Science subject leader training

How can we best plan and sequence

our science curriculum

to secure conceptual understanding ?

18 November 2021

13.00 – 15.00

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CAPITAL TEACHING ALLIANCE

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Aims of these two sessions

Session 1 (18th November 2021)

How can we best plan and sequence our science curriculum to secure conceptual understanding ?

Session 2 (26th January 2022)

Reflections on ‘takeaways’ from session 1

How can we best ensure that children use scientific vocabulary accurately and showing understanding ?

First part of today's session

Understanding is achieved by repeated exposure to key concepts over time, securing what has been previously learned and deepening knowledge by application and extension.

How well does our science curriculum promote secure understanding ? How do we know ?

This requires us to identify these key concepts and plan how children will encounter them both within units of work and as they go through key stages.

What are these key concepts ? How are they best expressed ?
What will help children think about concepts rather than tasks ?

“Know more, remember more”

Building blocks of progress

An ambitious curriculum … needs to identify the most important concepts for pupils to learn. It must also teach pupils how these concepts are related so that, over time, the logical structure of each scientific discipline is made explicit. (1)

We saw some excellent examples of schools that had carefully considered the building blocks of progress in history, identifying knowledge that was essential to pupils’ understanding of new material. (2)

In some schools, there was a misunderstanding of how to make progress in languages, step by step. Rather than focusing on the building blocks of a language (phonics, grammar and vocabulary), some schools were simply increasing pupils’ stock of words, through different topics. (3)

(1) Curriculum progression : What it means to get better at science Ofsted research review 29.04.21
(2) History in outstanding primary schools Tim Jenner HMI Ofsted blog 29.04.21
(3) MFL in outstanding primary schools Michael Wardle HMI Ofsted blog 04.05.21

Design and build

Dylan Wiliam

"A collection of topics and resources
is no more a curriculum
than a pile of bricks is a house."

Design and build

The bricks and mortar of the subject

The architecture of the subject

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Secure foundations for learning

Substantive knowledge

- the bricks

- the “know that” of science

Substantive concepts

– the cement in the mortar which binds the bricks together

– the “big ideas” of science

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Possible weaknesses

Secure foundations for learning

Substantive knowledge - the bricks - the "know that" of science

Substantive concepts – the cement in the mortar which binds the bricks together – the big ideas of science

Disciplinary knowledge – the right ratio of sand : cement : water to make a mix which is permanently "sticky" – how scientific knowledge has come about, how scientists formulate questions and how scientists observe, measure, test and communicate

Caution : Ofsted terminology

Table 1: Knowledge can be categorised according to its disciplinary nature and how it is used by an individual

	Substantive knowledge	Disciplinary knowledge
Conceptual... know that... because...	Liquids expand when they are heated (for example, the liquid inside a thermometer).	All measuring instruments, such as a thermometer, have a built-in degree of uncertainty.
Procedural[footnote 73]... know how to... and be able to...	Draw a particle diagram for a liquid.	Use a thermometer to measure the temperature of a solution.

Scientific enquiry integrates substantive and disciplinary knowledge, as explained in the table above, into an overall strategy to answer questions about the material world.

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Being clear about language we use

"Scientific enquiry integrates substantive and disciplinary knowledge"

"…It's what you do, not how you label it that matters."

Daniel Muijs, Ofsted director of research 2016-20

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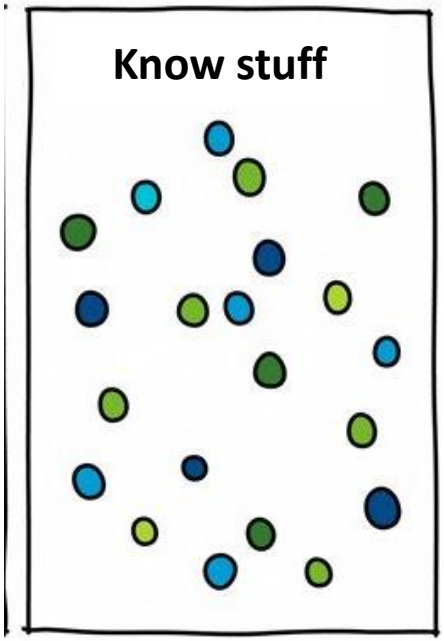
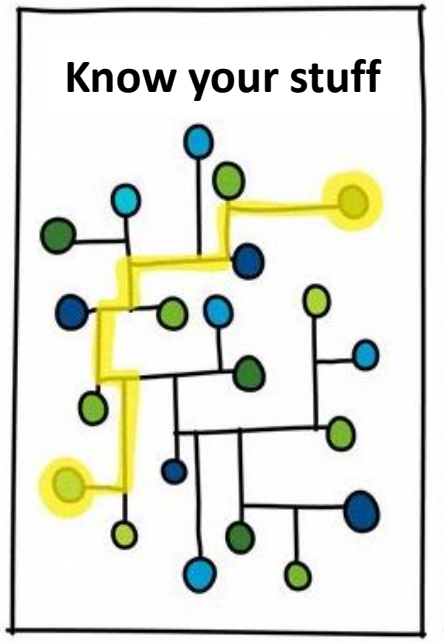
“Know more, remember more”





Making strong connections with substantive knowledge and building conceptual understanding

Curriculum coherence

Coherence comes from the Latin

'to stick together'

v. **cohere** = to make a connection

adj. **cohesive, coherent**

adj. **adhesive**

What kind of coherence ?

Science

Pushes and Pulls
Sorting Materials

- To know movement can be described in many ways
- To know toys can be made to move by push and pull
- To investigate what materials toys are made of
- To investigate which material is best for a bath toy.

P.E.

Dance - The magic toys & Firework Dance

Games - multiskills Coach David

History **Toys from the Past**

- To talk about toys from the past
- To ask questions about toys from the past
- To know how to decide whether a toy is old / new
- To play playground games from the past

Geography **Locating places on a map**

- We will locate toys/ games from around the world

Locate North Pole – Santa workhop

Religious Education

To learn about special celebrations.

- Diwali
- Bonfire Night
- Christmas

Toys R Us

Learn 4 Life - Who keeps us safe?

- Fire safety
- Road safety
- Firework Safety

Maths

Block C Unit 1 - Handling Data and Measures
Block D Unit 1 - Calculating, measuring, understanding shape
Block E Unit 1 - Securing number facts, calculating

ICT

- To explore 2create a story
- To add sound and movement to own story using icons
- Magic Grandad Programme - Toys

Outdoor Learning

- Playpark - explore forces and equipment

Class assembly dates

Squirrels

Otters

Hedgehogs

DT - Making a board game for Santa's Workshop

- To recognise simple features of a board game
- To recognise shapes in simple structures
- To make models that reflect ideas
- To evaluate products

Literacy

- **Traditional stories**
  Goldilocks and the 3 bears
  3 little pigs
- **Instructions**
  Making toys
- **Stories with familiar settings**
  Night Before Christmas

Music

- Music Express Scheme

Art

Observational drawings of favourite toys.
Investigate a range of materials and processes.

Identifying coherence

Pushes and pulls	Sorting materials
To know that movement can be described in many ways	To investigate what materials toys are made of
To know that toys can be made to move by push and pull	To investigate which material is best for a bath toy
Physics	Chemistry

Substantive knowledge

Pushes and pulls

To know that movement can be described in many ways

To know that toys can be made to move by push and pull

Physics

Substantive concept

Pushes and pulls

To know that movement can be described in many ways

To know that toys can be made to move by push and pull

Physics

Forces

What forces are and how they work

Substantive concept

Pushes and pulls

To know that objects can be made to move by push and pull

To know that all movement can be classified as a push or a pull

Physics
Forces
What forces are and how they work

Substantive and disciplinary knowledge

Pushes and pulls	Sorting materials
To know that movement can be described in many ways	To investigate what materials toys are made of
To know that toys can be made to move by push and pull	To investigate which material is best for a bath toy
Physics	Chemistry

What do you want them to think about ?

Why is coherence important?

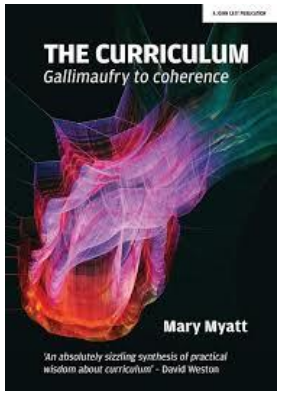
"Toys" is not a scientific concept.

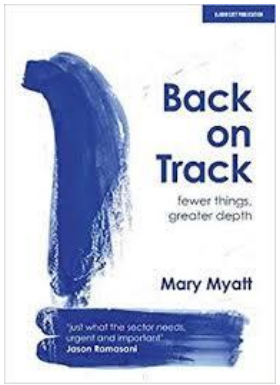
What are the scientific concepts being taught here?

How are these being made explicit ?

"Concepts act as holding baskets"

Mary Myatt





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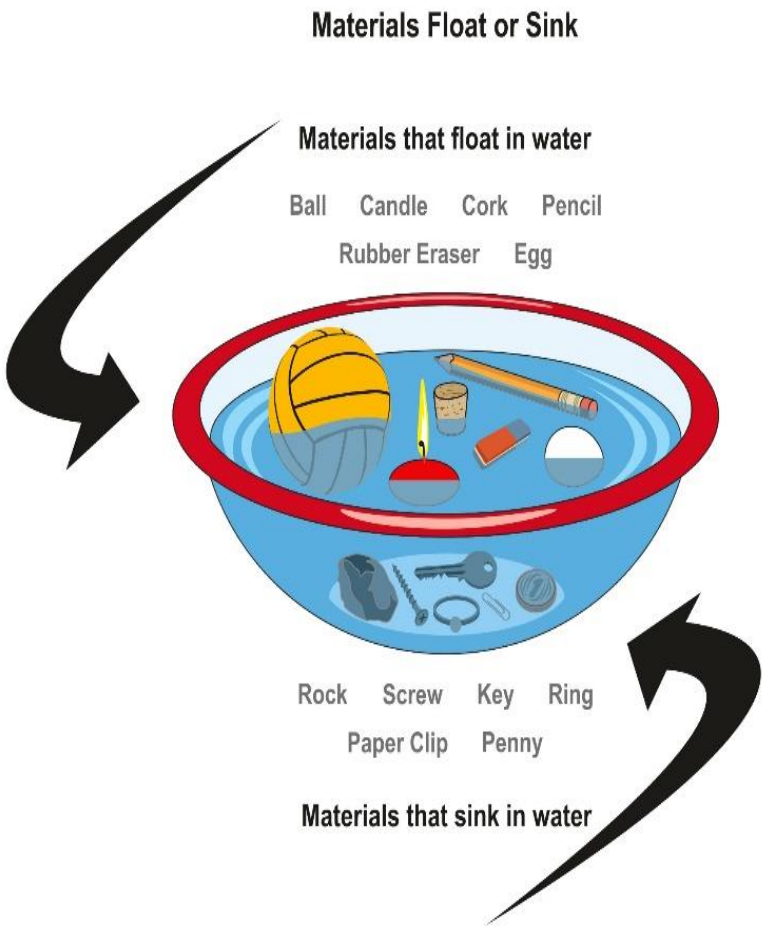
Spot the misconception(s)



Pushes and pulls

To know that movement can be described in many ways

To know that toys can be made to move by push and pull

Sorting materials

To investigate what materials toys are made of

To investigate which material is best for a bath toy

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Thinking about knowledge and concepts

Substantive concepts

Whether an object floats or sinks is not related to the property of the material from which it is made.

Whether an object floats or sinks is determined by its density relative to the density of the liquid.

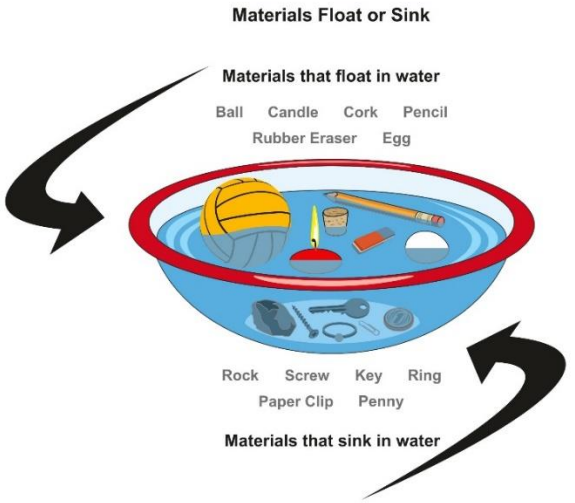
Disciplinary knowledge

Formulating questions

Observation

Testing and checking

Recording and communicating findings



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Thinking about how knowledge builds

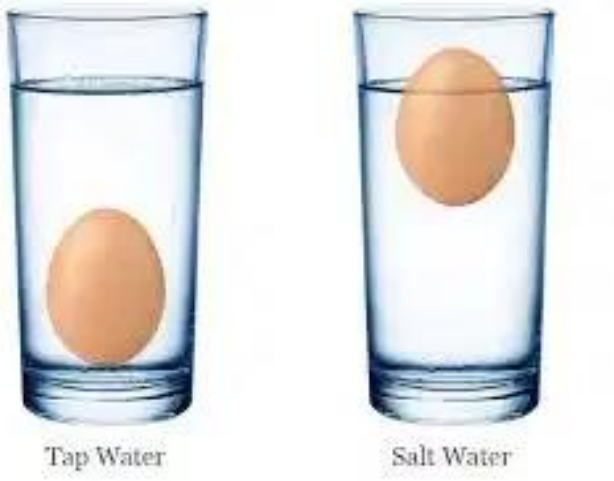
Substantive concepts

Objects have a density which can be calculated – mass divided by volume, measured in g/ml or kg/l.

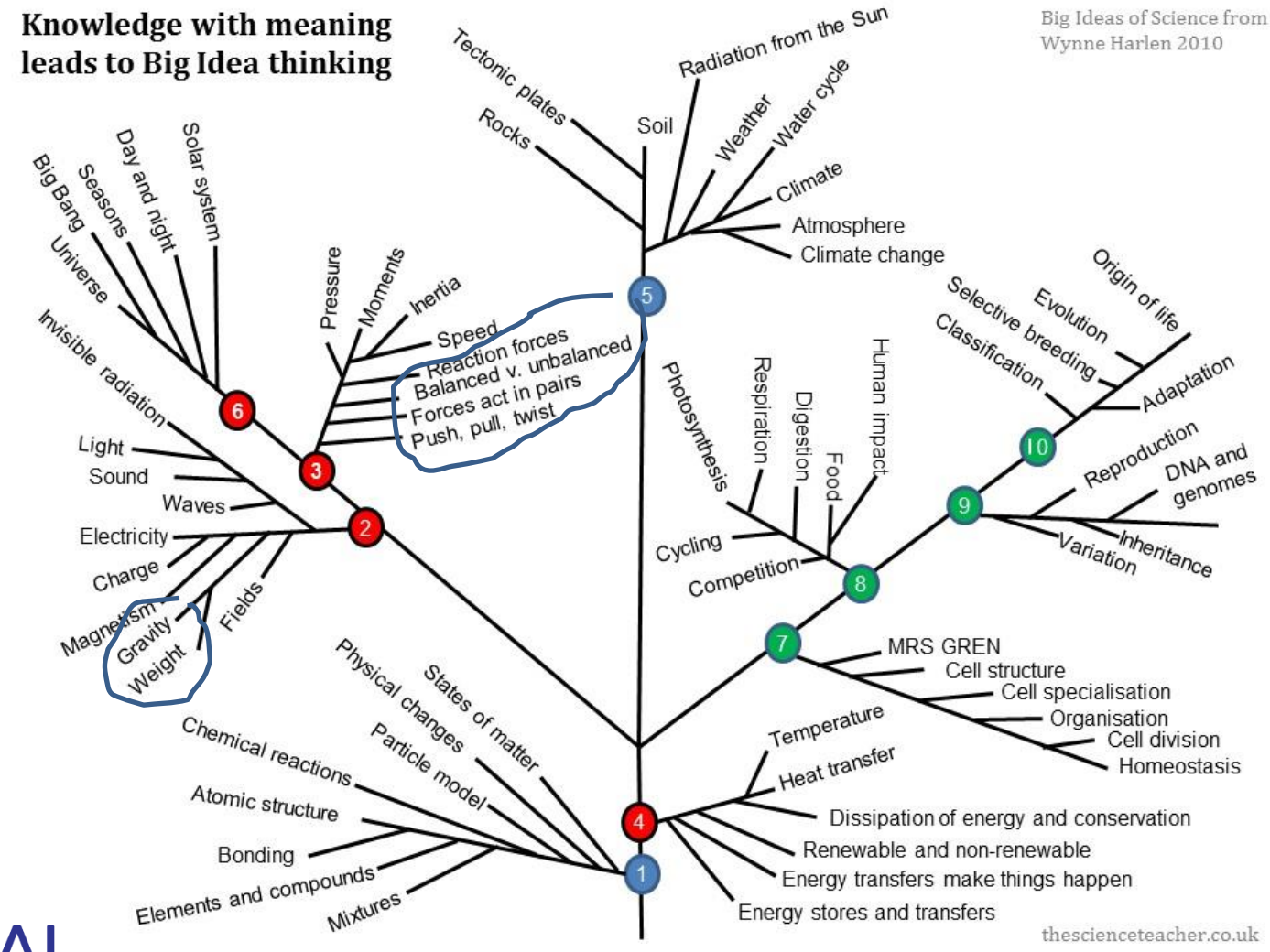
An object with a relative density > that of water will sink.
An object with a relative density < that of water will float.

Disciplinary knowledge

Formulating questions
Observation
Testing and checking
Recording and communicating findings



Big ideas of science



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Big ideas of Physics

Physics 'big ideas', enquiry questions and substantive vocabulary

- The universe follows unbreakable rules that are all about forces, matter and energy.
- Forces are different kinds of pushes and pulls that act on all the matter that is in the universe.
- Energy, which cannot be created or destroyed, comes in many different forms and tends to move away from objects that have lots of it.

What makes objects move and stop moving?	*How does energy make things happen?*	*How can forces be changed and controlled?*
What can magnets do? Can anything fall upwards? Can we slow the movement of an object down or speed it up?	Where does light come from? What is darkness? How do we see? Do we perceive all images the same way? How are sounds made? How do we hear sounds? What makes a range of sounds different from each other? Why can we hear but not see round corners?	How can we use electricity to make a machine work? Does electricity flow easily through all objects? How can we make it easier to make something move?
magnetic force, magnetism, attract, repel, pole push, pull, force gravity, gravitational force, air resistance, water resistance, upthrust, friction balanced forces	light source, natural light, artificial light light, darkness, shadow reflection, mirror, refraction spectrum filament, cornea, retina, pupil, optic nerve, rods, cones sound, vibration, pitch, volume, tone ear drum, cochlea, hammer, anvil, stirrup	electrical circuit, cell, battery, wire, switch, bulb, buzzer, motor, appliance conductor, insulator machine, lever, pulley, gear, mechanics weight, Newtons, mass

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Rethinking

Sorting materials

To investigate what materials toys are made of

To investigate which material is best for a bath toy

Chemistry

Rethinking

Sorting materials

To classify what materials toys are made of

To investigate which material is best for a bath toy

Chemistry

Rethinking

Sorting materials

To classify what materials toys are made of

To investigate which material is best for a floating bath toy

Chemistry

Rethinking

Sorting materials

To classify what materials toys are made of

To investigate which material is best for an absorbent bath toy

Chemistry

Progression in substantive knowledge

Chemistry 'big ideas', enquiry questions and substantive vocabulary

• All matter in the universe is made up of tiny building blocks. • The arrangement, movement and type of the building blocks of matter and the forces that hold them together or push them apart explain all the properties of matter. • Matter can change if the arrangement of these building blocks changes.	
What are things made from?	***How can form change?***
How do we choose the right materials for a job? Are all materials the same? What different ways can we group materials? How do we use materials to protect and help us?	What are the ways in which water can be formed? What happens when things heat up and cool down? Does everything freeze and boil at the same temperature? Is it possible to separate everything from mixtures?
material, natural, man-made, synthetic wood, plastic, rubber, metal, paper, cardboard, glass, stone, brick, pottery hard, soft, bendy, stretchy, rigid, flexible, pliable absorbent, water-resistant, waterproof, pervious, impervious flammable, non-flammable shiny, dull, reflective, transparent, opaque, translucent chemistry hardness, solubility, concentration, transparency, conductivity, insulation	solid, liquid, gas, state, particles, molecules evaporation, vapour, condensation, droplets temperature, degrees Celsius, freezing, solidifying, cooling, heating, melting, boiling reversible, irreversible sieving, filtering, solution, dissolving

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Progression in substantive knowledge

Biology 'big ideas', enquiry questions and substantive vocabulary

- Living things on Earth come in a huge variety of different forms that are all related because they all came from the same starting point 4.5 billion years ago.
- Living things are special collections of matter that make copies of themselves, use energy and grow.
- The different kinds of life, animals, plants and microorganisms, have evolved over millions of generations into different forms in order to survive in the environments in which they live.

What kinds of life are there?	*How do living things survive and grow?*	*What makes life go on?*
Is everything on Earth alive? Are all animals and plants totally different? What is a plant? What different ways can we group living things?	How do animals and plants stand up and move? Does everything grow in the same way? What eats what and why? Is all food good for us? How do humans and animals change?	Why do we need to grow old? What do living things inherit from their parents? Why have some animals become extinct?
mammal, fish, bird, reptile, amphibian kingdom, class, species carnivore, herbivore, omnivore skin, fur, hide, feathers, scales biology, zoology, botany vertebrate, invertebrate insect, arthropod, gastropod, micro-organism classification, taxonomy	water, light, temperature, nutrition, transportation skeleton, organs, muscles food chain, energy habitat prey, predator, producer, consumer leaf, root, stem, seed, fruit, flower, petal pollination, dispersal, reproduction canine, incisor, molar digestion, saliva, acid, enzyme circulatory system, heart, valve, blood vessels, veins, arteries respiration, oxygenated, de-oxygenated foetus, embryo, gestation, womb puberty	life cycle fossil inheritance, genetics adaptation, evolution

Progression in substantive knowledge

Earth science 'big ideas', questions and substantive vocabulary

- The Earth is one of eight planets that orbit the sun.
- The Earth is tilted and spins on its axis leading to day and night, the seasons and the climate.
- The Earth is made up of several layers, including a thin rocky surface which is divided into tectonic plates, and the movement of these plates leads to many geological events.

What is the Earth made from?	*How does the Earth's position in the solar system dictate its climate and conditions for life?*
Where do rocks come from? Are all rocks made in the same way? Is a fossil a rock? Is soil a type of rock?	Why do we have day and night? Is the weather the same every day? Why does the moon seem to change shape? How do we know the Earth is moving?
Earth's crust, mantle, core, plate, tectonic, fault igneous, volcanic, eruption, lava, granite, pumice sedimentary, sandstone, coal, chalk fossil, fossilisation metamorphic, slate, marble permeable, impermeable soil, soil type, sand, loam, clay, silt organic, carboniferous, minerals geology	Sun, sunshine, daylight, darkness, daytime, night-time, dawn, dusk, rotation, axis Summer, Spring, Autumn, Winter, seasons, tilt planet, orbit, Moon, satellite, phases of the moon, waxing, waning astronomy solar system, galaxy, star, constellation, universe

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How can leaders best support teachers?

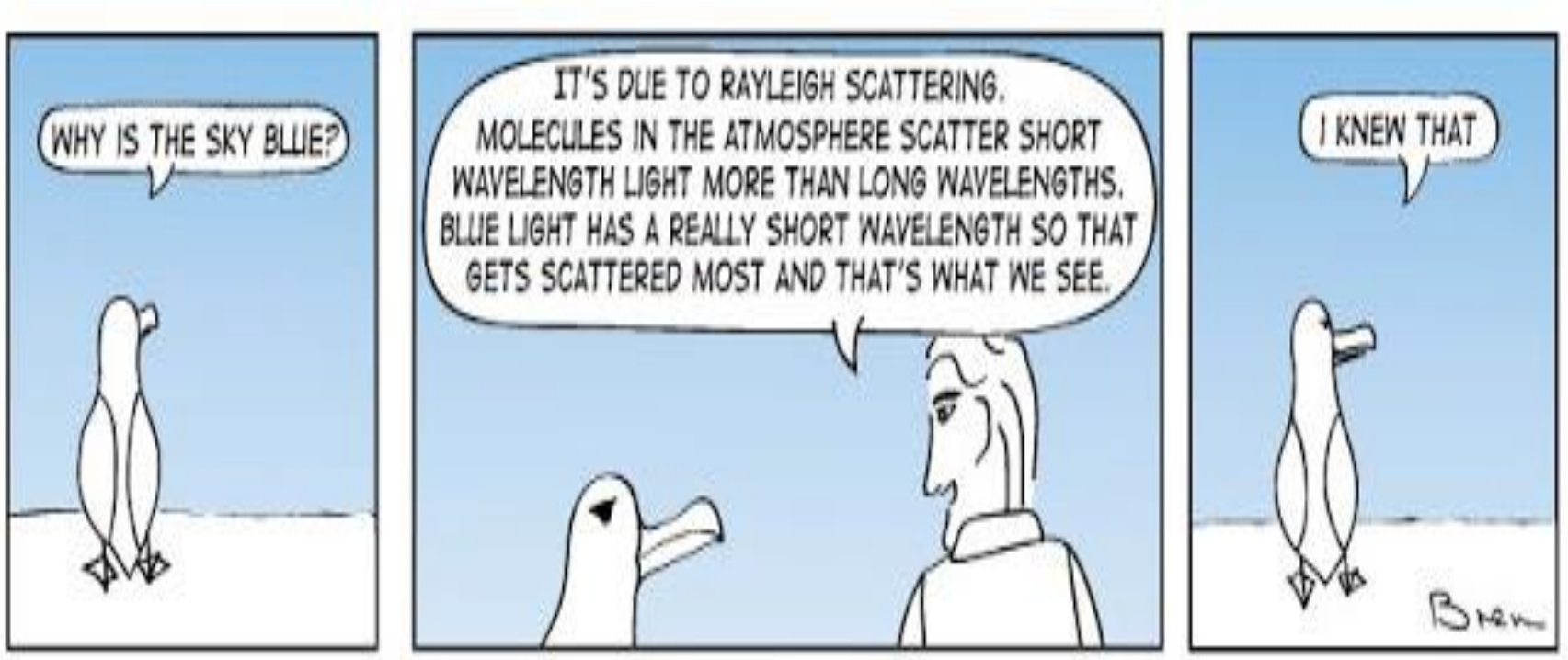
Making sure that building blocks of knowledge are identified and planned for explicitly.

Helping teachers see how knowledge connects conceptually and that this builds understanding over time.

Helping teachers decide how scientific enquiry and thinking supports the development of conceptual understanding.

Curiosity and knowledge

"I want them to be curious"



Scientific concepts which underpin learning in other subjects

Some scientific learning dovetails with geographical and historical learning.

We need to make links which are conceptual rather than just thematic.

For which specific examples is this the case and what are the implications for sequencing ?

Scientific concepts which underpin learning in other subjects

Materials

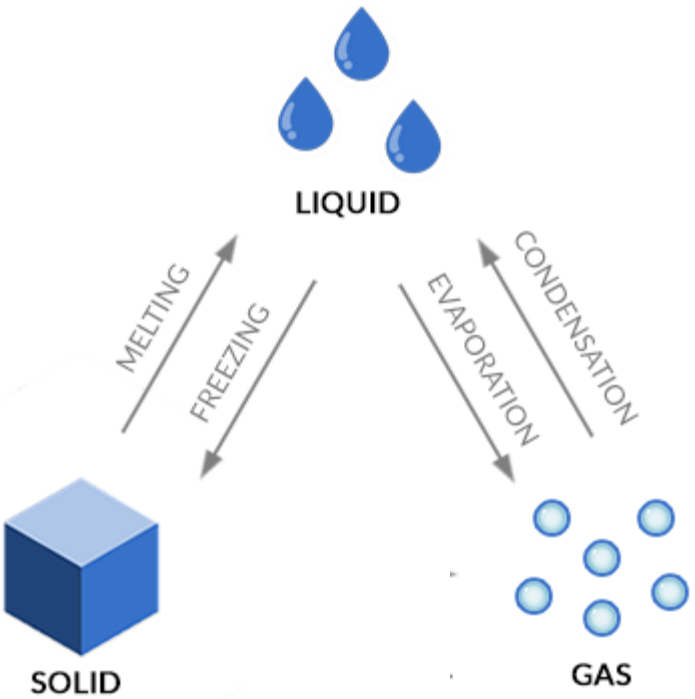
- Change of state
- Properties of metals
- Rocks and soil

The water cycle

Ancient civilisations

Volcanic regions

Change of state



Progression in substantive knowledge

Chemistry 'big ideas', enquiry questions and substantive vocabulary

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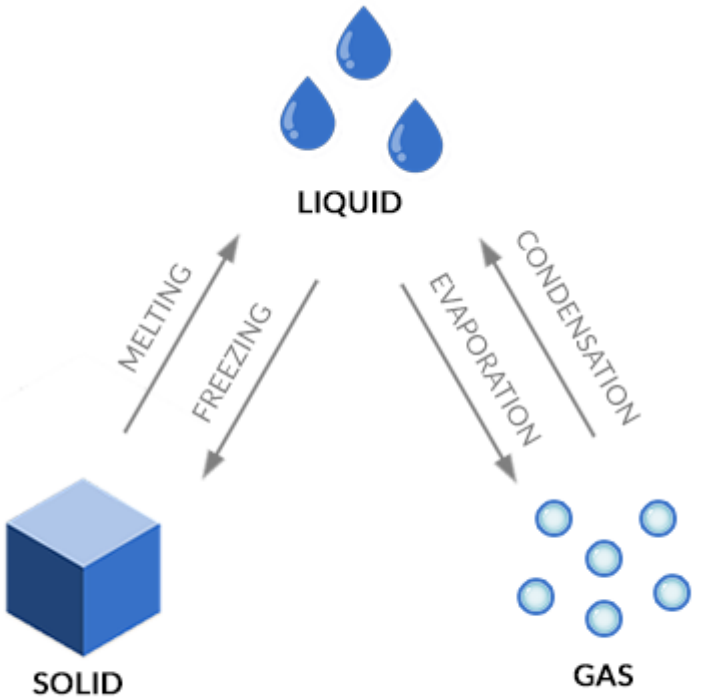
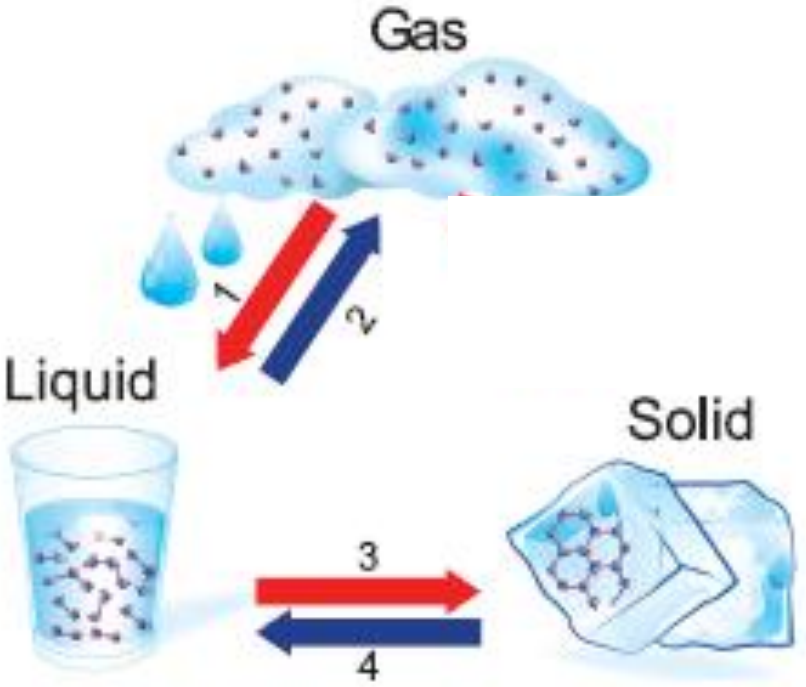
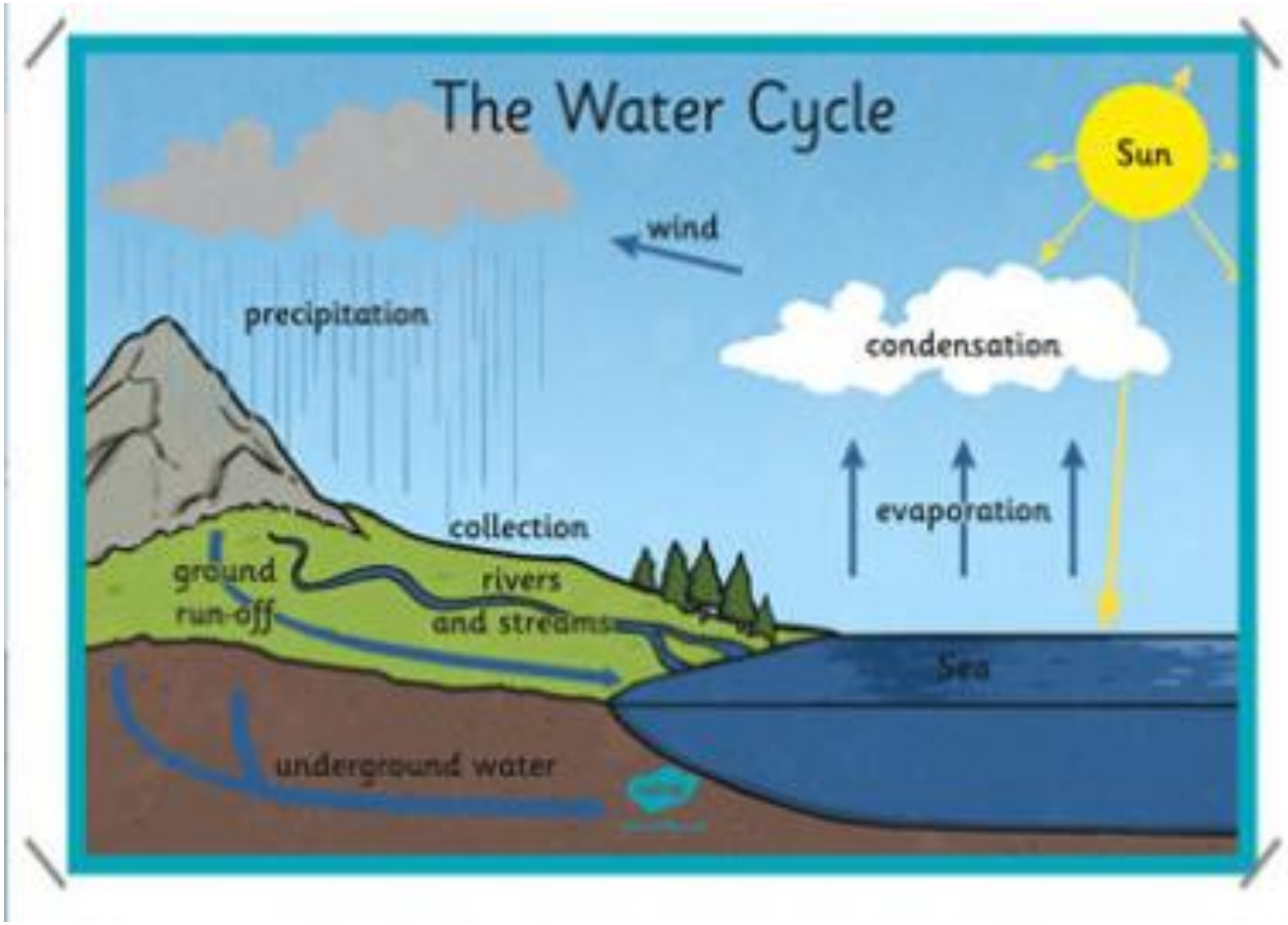
Change of state





Geographical knowledge is underpinned by scientific knowledge



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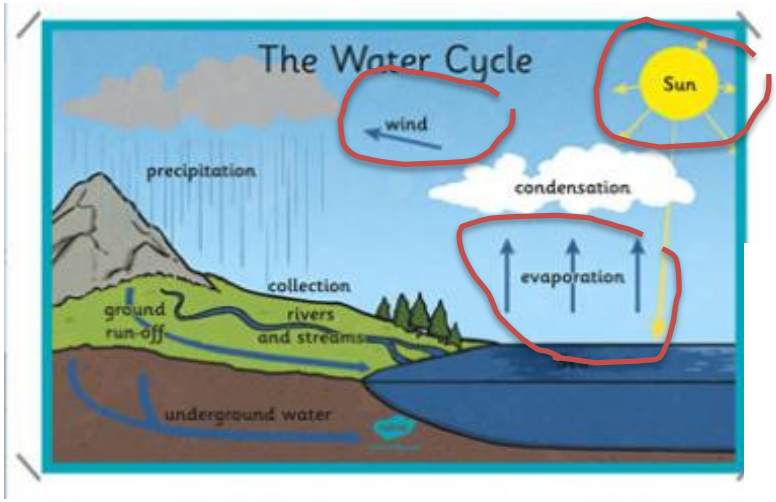

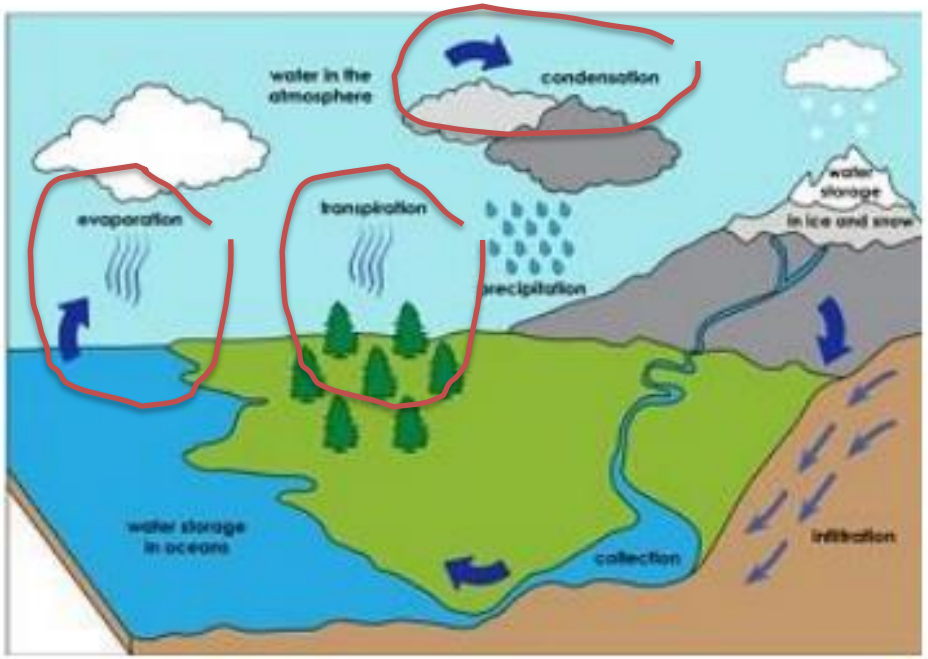

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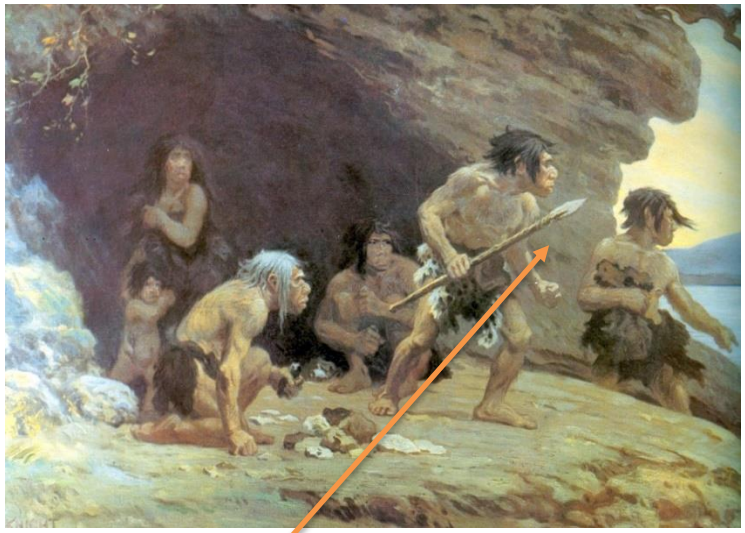
Historical knowledge is underpinned by scientific knowledge



Expansion of the Roman Empire : raw materials

What's special about copper and tin?

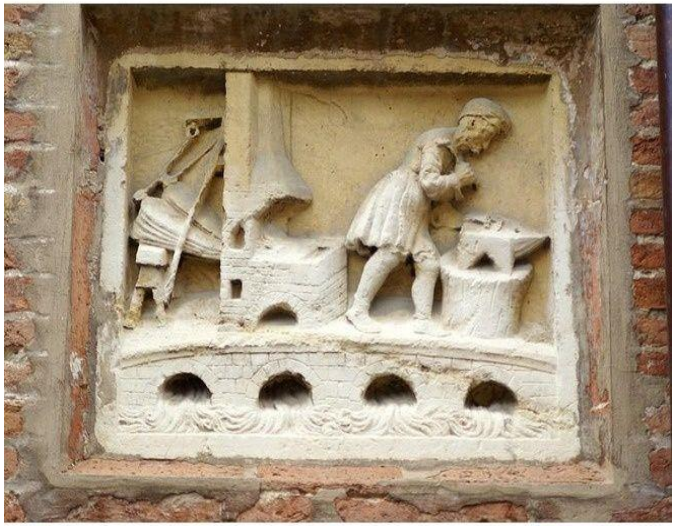
When copper and tin ores are melted, mixed and cooled, they make the alloy bronze

The Romans were expert metalworkers

mining

smelting

forging



What's special about bronze?

Key properties of bronze

Exceptionally hard
Doesn't wear out
Can be finely decorated

Doesn't rust

Conducts heat well

Different kinds of rock

Igneous

Formed from cooling magma or lava.

- Has tiny crystals
- Sharp rough edges
- Can look like black glass
- There will not be fossils!
- Usually quite tough

Metamorphic

Formed from igneous or sedimentary rocks which have been either melted, bent, folded or squashed.

- It can look wonky
- There might be squashed layers.
- There wont be any crystals or fossils.

Sedimentary

Formed from small parts of other rocks settling one on top of the other (compaction).

- There may be fossils present
- There will be different stones mixed in.
- Easy to break or chip.

- **There may be a layer of metal ore between layers of rock**

Different kinds of rock

Igneous

Formed from cooling magma or lava.

- **Volcanic**

- Has tiny crystals
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Sedimentary

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- There may be fossils present
- There will be different stones mixed in.
- Easy to break or chip.

Why would you live in the shadow of a volcano?

Fertile soil

Rich in minerals

Scientific knowledge typically underpins historical and geographical knowledge

Materials

- Change of state
- Metals
- Rocks and soil

Plan to activate prior learning

Activating prior learning is a crucial element of science pedagogy. Typically, children may remember activities but be less secure in scientific explanation which shows conceptual understanding.

How can we best design activities which activate prior learning and show teachers what children have retained and understood from previous learning and what may need revision or even reteaching ?

What different ways can we group living things ?












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Put these in order according to number of legs

?

What makes insects special ?

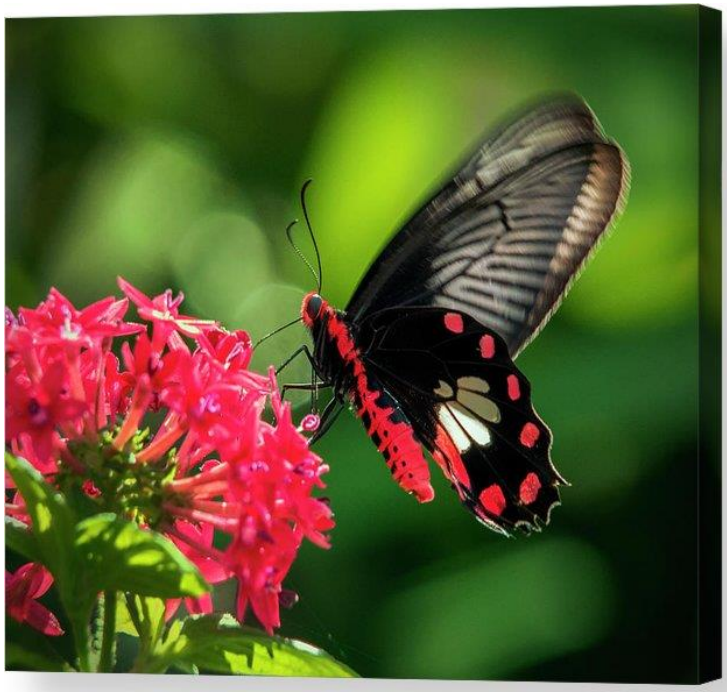
no legs

six legs

?

eight legs

Help them to organise their thinking



What do you notice ?

Insects

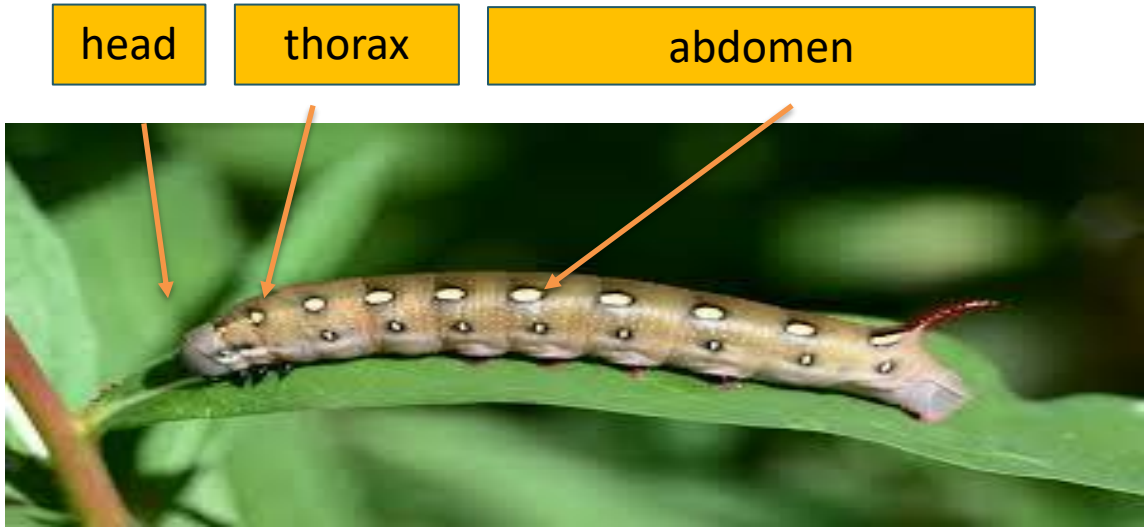
head

thorax

abdomen

All insect bodies are divided into three parts: the **head** which is connected to the **thorax**, which in turn is connected to the **abdomen**.
All insects have **six legs** which attach to the thorax.
Most, but not all, insects have **wings**.

Insects



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Insects

head

thorax

abdomen

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All insects have **six legs** which attach to the thorax.
Most, but not all, insects have **wings**.

What are they sure of ?

Ladybirds have faces

Ladybirds can smile

Ladybirds are red

All ladybirds are red

Ladybirds have six spots

All ladybirds have six spots on their bodies

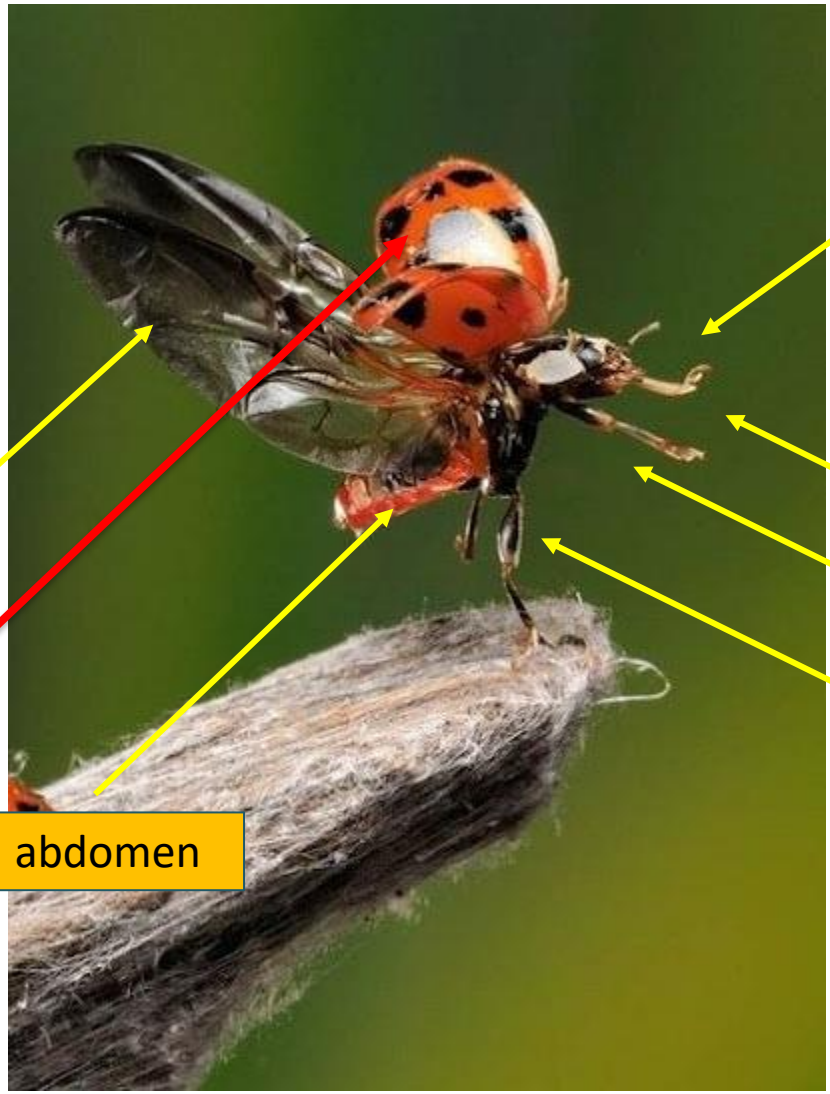
Ladybirds have wings

Ladybirds have two wings

Labelling a ladybird

antenna head leg wing spot

Show how you know that a ladybird is an insect



head

wings

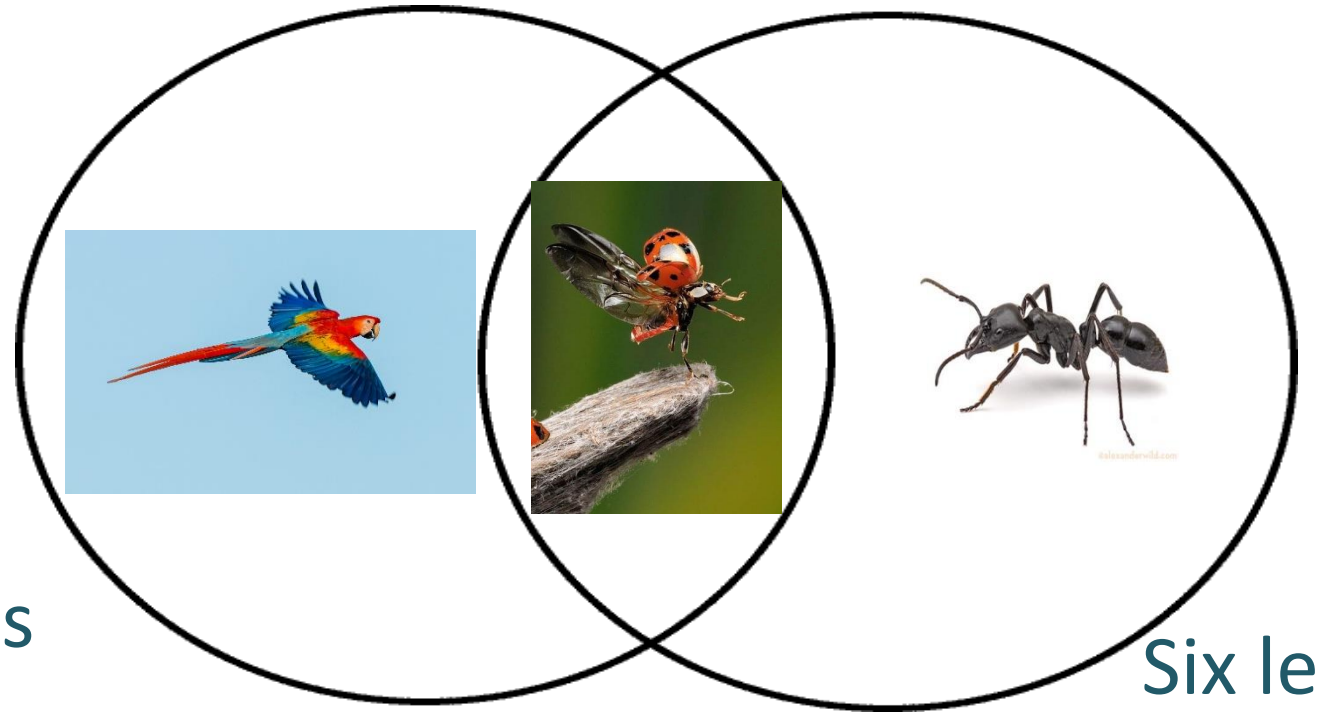
eletrya

abdomen

Legs connected to thorax

Building knowledge to reveal concepts

What makes insects special ?

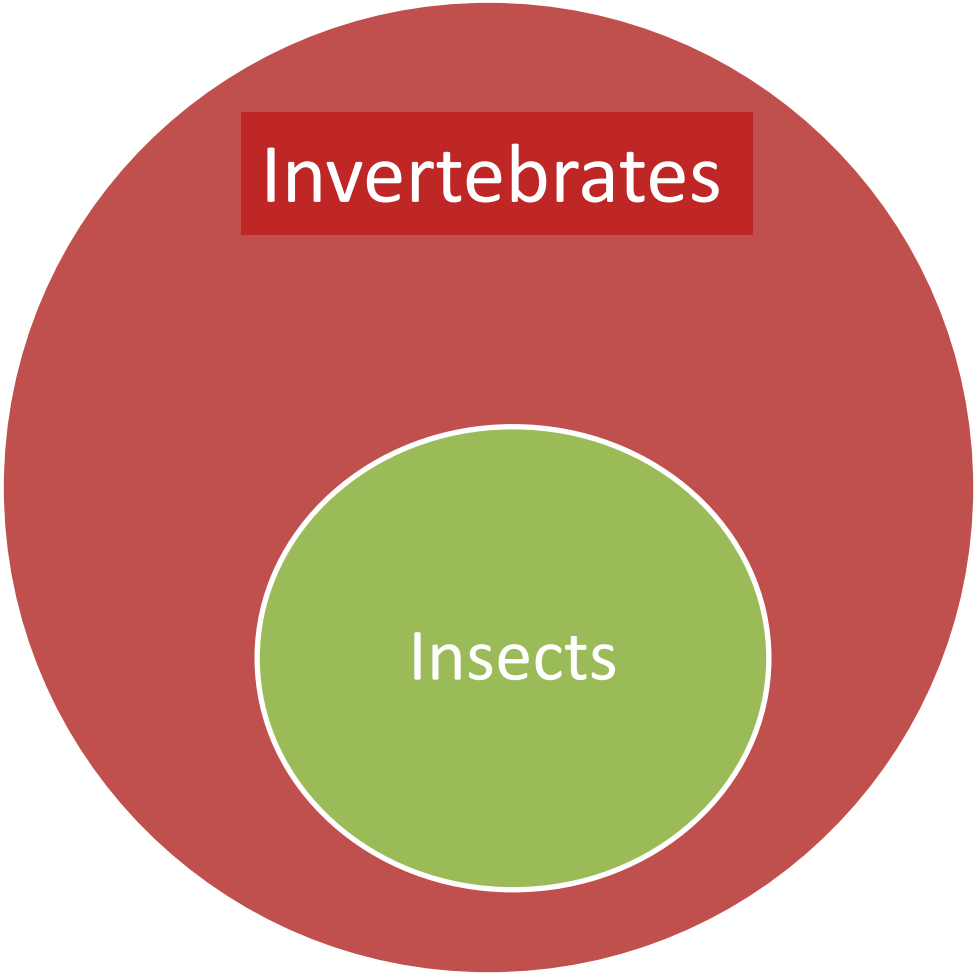


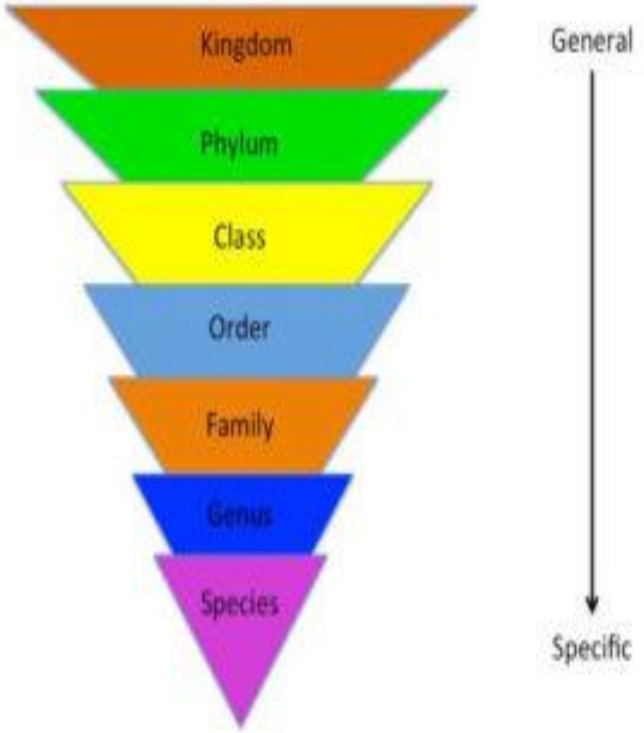
“Why is a spider not an insect?”

“Why is a spider not an insect?”

		
Alfie says “A spider can’t be an insect because it has a different body from insects like bees.”	Chen says “A spider can’t be an insect because spiders don’t have wings and insects do.”	Megan says “A spider can’t be an insect because it makes a web and insects don’t do that.”

Plan for conceptual understanding





How can leaders best support teachers?

Planning and sequencing how children encounter concepts requires strong pedagogical subject knowledge, with which some teachers need considerable support.
How can leaders best support their less confident colleagues ?

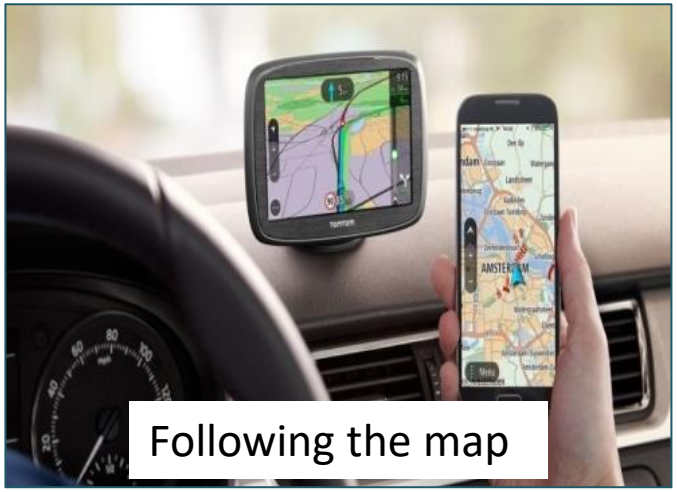
Making sure that building blocks of knowledge are identified and planned for explicitly.

Helping teachers see how knowledge connects conceptually and that this builds understanding over time.

Helping teachers decide how scientific enquiry and thinking supports the development of conceptual understanding.

CAPITAL TEACHING ALLIANCE

Mapping the subject



CAPITAL TEACHING ALLIANCE

Next time

Wednesday 26th January 2022
13.00 – 15.00

Reflections on ‘takeaways’ from session 1

How can we best ensure that children use scientific vocabulary accurately and showing understanding ?

Contact details

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