & Glove Investigation*** **Probing Question** ❖ *How does a glove keep our hands warm?* ❖ *Is the glove a warm object?* If an infrared camera is available, select students to measure the temperate of the glove with the infrared camera/recorder. Alternatively, show the image of two hands, one of which has a glove on. ❖ *Why does the hand in the glove appear cooler?* NB: Make students aware - gloves don't produce heat, but trap the heat from the body so heat is not lost to the air – The body is like a heat engine powered by food we eat.	Can students distinguish between feeling warm in clothing, whereas the clothing is not warm in itself? Can students appreciate that our bodies produce heat – are 'heat engines'?
Mathematics: Consideration of an informal temperature scale and identification of patterns in temperature	***Posing representational challenges*** Students explore and represent why there is temperature variation on objects	**Investigation – if there is an infrared camera available** *(15 minutes)* **Probing Question:** ❖ What other things we might get infrared images of, to explore what's happening. Provide through discussion some ideas of things to try. Each group should think about an interesting image and predict and explore. Be creative!! Help students produce images for discussion. Investigate infrared images of different places such as: • a bench with the sun on it (go outside possibly) • two hands, one rubbed and one not. • a surface with a hair drier on it (or with the sun on it). • people's heads - why are there different temperatures? • a box with a rug wrapped round it. **Representation: Statements** *(15 minutes)* Students write statements in their books about some hot and cold places, and represent these with drawings (e.g. if you rub your hands they become hotter; when you put your hand on something a warm handprint stays. If I rub the bench it gets warmer. If I put a rug on the bench it doesn't get warmer ….)	What have students experienced with the infrared camera (if available)? Can they develop a language to speculate about what is happening with heat and why there is variation? ❖ Insulation ❖ Absorption ❖ Conduction ❖ 'trapping' Can they express the idea of variation in temperature diagrammatically? Can they suggest different things to make surfaces/people warmer?
		The lesson could be broken at this point if only 60 minute time slots are available	

		Investigation Equipment *Class set (one per small group) of thermometers. If possible – one or more infrared cameras; 2 sets of five plastic cups with water: Cold water from fridge, ice water, warm water, cold water from tap, water left out on the bench, hot water from tap 6 or so warming clothing bits- gloves, or scarves.*	
Mathematics: Formal and informal measures Measurement processes Data tabulation and representation **Science:** Variation in temperature of objects. Factors determining temperature	***Posing representational challenges*** Students explore temperatures and construct, and represent a formal/informal temperature scale	**Establishing a temperature scale** *(20 minutes)* Whole Class Demonstration & Group Thermometer Exploration: Demonstrate and explain the use of a thermometer Work with the class to show them how to read the thermometer. Introduce Task "We are going to construct a temperature scale" **Probing Questions:** ❖ What are some hot places we could explore? ❖ We have water at different temperatures – will explore that. ❖ What are some colder places we could explore. ❖ What will we record? ❖ How will we record it? (Get class agreement on a way to represent their results as a class set on the board) ❖ Temperature, where it is, what's causing it to be hot or cold? Suggest and make available: cold water from fridge, ice water, warm water, cold water from tap, water left out on the bench, a warm place in the room e.g. sun on a bench, cold place in a room, temperature of the body, inside clothing e.g. under the arm Construct a list of places on the board. Students predict, for at least a few of these, what the temperature might be. Groups are assigned thermometers and measure different places on the list. The list should be in the form of a table with a place for groups to enter temperature. **Student Representation: Temperature scale** *(10 minutes)* Using the class results, each child (working in a group) constructs a representation of an informal temperature scale, for a variety of places that were investigated. **Probing questions** ❖ How can we line up the different places to show a temperature scale? ❖ What do we need to think about? (having an interval scale). ❖ Should the scale be horizontal or vertical? (Students can decide).	Do students have reasonable suggestions for hot and cold places? Can they suggest ways to measure temperature, safety procedures, and ways of recording class results? (Can students suggest a table as a data entry device?) How well are students able to predict temperatures? Can students suggest an interval scale for temperature to lay out the temperatures of the different places? (Do not impose this, but acknowledge such suggestions). Can they explain what the benefits of an interval scale are?

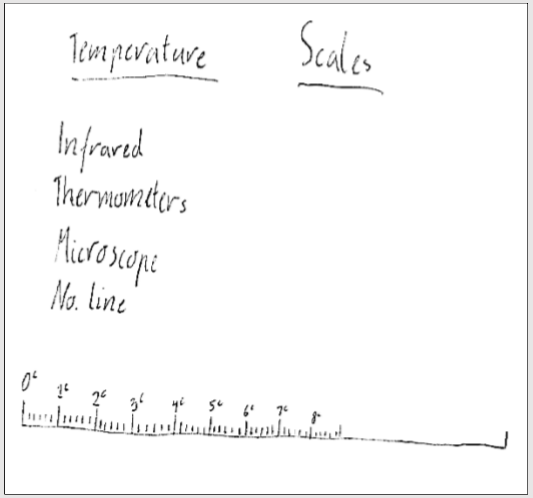
Samples of student work: bookwork

Examples of different temperature scales.

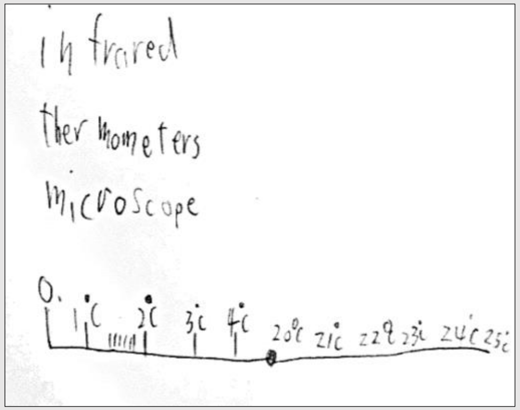
NB: Student incomplete data and many students only representing low temperatures



Representing low temperatures only



Limited and low temperature range



Greater temperature range, uneven increments

Use of arrows to indicate increasing temperatures, counting in tens

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Science & mathematics: Constructing an interval temperature scale	***Building consensus:*** Students share and compare their different constructions of a scale. The teacher guides a consensus version of the scale	**Whole Class: Teacher lead Discussion and Student Sharing** *(5 minutes)* **Select students to share their scales** Students compare and contrast others' representations and ideas. ❖ *What can you tell from the different representations?* ❖ *How effective are they?* ❖ *What do they show?* ❖ *What don't they show?* ❖ *What features are helpful?* **Teacher Guided joint construction– Board Temperature Scale (clean version)** Construct, on the board, a clean version of the temperature scale with different places marked in (NB: numberline with equal intervals)	What aspects of students' scales are clear and informative? Can students suggest, and appreciate the advantage of an interval scale?
Science: Heat transfer, temperature scale **Mathematics** Constructing temperature maps to show patterns in data	***Applying and extending conceptual understanding:*** Students use their ideas of temperature scale, and heat transfer, to represent and explain the variation in temperature on bodies	**Group Investigation & Representation: Body Temperature** *(15 minutes)* Groups investigate the temperature of their bodies and the effect of clothing & represent their findings in their books **Probing questions** ❖ *Why are different places on our bodies at different temperatures?* ❖ *How do we keep ourselves warm?* Students investigate and represent the temperature of different parts of the body- tip of nose, neck, under arm, bare hand compared to hand in glove. Students record (reading their thermometers) & represent the different temperature readings (body & location) Each student constructs a 'Temperature map of the body' in their books. Students annotate their map with brief explanations of why different places are at different temperatures, and represent why in terms of heat transfer. **Probing questions** ❖ What happens when you put on a jumper, or a beany? ❖ Why is it warm under our arms?	Can students select places to measure temperature in a deliberate way? Can students represent their patterns of temperature on body maps in a way that shows key variation?

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	Building consensus The teacher guides a shared understanding of the temperature variation and reasons for this in terms of heat exchange	**Gallery Walk and teacher led discussion** *(10 minutes)* Students compare and contrast others' representations and ideas. ❖ *What can you tell from the different representations?* ❖ *How effective are they?* ❖ *What do they show?* ❖ *What don't they show?* ❖ *What features are helpful?* **Review question** ❖ *What are the reasons for differences in temperatures?* **Joint construction (from student ideas)** Construct on the board a representation of a body with clothing, and representations of why different parts are at different temperature.	Can students use heat exchange ideas, or the idea of trapping heat, to explain variation in body temperatures? Can students represent heat exchange processes using arrows or other means?

Samples of student work: Student body maps and a photograph of teacher's work on the board.

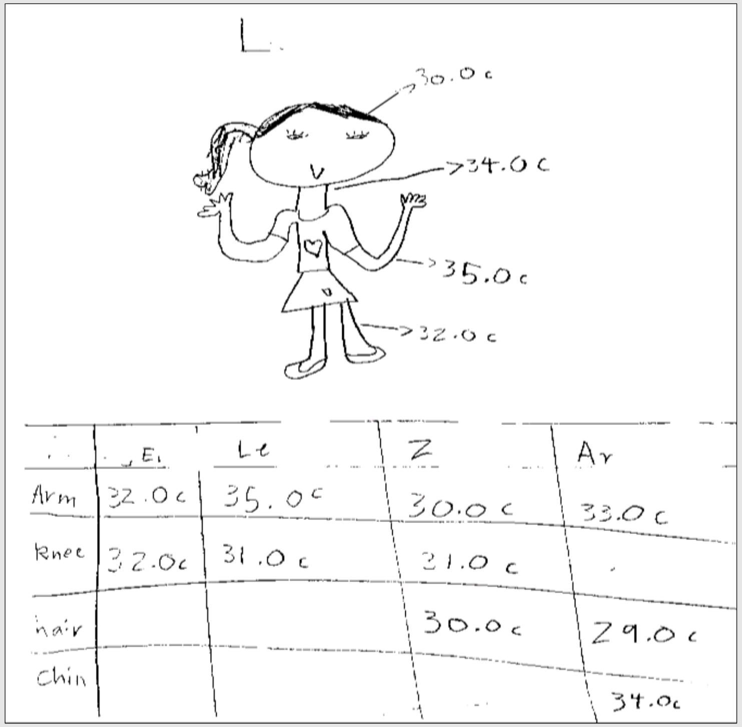
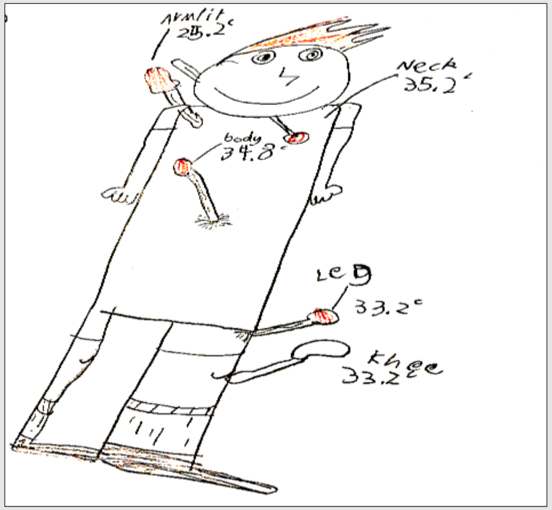
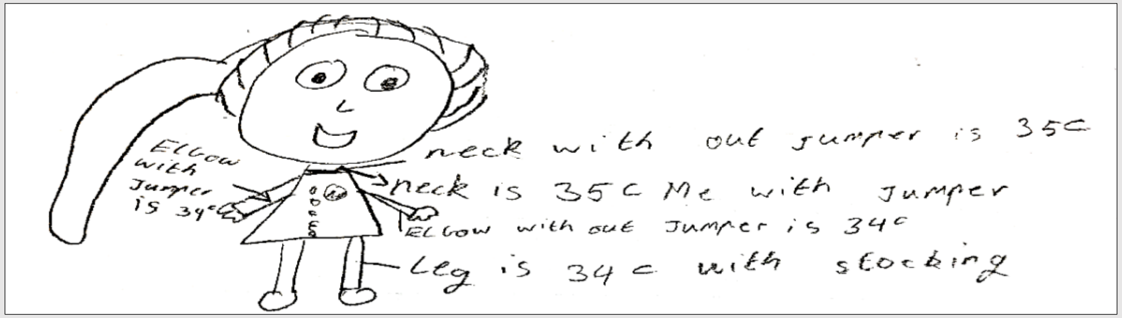


Table to compare different students body part temperatures as well as a diagrammatic body temperature representation



Use of colour to represent temperature scale. No legend or explanatory labeling of colour corresponding temperature representation though



LESSON 3: How does heat travel through different spoons?

(Approximate duration: 120 minutes or 2 x 60 minute sessions)

Learning focus

Science ideas and practices

Heat transfer
Conductors and insulators
Investigation: planning and conducting and interpreting

Mathematics ideas and practices

Constructing tables with two conditions
Inventing an informal measure of temperature

Learning Intention:

Students will experience and understand:

- heat transference, that different materials conduct heat differently and heat can be maintained through insulation
- the relationship between heat and particle movement and energy
- The affordances of tables and graphs to record and model data
- The construction and use of informal temperature scales

Equipment/Resources

Plastic cups 6
Metal teaspoons 6 (teaspoon size)
Wooden spoons 3 (teaspoon size)
Plastic spoons 3 (teaspoon size)
Source of hot water

Equipment required for all lessons
Students: student workbooks (unlined), pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

The lesson at a glance:

In this lesson students investigate heat transfer through metal compared to wood or plastic. They construct and use an informal temperature scale, and develop and use tables to organise and investigation, and line graphs to compare temperature vs. time. They develop a particle model of heat transfer.

LESSON 3: How does heat travel through different spoons?

(Approximate duration: 120 minutes or 2 x 60 minute sessions)

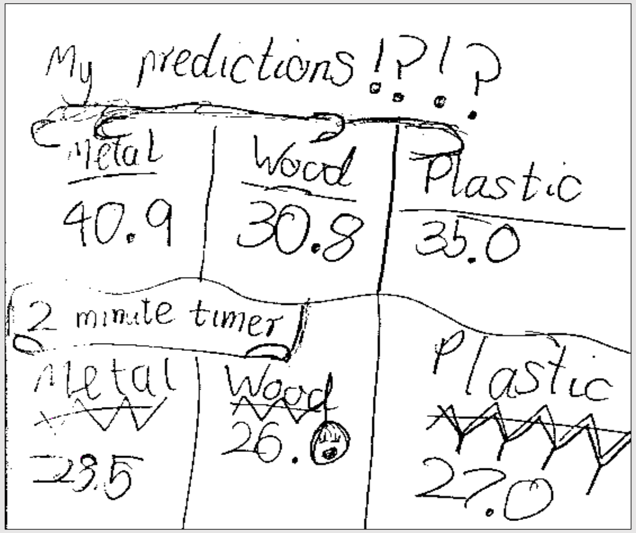
Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
Science: Metals conduct heat more readily than other substances	***Orienting*** Students are alerted to the fact that different materials respond differently to heat Students consider how this phenomenon might be investigated	**How does heat transfer along different materials?** *(10 minutes)* **Probing Question** ❖ *What kind of spoon gets hot when you put it in hot water?* ❖ *What kinds of things gets hot when they sit in the sun?* Jointly construct on the board student responses about differences in how different types of materials respond to heat. ❖ *How can we test these different ideas?* NB: Students often incorrectly think metals are good insulators, drawing on metal vacuum flask experiences. **Introduce the Spoon Heat Transfer Activity** We will investigate to see what type of spoon gets hottest	What have students experienced about the difference in response to heat between metals and other substances? What are the alternative conceptions students have about heat conduction? Are students thinking of heat as something that can be transferred from one object to another?
Science: Experimental design, control of variables **Mathematics:** Predicting and designing measures of temperature and time	***Orienting*** Students are oriented to the needs of comparing spoons and measuring ***Posing representational challenges*** Students are prepared to think about how they will organise their data and thus what data is generated and how	**Discussing Investigation Design; establishing informal measures** *(15 minutes)* Develop ideas on how the measurements will be recorded ❖ *How could we conduct an experiment to compare different spoons and how hot they get in hot water?* ❖ *What are we comparing? (material of the spoon)* ❖ *What will we measure (the hotness of the end of the spoon)* ❖ *How will we measure it?* Jointly construct with the class an informal scale of temperature, for example: • Cold • Cool • Slightly warm • Warm • A bit hot • Hot	Can students: a. Appreciate the purpose of the experiment and plan a fair test? b. Develop a plan for judging temperature? Can students suggest the need to construct a scale that orders temperature meaningfully?

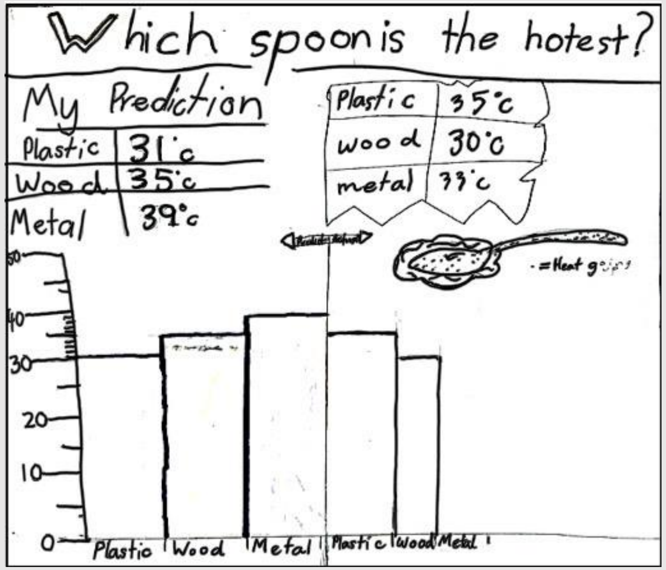
		❖ *What will need to be the same in each case? (*Fair test and comparison: temperature of water, amount of water, time the temperature is measured*)* ❖ *How will we measure the time?* (Teacher reviews timing measure) ❖ *How will we record our results?* NB: Encourage the idea of graphing, and open up the idea of a line graph (don't impose- it would be useful to have some variation). ❖ *How will we represent any change?* (measure the temperature at the start before the spoon is put in, and after 30 sec, 1 minute, 1 min 30, 2 minutes ...)	Are students able to suggest construction of a table that records the temperature over time for both spoons?
Mathematics: Predictive representations Constructing line graphs Data modelling to compare measures of temperature over time	***Posing representational challenges*** Students engage with the meaning of the line graph as a representation that captures temperature change differences ***Building consensus:*** Synthesising student ideas to establish the affordances of line graphs for identifying patterns	**Investigation Prediction Representation (bookwork)** *(10 minutes)* Students represent what they think will happen with the temperature over 2 minutes. ❖ *How will the temperature change of different spoons be different?* ❖ *What will the graphs of the changing temperatures of each spoon over two minutes look like* **Class sharing and discussion** *(10 minutes)* ❖ *Which graphs show what we think will happen?* Jointly construct on the board an agreed prediction of how a graph might look.	Can students represent their ideas of changing temperature using a bar or line graph? Can they predict comparisons through graphical means? Can students construct a temperature-time graph that shows comparative trends? What variation in students' work can be drawn on to discuss possible ways of representing?

Samples of student work

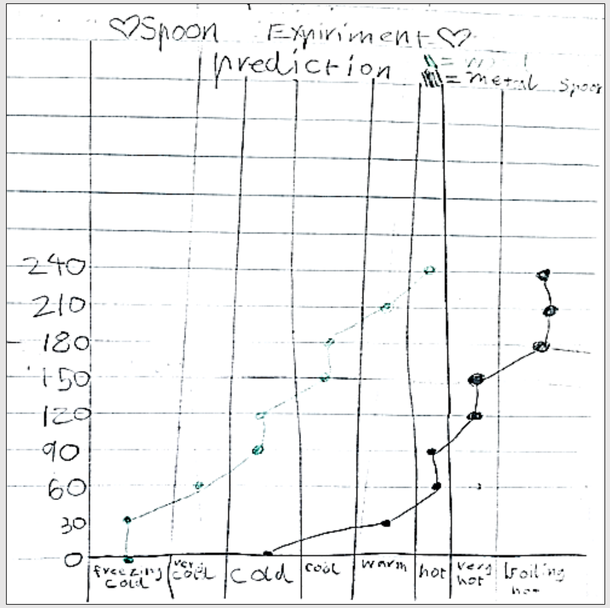
Examples showing the range of student predictions

NB – Students did not formally measure with a thermometer. Many students however wrote 'guesses' in degrees in their representations





Student added increments to the right axis (time minutes), however confusion with time and temperature representation. No temperature (informal) reference - horizontal axis different spoons.



Student representing informal change in temperature (horizontal axis) over time (vertical axis – time). Informally comparing the prediction to actual temperature.

Science: Planning investigations **Mathematics:** Constructing appropriate data displays Conceptualising the use of an informal temperature scale	***Posing representational challenges*** Planning for measuring and recording practices.	**Investigation Preparation: Spoons heating up** *(15 minutes)* *Equipment: 6 groups x (1 metal spoon, 1 plastic spoon, 1 plastic cup, hot water)* Each group has a metal spoon (teaspoon) and EITHER a plastic or wooden spoon. Students will make informal measures, using touch, of how hot the end of the spoon is, at 30 second intervals, to see differences in how heat travels up the metal spoons. ❖ *What do you think will happen?* ❖ *How will you record your results?* Students feel the end of the spoon at 30 sec intervals for 3 minutes, using a scale – cool, slightly warm, warm, a bit hot, hot. **Data Recording Preparation** Students construct their tables in readiness for recording the temperatures over time.	Can students organise to conduct a series of measurements and record results? What variation is there in students' representations? Can students set up data tables in an organised way to compare results?

At this point the lesson could be broken and the investigation pursued in a second 60 minute lesson

		Equipment: *Thermometers – 6 per class; Plastic cups 6; Metal teaspoons 6; Wooden spoons 3; Plastic spoons 3; Source of hot water*	
Science: Planning and conducting investigations Devising valid measurement processes **Mathematics:** Representing results in tables, and transferring to graphical representations.	***Posing representational challenges*** Students measure and record their data in an organised way Students represent their ideas about how the handles get hot at different rates	**Conducting the Investigation (groups)** *(20 minutes)* Groups conduct their spoon Investigation and represent findings Students are supported to measure (using the agreed informal scale) the how hot the ends of the different spoons are at each point in time. Students enter their data each 30 seconds. The teacher manages the timing so every student is reminded when to touch the spoon handles and enter results. Recording the hotness: Students record how hot the handle is, for each spoon, every 30 seconds over 3-4 minutes. Students represent their results in a table and then on a graph Students write their result – which spoon gets hottest? Students interpret their result: they construct a representation of what's happening to make the metal spoon heat up.	**Questions to consider when circulating** Can students organise their measures systematically? Can students describe what is happening and point to their data tables and graphs to illustrate the trends? Can students describe their ideas about how heat transfers up the spoon or not?
Mathematics: Using and interpreting line graphs to represent change over time **Science:** Representing the movement of heat through a substance, linked to temperature	**Building consensus** Assessing and synthesising students' ideas and representations Refining and consolidating representations and understandings	**Sharing and discussing results and representations** *(10 minutes)* **Gallery walk** Students compare and contrast others' representations and ideas. ❖ *What can you tell from the different representations?* ❖ *How effective are they?* ❖ *What do they show?* ❖ *What don't they show?* Co-construct on the board a representation of the typical pattern for each spoon, on the same graph (line graph) On the board also co-construct a representation of heat passing along the spoons (based on students' ideas about what is happening).	Can students construct and interpret graphs representing change over time? Can students appreciate the power of a line graph? Can students represent the passage of heat through a conducting material, for instance using arrows?

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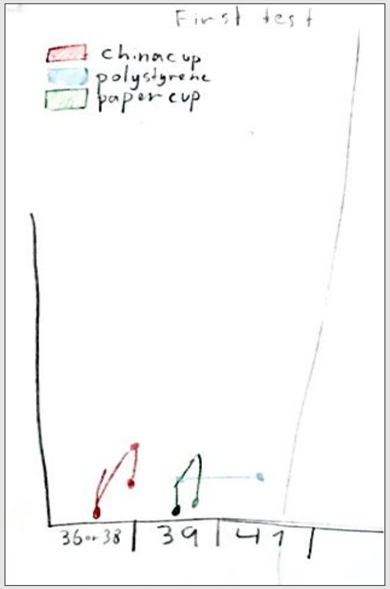
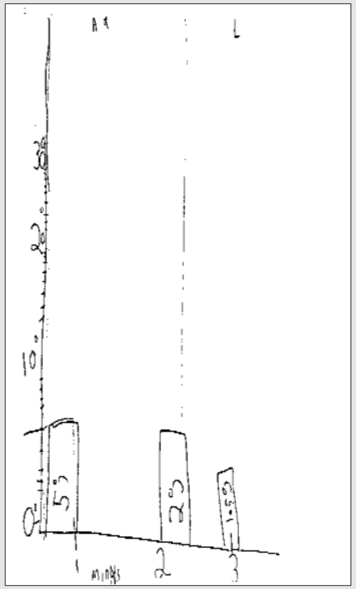
Samples of student work

Examples of students' graphical work showing variation.

NB – Students did not formally measure with a thermometer. Many students however wrote 'guesses' in degrees in their representations



Example of a legend for different spoons and no vertical axis and 'made up' temperatures



Incomplete and inaccurate data

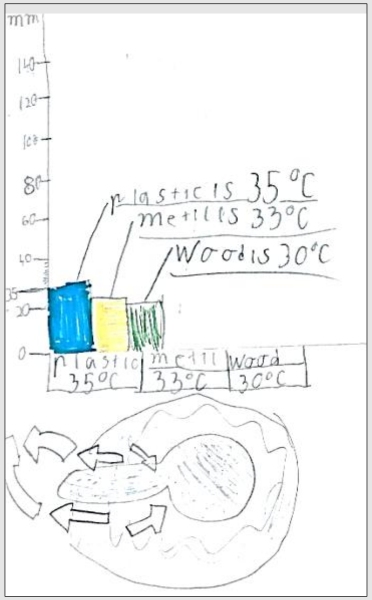
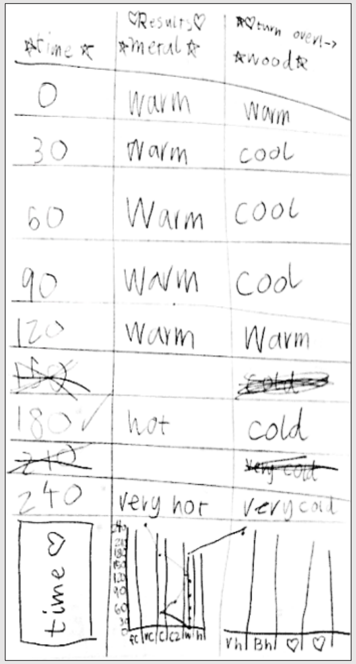
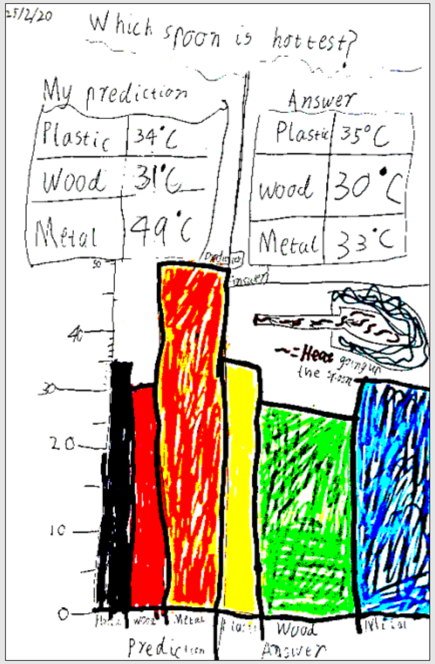


Diagram representing heat traveling up the spoon. Colour coded results and 'made up'

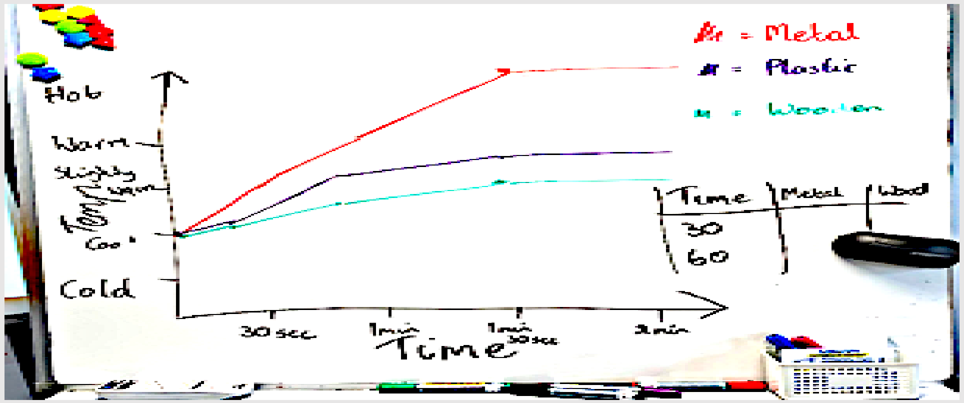


Use of informal measures for comparison over time (30s periods) with a line graph representation



Student table and bar graph comparison of predicted data and 'formalised guesses' of informal temperature

Sample of board work illustrative of what the teacher might pull together



Science: Interpreting the movement of heat through a substance using particle ideas. Temperature as the degree of motion of particles.	***Extending conceptual understanding*** Posing new representational challenges, in this case an embodied understanding of particle interpretations of heat and temperature Translating the role play into diagrammatic form ***Building consensus*** Sharing, evaluating and synthesising representations and ideas Refining and consolidating representations and concepts	**Role play of heat conduction using students' bodies** *(5 minutes)* Inform students – Spoons are made up of particles, they are so small we can't see them Role play - Direct students to form a spoon with their bodies, with one end being the end that will go into the water – 'going to the hot water'… "Let's pretend we are particles of a spoon, a spoon is a solid, particles of a spoon are fixed, they don't move. When they are heated up though they jiggle, they get energy". "The particles bump into each other as they get more heat energy, and the jiggling spreads along the spoon" (like dominos the jiggling will go up the spoon – heat transference) **Students Representations** *(10 minutes)* **Drawing, heat conduction in their books:** Represent the heat traveling up the spoon using the particle idea, using drawing and writing. **Sharing and evaluating representations** *(5 minutes)* Student work is selected to compare and share ideas. ❖ *What does the representation show? What doesn't it show?* ❖ *Which representations help us understand what's happening?* **Whole class: Final representation on board** *(10 minutes)* Sample student representations are selected to co-construct a drawing on the board, and a summary statement.	 Can students imagine the particles jiggling as the metal becomes hot, and transferring up the spoon? How can we imagine what's happening with a wooden spoon? The particles can't easily bump into each other? Can students translate from the role play to a diagram of heat transfer using particle ideas? Can they represent temperature as movement of particles? Can students use the idea of heat being conducted through a material at different rates, to explain the difference?

LESSON 4: Keeping the heat in

(Approximate duration 90 minutes or 2 x 45 minutes)

Learning focus

Science ideas and practices:
Heat transfer, conduction and insulation
Investigation: planning and conducting and interpreting

Mathematics ideas and practices:
Constructing tables with two conditions
Constructing and interpreting line graphs to compare rates of cooling

Learning Intention:

Students design insulation for a paper cup to experience and understand:

- heat transference, that different materials conduct heat differently and heat can be maintained through insulation
- How to represent the passage of heat through materials
- planning and conducting a controlled investigation, measuring and recording data.
- The affordances of tables and graphs to record and graphically model data
- The construction and use of informal temperature scales

Equipment/Resources

6 thermometers (12 is better)
12 paper cups (2 for each of 6 groups)
Material for insulating the cup:
Aluminum foil
Cardboard
Flexible foam
Tape and scissors (one each per group)
Source of hot water

Equipment required for all lessons
Students: student workbooks (unlined), pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers paper for shared recording and pens

The lesson at a glance:

In this lesson students consider heat transfer processes, conduction and insulation to re-design a paper cup using insulating materials, to keep a cup of hot chocolate hot for as long as possible. They plan measurement of temperature over time, data entry processes and devise line graphs to track the cooling of hot water in the design cup compared to a control cup. They explain their findings using heat transfer representations.

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LESSON 4: Keeping the heat in

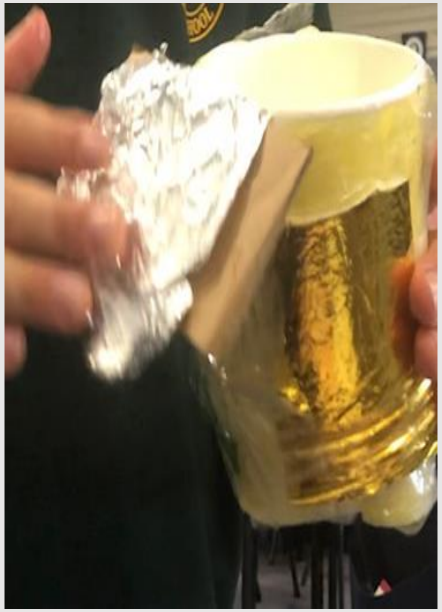
(Approximate duration 90 minutes or 2 x 45 minutes)

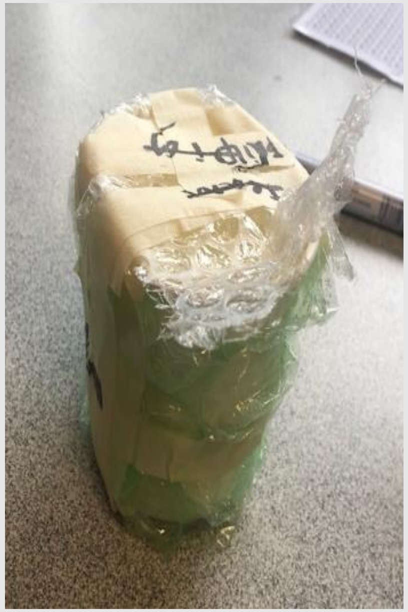
Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
Science: Heat conduction through different materials Heat transfer	***Orienting*** Students discuss their experience of hot drinks cooling down	**Class Challenge: Keeping the warmth in** *(10 minutes)* **Probing Question:** ❖ *What sort of cup keeps hot drink from getting cold?* "Let's pretend the water/cup is really a cup of hot chocolate… " Describe the scenario – How could we keep a cup of hot chocolate hot in winter? **Question:** ❖ *How hot is a freshly made cup of hot chocolate?* ❖ *How long does it normally take to cool down so you can sip it?* The teacher could model this to test their predictions. The groups will compare the cooling pattern for a paper cup, and a 'design cup' that is designed to keep the drink hot using various materials. • Students suggest ideas for insulating the paper cup, their reasons for that, and what will cause the difference. • Note students' suggestions on the board – with attention to language of 'insulation, conduction, trapping etc. • As appropriate, sketch students' ideas on the board under the heading "What could we do to keep the drink in the paper cup warm?" NB: the main feature that makes a difference is the lid. Wrapping in foam also helps. Alfoil also seems to help although metals conduct heat.	What have students experienced of hot cups, and the transfer of heat. Can they develop a language to speculate about what is happening? ❖ Insulation ❖ Absorption ❖ Conduction ❖ 'trapping' Can they express the idea of transfer of heat diagrammatically? Can they suggest different things to keep the cup warm?

Science Investigative design. Inquiry skills **Mathematics;** Measurement of temperature – formal measures Measuring and representing time Organisation of data	***Orienting*** Planning for measurement and recording	**Group Investigation: Testing students' Ideas** *(10 minutes)* **What keeps warmth in?** Discuss the design of a controlled experiment, measurement procedures and recording method, for testing the cup design ❖ *What is being changed, to compare?* ❖ *What needs to be the same?* ❖ *What will we do? How often will we measure?* (2 minutes would be appropriate, but 1 min or 3 min would work) . ❖ *How will we keep track of the time?* (Teacher should manage timing, with a countdown into each measuring event) ❖ *How will we record?* (table with recording at time intervals) ❖ *How will we present results?* **Write the two main questions on the board:** ❖ *Which type of cup keeps a hot drink hot for longest?* ❖ *Does a lid help in keeping a hot drink hot?* Discuss the difficulty encountered in lesson 3 in using informal judgments of temperature (It's hard to judge. Everyone has a different version of 'warm' …) ❖ *What is the advantage of a formal temperature scale?*	Can students design a controlled test? Can students suggest ways of measuring over time? Can students predict what might happen?
Mathematics: Graphical construction and interpretation **Science:** Predicting experimental results, based on ideas of heat transfer, insulation	***Posing representational challenges*** Students predict, invent ways of recording data, invent a graphical display Sharing and evaluation of graphical representation	**Predictions and design a data table** *(20 minutes)* ❖ *What we think will happen?* Students write their predictions and reasons in the books using text and drawing, in their books. Encourage the sketching of line graphs of temperature over time, as prediction Students set up a recording table. Circulate and check their work as they begin the experiment. Before starting, select a sample of students' work to draw attention to different ways students constructed graphs to predict what would happen.	Can students write a prediction, and represent this by graphical means? Can students suggest and construct ways of systematically recording data? Can students construct a line graph to represent their predictions? Focus on form of graph with time on horizontal axis
At this point the lesson could be broken and the investigation pursued in a second 45 minute lesson			

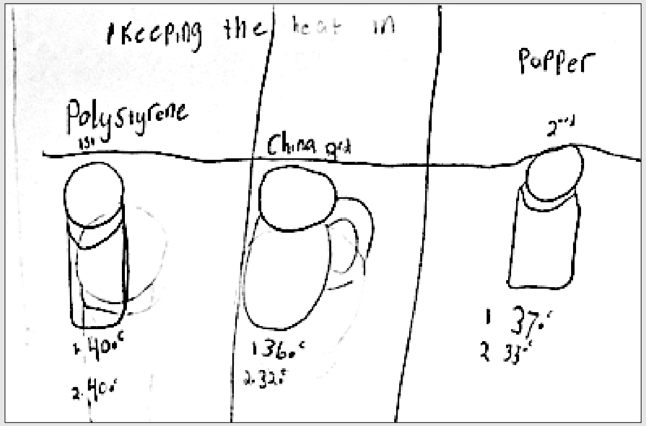
Science: Inquiry skills: conducting investigations, measuring, recording, communicating. Heat transfer, insulation and conduction **Mathematics:** Measurement Data modelling	***Posing representational challenges*** Students represent results in data tables, construct graphical representations, and also explain using a diagram how their design cup works	**Conducting the investigation: Students construct their 'design cup'** *(20 minutes)* Preparation: Hot water (not boiling, but hot bath temperature is best) needs to be poured into the cups at the same time. NB: Please beware Teacher guided whole class timing. Prompt students to 'start' when they are all ready, and each 2 minutes give a count down. If each group has one thermometer they will need to measure first one cup and then the other. Students need to let the thermometer temperature settle for 20s or so before reading the second cup. An alternative is for the teacher to conduct the comparison measure of the paper cup without insulation, so that each group only needs to track their own cup's temperature. In that case they can leave the thermometer in the water. **Questions on circulating**: ❖ *Why did you design it that way?* ❖ *Have you left a hole, or method for putting hot water in?* ❖ *Where does the thermometer go?* Each group tests the paper cup and design cup Groups measure & record the temperature of their water in each cup at 2 minute intervals (entering results in their table) **Groups represent & explain their results in their books** *(15 minutes)* This includes: 1. The table of temperature measures at the different times, including the control cup 2. a graph of the data (a line graph is more effective) 3. Representation showing why their results happened 4. Statement – explanation	Can students organise their measures? Can they record systematically? Can students construct a line graph? Can students suggest a reasoned explanation of differences? Can students sensibly represent heat transfer, insulation in a diagrammatic form?

Samples of student designs: Student design cups

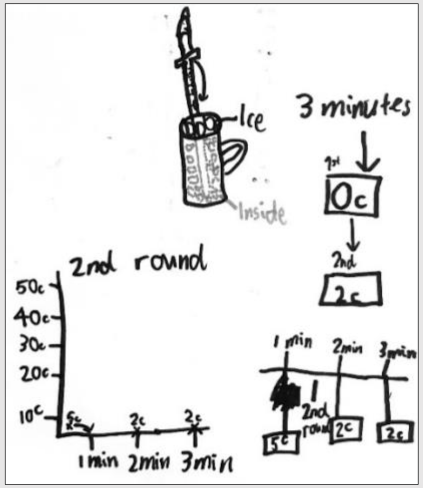




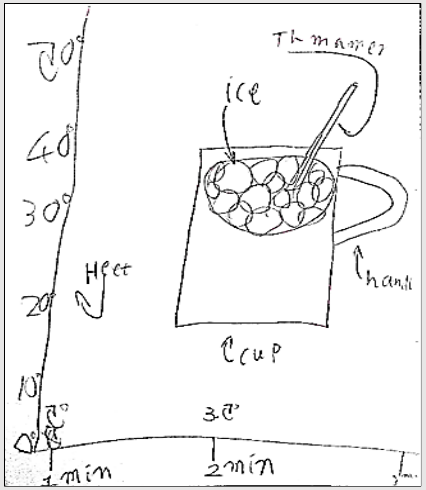
Samples of student work: Students recordings and representations



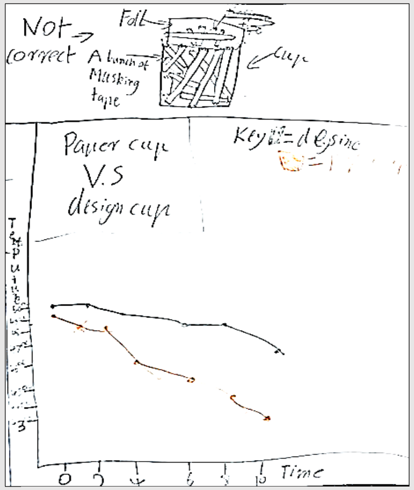
Keeping heat in comparison – labeled difference in design and no change over time represented.



Slowing increasing temperature represented, incomplete data.

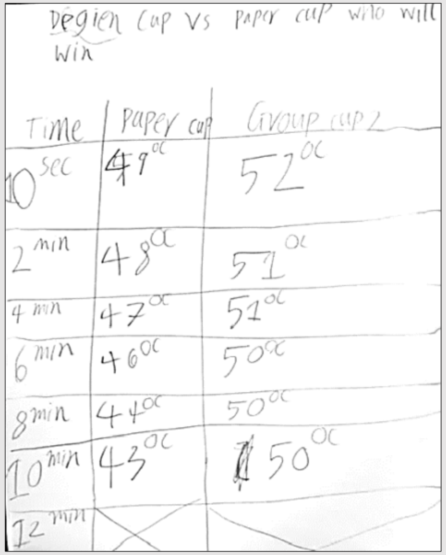


Incoplete data with unnamed axis. Some numbers inverted.

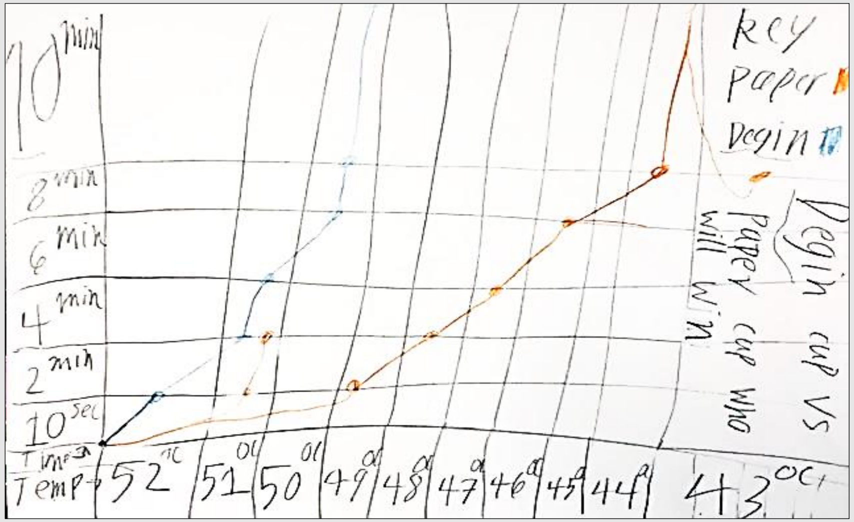


Line graph of recorded dropping temperatures and comparing their design and control cup.

Student decided a line graph more appropriate adding a ‘line graph layer to their bar graph.
Using ‘rate’ with reference to time.



Tabulated comparison of a standard paper cup and the design cup.



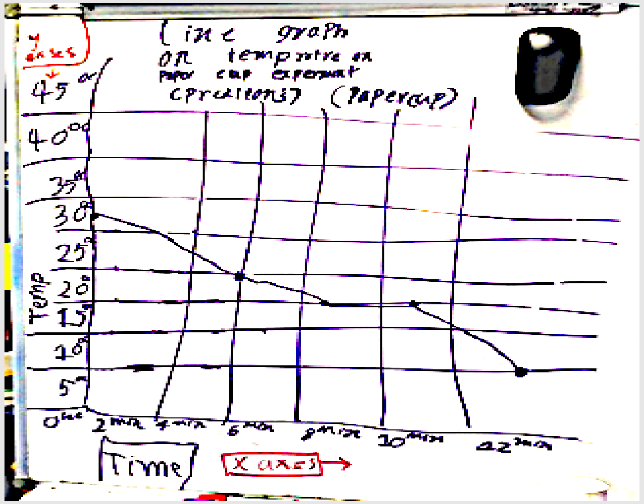
Line graph comparing control (paper) cup and design. The reverse of these axis may visually represent the falling temperature more effectively.

Developed as part of the Australian Research Council Project: Enhancing Mathematics and Science Learning: An Interdisciplinary Approach https://imslearning.org Deakin, Macquarie, and Vanderbilt Universities.

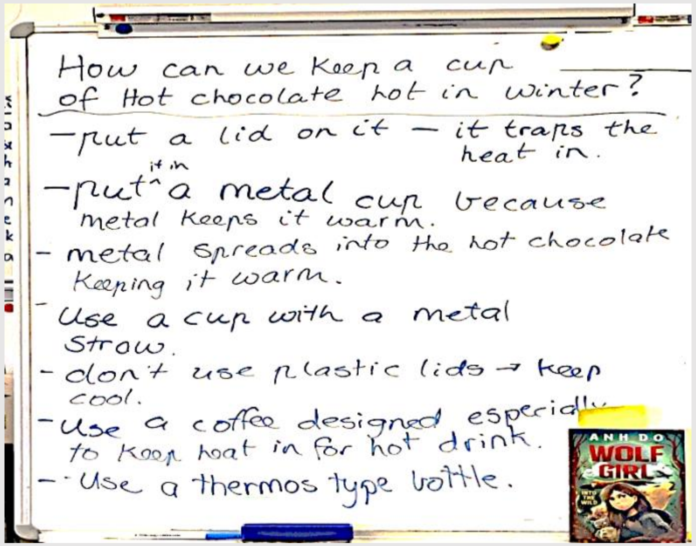
Science: Inquiry skills: recording, communicating. Heat transfer, insulation and conduction Representational competence **Mathematics:** Constructing and interpreting line graphs	***Building consensus*** Comparing, evaluating and synthesising findings. Refining and consolidating concepts of heat transfer and insulation	**Groups share their productions** *(10 minutes)* **Gallery Walk** (5minutes) Each group (or teacher selected groups) presents/shares their findings Discussion should centre on ❖ *Which data tables are particularly clear?* ❖ *Which graphs show the results clearly?* ❖ *Which cups seem to work well?* ❖ *What is the reason for that? How do the successful design cups work?* **Joint construction on board** On the board, with students' help construct a line graph summarising the patterns of data, write a final statement summarising the findings: ❖ *Which cup is best at keeping the hot drink hot?* ❖ *Why does that work?* ❖ *How do we represent what's happening?* **Further question:** Would we get the same result for which cup best keeps cold drinks from warming up?	Focus on: Clear data displays – layout, labelling Graphs – axes, clear distinction between conditions Representations of heat transfer and development of language Can students use the results to suggest the key factors involved in keeping the water warm? Can they articulate the effect of the lid, in terms of trapping heat? Can they represent that? Can they effectively use words like 'insulate', 'heat flow', ' trapping' heat?

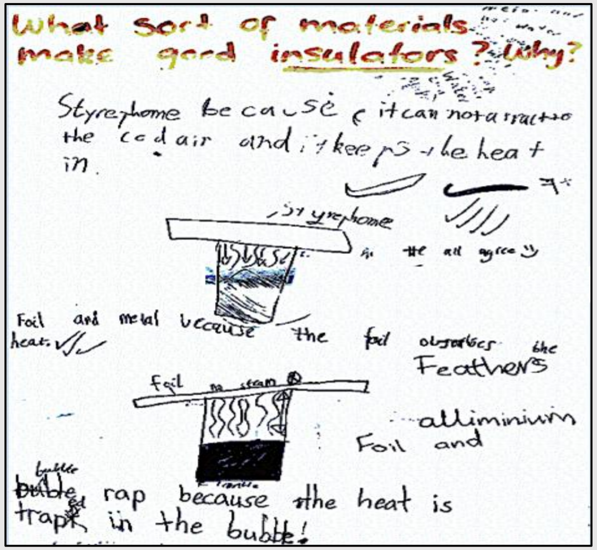
Samples of class work

Student composed, shared data and agreement



Student composed, shared data line graph





Teacher recorded student agreed statements – "How can we keep a cup warm?"

LESSON 5: The iceblock challenge

(Approximate duration 90 minutes: This could be split into a 30 minute lesson followed by a 60 minute lesson)

Learning focus

Science ideas and practices:
Heat transfer, insulation
Investigation: planning and conducting and interpreting

Mathematics ideas and practices:
Constructing tables with two conditions
Constructing and interpreting linear graphs

Learning Intention:

Students learn about the insulation characteristics of different materials and construct representations of heat transfer to melt a block of ice. Students measure the amount of melt over time, construct data tables and line graphs to compare two conditions.

The lesson at a glance

Students in groups of 2-3 are given two iceblocks – a control, and one they will act on to either make it melt faster, or slower (half do each condition). Students will need to work with ideas about heat transfer, about ideas about measurement of how much of the ice block has melted, and about tables and graphs.

Equipment/Resources

(for 7 groups)
2 iceblocks for each group (14)
7 saucers for the iceblocks
7 measuring cups (measuring medicine)
7 plastic pipettes

Alfoil, Paper, Woolen cloth, Rubber glove material, Sponge, Polystyrene , Scissors, Tape, Metal and plastic sheets

Equipment required for all lessons
Students: student workbooks (unlined), pencils, colours and rulers

Teachers: Board (IWB/whiteboard) and or butchers' paper for shared recording and pens

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LESSON 5: The iceblock challenge

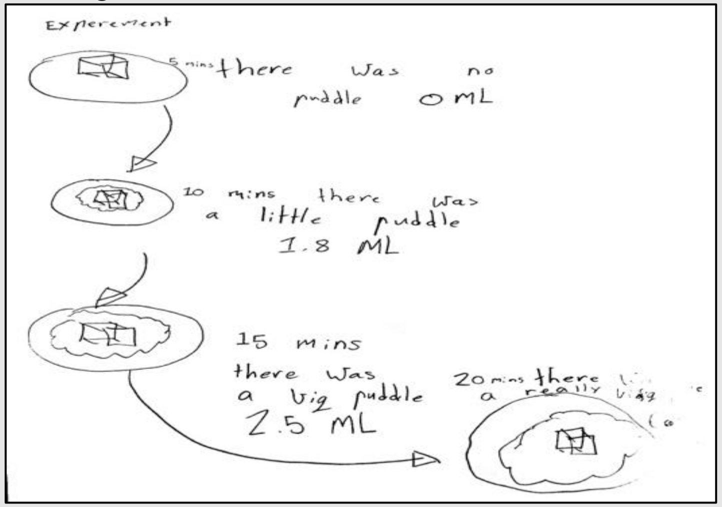
(Approximate duration 90 minutes: This could be split into a 30 minute lesson followed by a 60 minute lesson)

Learning focus	Pedagogical stage	Lesson Outline *(NB: time allocations a guide only)*	Monitoring and supporting learning
Science: Insulation Heat transfer Change of state **Mathematics:** Measurement processes Data table construction Line graph	***Applying and extending conceptual understanding*** This activity extends the understandings and representational practices developed in previous lessons ***Orienting*** Students review ideas from previous lessons and are introduced to the challenge. They discuss possible approaches.	**Design challenge preparation** *(20 minutes)* Review learnings from the previous lessons, particularly ask students: ❖ *What did we find about what material cup kept the hot drink hot?* ❖ *Why was that? How did we represent the heat escaping?* **Challenge Explanation:** To devise a strategy for keeping an iceblock from melting, or for speeding up the melting. Assign students to groups that either slow down or speed up the melting rate. **Record student ideas on the board** ❖ *What might you do to slow down the melting? How will that work?* ❖ *What might you do to speed up the melting? How will that work?* **Design challenge set up and considerations** **Requirements:** Students have two iceblocks each one in a plastic cup. Materials available for design challenge -aluminium foil, woollen cloth, cotton cloth, paper, sticky tape, rubber glove material, sponge, polystyrene, scissors, metal or plastic plates, hot water under the dish. **Task Prompt:** For slowing down or speeding up the melting, you will keep the iceblock in the dish, and work out a way by wrapping it, or putting it somewhere different. **Recording set up** Work out a way of recording your data, including drawings of each iceblock Students need to measure the size of their iceblocks at the start (a linear measure should be enough, so they can check it is decreasing in size) ❖ *How will you measure the iceblocks before starting?* Students need to devise a way of measuring, every 10 minutes, how much the iceblock has melted by measuring the amount of water (using a plastic pipette to suck up the water in the saucer – they will need to work out the total melted by calculating a cumulative total after each measure) **NB:** Remind students: they must work out a way of recording every 10 minutes, and they mustn't lose any of the water from the ice cube.	Can students link their findings from last week to this challenge? Do students use appropriate words to explain what they think will happen? Can students come up with a variety of valid ideas for slowing down or speeding up the melt, that open up discussions of heat transfer, insulation, conduction? Can they, for instance, suggest wrapping the cube in plastic, or sitting it in the sun, or arranging an aluminium reflector to focus sun's rays on it, or touching it with their fingers, or floating it on a warm water bath? Do students have alternative conceptions that might be discussed and challenged? NOTE: it may be efficient to have a standard iceblock on the teacher's desk, the same size as all the iceblocks, for ongoing comparison.

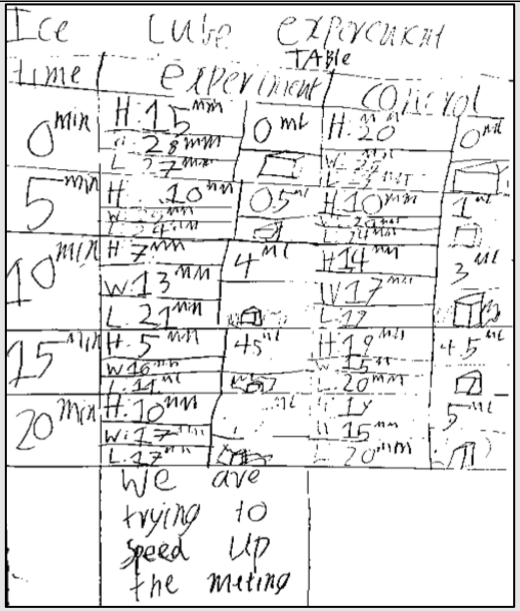
Mathematics: Organising data Data modelling **Science**: Heat transfer Insulation and conduction Change of state	***Posing representational challenges*** Students consider how to measure in systematics ways and represent these measures	**Data discussion** *(10 minutes)* ❖ *How might you record your data?* Workshop with the class possible ways of setting up a table. Students will need to record for each ice cube: the amount of water melted, and a drawing recording visible change.	Do students show clarity in thinking of the measurement process, that can be drawn on?
At this point the lesson could be broken and the investigation pursued in a second 60 minute lesson			
	Posing representational challenges Students devise and carry out measures and record data, and interpret their results using graphs and diagrams	**Investigation: Iceblock melting** *(40 minutes)* Before being given the iceblocks, groups must work out what students are going to do, and how they will set out their results. Students will report this to the teacher. They then conduct the investigation, recording as they go. Every 5, or 10 minutes? In between measurements, students draw why they think their approach will work. They devise a way of tracking the melting of the two cubes using a graph. **Recording and reporting, during and after the investigation** Students write a report in their books, with drawings. This should include, with drawings: • The question we were answering • What we did • What we found (can you show this on a graph?) • Why it worked	Can students carry out measurement methods sensibly? Do any groups generate inventive ideas that can be shared? Can students conceptualise and construct a line graph showing the amount of melt, drawing on their pipette readings?

Samples of student work

Recording methods



Diagramatic drawing with arrows representing change over time with student recorded measures and time



Student tabulation of control and design data Including water measurement and time

Student table – Confusion with water melted called 'temp' and ice 'dissolving' rather than 'melting'. Bar graph employed – line graph woulld be better for change over time

Mathematics

Evaluating and refining ways of representing and interpreting data

Science

Heat transfer processes, melting, insulation and conduction

Building consensus

Students share and evaluate representations and ideas, and refine their reports

Sharing and reviewing results *(10 minutes)*

Gallery walk

Ask students to consider:

- *How quickly or how slowly did the ice melt, under the different conditions?*
- *What things seemed to make the most difference?*
- *What is a good way of presenting the results?*
- *What representations were helpful in explaining what was happening?*

Class discussion: Summing up and evaluating *(10 minutes)*

After the gallery walk, ask students:

- *What did you learn?*
- *Which reports were interesting and clear?*

Select some examples to share –

- *Why is this clear?*
- *Is this a good explanation?* (select representations that include heat transfer ideas)

NB: Provide time for students to complete their reports, adding to them after the discussion.

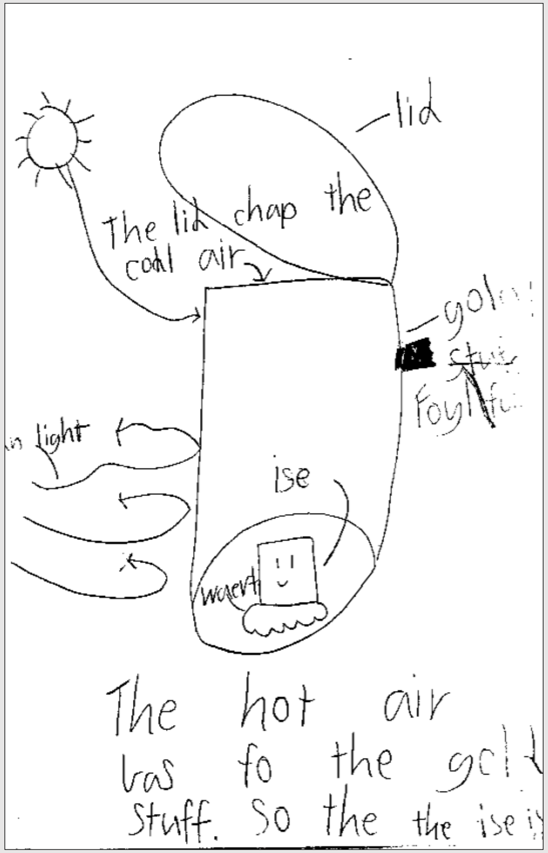
Science ideas to look for –
Insulation, movement of warm air, heat transfer to the ice cube, use of arrows or other symbols to represent heat.

Mathematics ideas –
Clear display/organisation of data
Use of graphs – line or bar and features of axes, scale.
Measurement processes

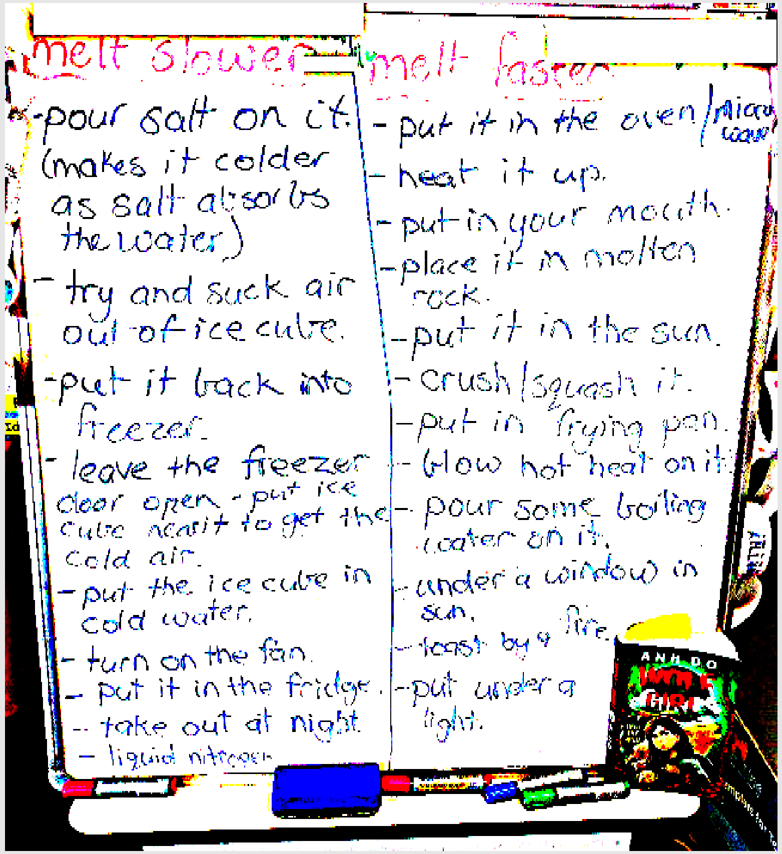
Samples of student work

Examples of student explanations and class agreement – What makes ice melt slower and what melts ice faster?

Student arrows demonstrating heat being reflected



Representation demonstrating the lid 'trapping the cool air' and arrows demonstrating the the foil reflecting the heat ('light')



Example of class derived list of ideas and agreement – What melts the ice at a slower, and faster rate?

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Samples of student responses: Post Sequence Assessment Task

Name: ________________________ Class: _________

Post Sequence Assessment: HEAT AND TEMPERATURE

1.) Lucy is watching a game of soccer outside on a cold day. During the game she uses three ways of warming up. For each of these ways, represent in a drawing and words why this works to warm her up.

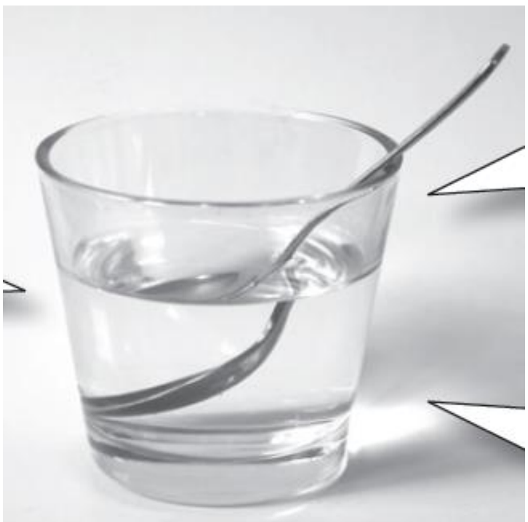
A. She wraps a blanket round her

B. She curls up in a ball

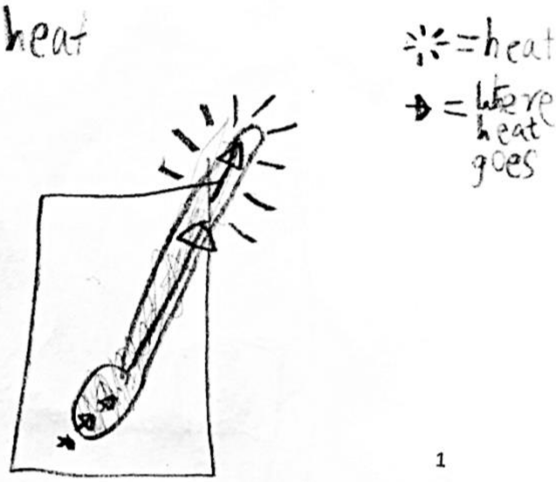
C. She stands in front of a heater

The Blanket Traps the heat in. | Traps heat in her. | The heater goses stret on her.

2.) Lucy touches a metal spoon sitting in a glass of hot water. The spoon handle is quite hot to touch. Represent using a drawing and words how the spoon handle gets hot.

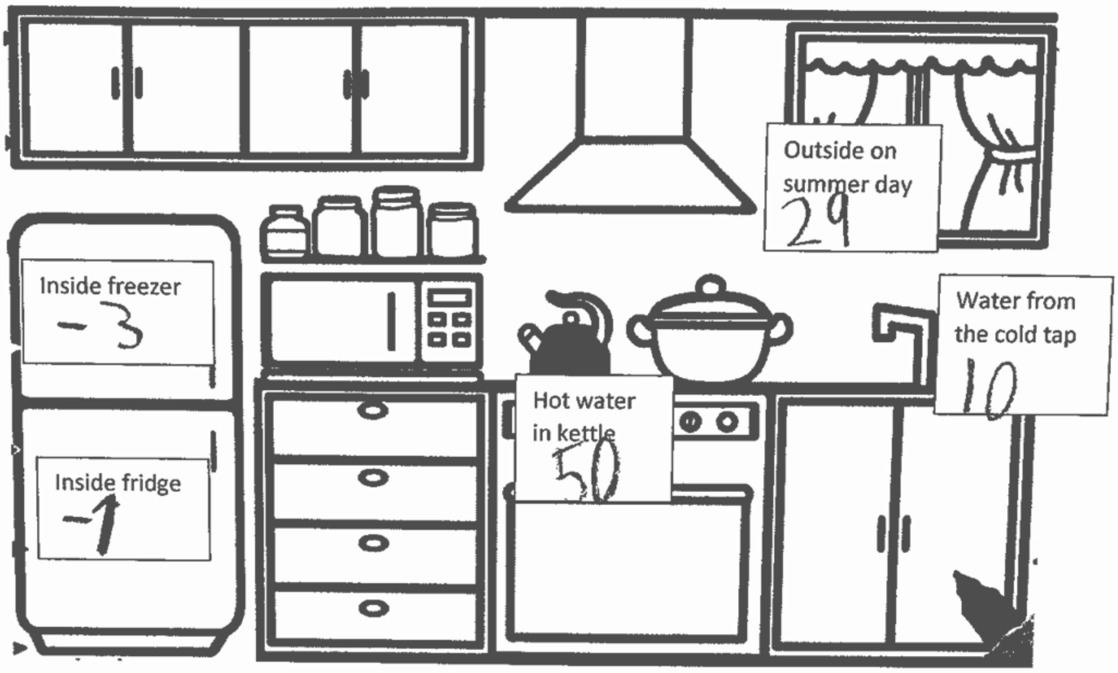


the spoon absorts the heat



Typical student response

3) 3A. Write what you think the temperature will be in °C at the five places with rectangles, in the picture.



3B. Explain in a drawing and words how the kettle works to heat the water.

it is plugged in a power point Wich heat s up the inside.

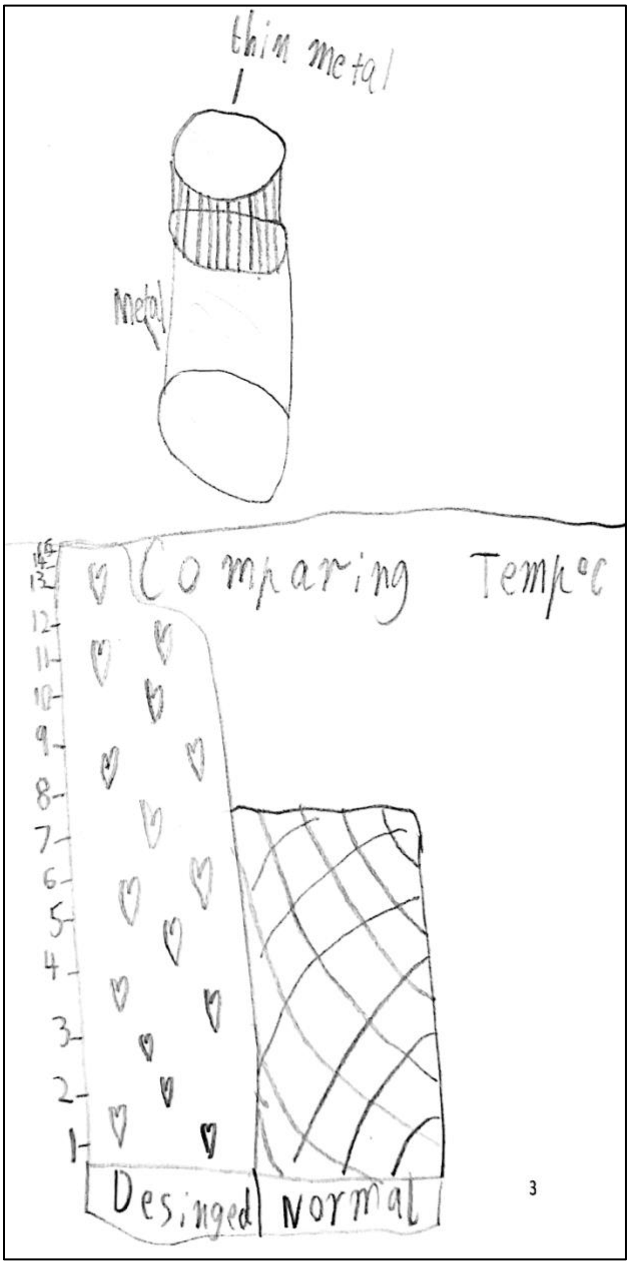
4) Design challenge: You are to design a container for your hot lunch that will keep the lunch hot.

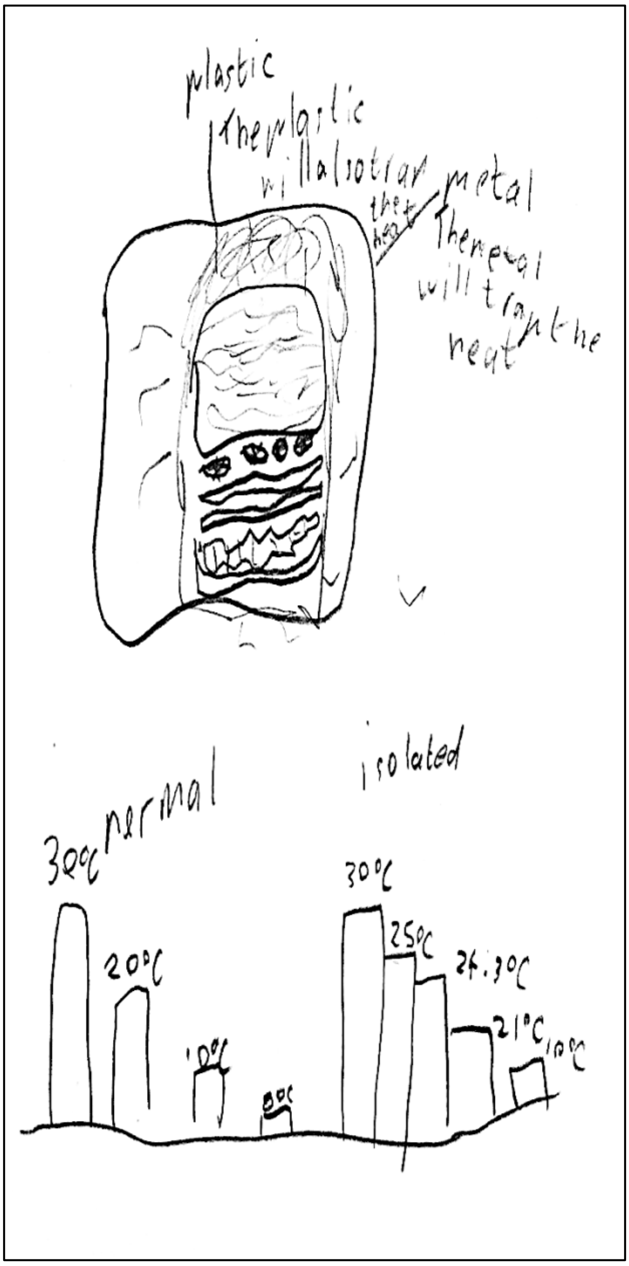
a. Draw your lunchbox design.

b. ***Label the materials*** and represent / explain ***why your design will work*** to keep your lunch hot.

c. Draw a graph showing how the temperature will change over the day for your lunchbox compared to a normal lunchbox.

Student response example 1. Student response example 2.





Pre/Post Sequence Assessment Task

Name: ________________________ Class: _________

Post Sequence Assessment Task: Heat and Temperature

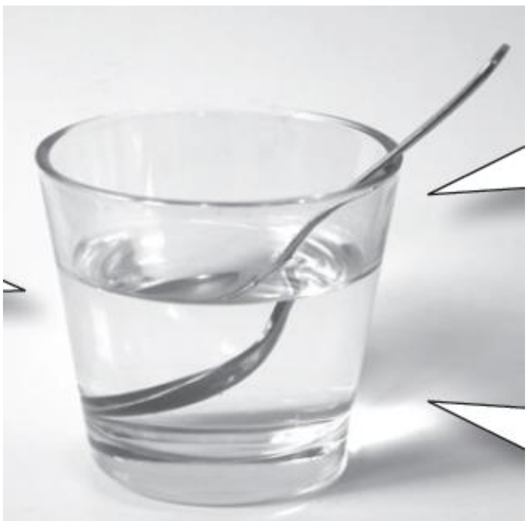
1) **Lucy is watching a game of soccer outside on a cold day. During the game she uses three ways of warming up. For each of these ways, represent in a drawing and words why this works to warm her up.**

4 She wraps a blanket round her

5 She curls up in a ball

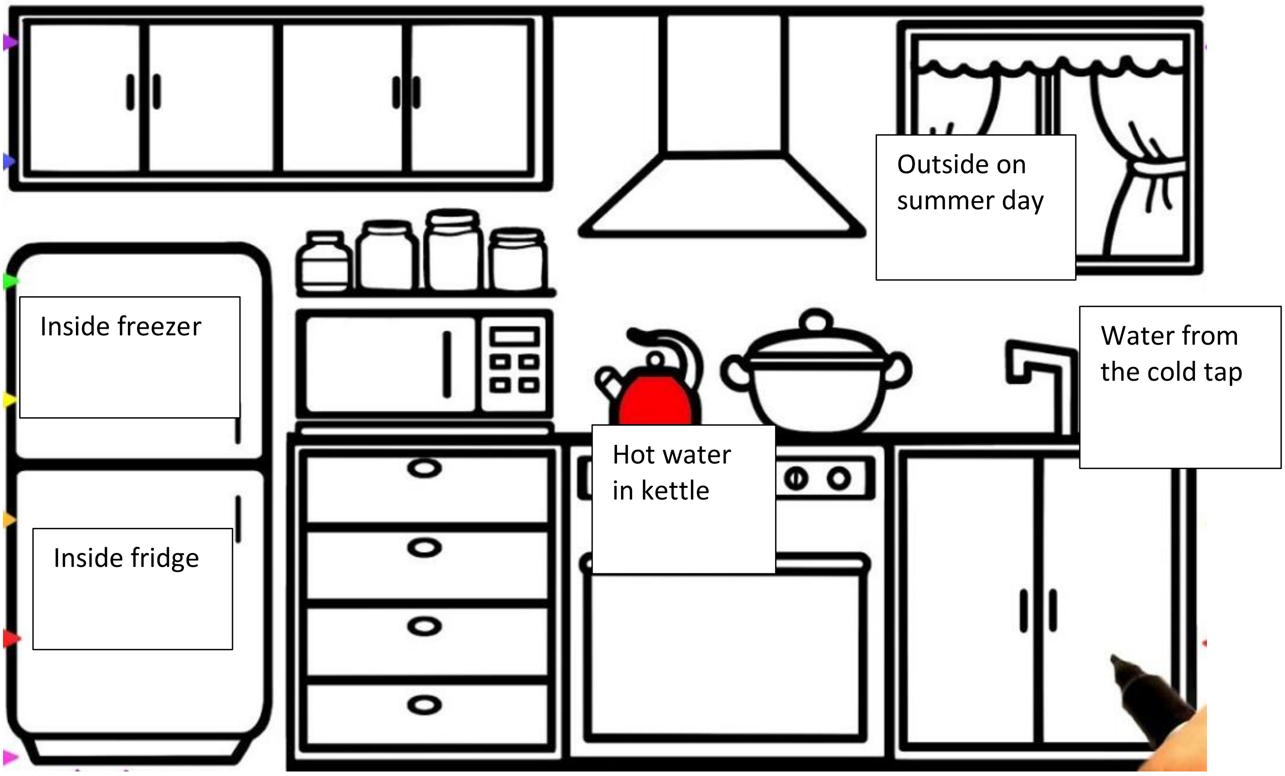
6 She stands in front of a heater

2) **Lucy touches a metal spoon sitting in a glass of hot water. The spoon handle is quite hot to touch. Represent using a drawing and words how the spoon handle gets hot.**



3a

3a) Write what you think the temperature will be in °C at the five places with rectangles, in the picture.



3b) Explain in a drawing and words how the kettle works to heat the water.

4) Design challenge: You are to design a container for your hot lunch that will keep the lunch hot.

a. Draw your lunchbox design.

b. ***Label the materials*** and represent / explain ***why your design will work*** to keep your lunch hot.

c. Draw a graph showing how the temperature will change over the day for your lunchbox compared to a normal lunchbox.