Primary science: supporting children's learning

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About this free course

This free course is an adapted extract from the Open University course E209 *Developing subject knowledge for the primary years*: www.open.ac.uk/courses/qualifications/details/e209.

This version of the content may include video, images and interactive content that may not be optimised for your device.

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www.open.edu/openlearn/education-development/education/primary-science-supporting-childrens-learning/content-section-0

There you'll also be able to track your progress via your activity record, which you can use to demonstrate your learning.

Contents

Introduction

This free course, *Primary science: supporting children's learning*, provides a brief insight into the nature of scientific knowledge and some of the factors that affect our attitudes to science. As you evaluate, revise and extend your knowledge of a selection of science topics that are commonly found within the primary curriculum, you will focus on how children learn scientific concepts and how they can be supported to develop scientific knowledge, understanding and skills.

This OpenLearn course is an adapted extract from the Open University course E209 *Developing subject knowledge for the primary years*, relevant to anyone interested in the education of 3 to 11 year old children.

Learning Outcomes

After studying this course, you should be able to:

- evaluate and advance science subject knowledge
- reflect upon some key scientific concepts and skills relevant to children's learning in the primary years
- consider what can make science difficult or easy to learn, and explore some common misconceptions about science and how they can be addressed
- reflect upon the importance of promoting positive attitudes to science and making children's science learning meaningful, relevant and engaging
- use and evaluate some different approaches to teaching science, such as those involving concept maps and modelling.

Teaching primary science: developing your subject knowledge

1 Science subject knowledge

Many of the activities in this course involve you reviewing elements of your science subject knowledge. Questions often focus on aspects that cause confusion for children and adults, so don't worry if you find them challenging. Sample answers and commentaries are provided so that you can develop your science subject knowledge while thinking about how to support primary-aged children's learni\ng in science.

Please note: while a range of science topics have been selected to illustrate how children's learning can be supported, this course does not touch on experimental design, practicals or inquiry-based learning.

1.1 Attitudes to science

Attitudes to science and scientific knowledge are not fixed – they change over time and between different groups of people. Here you will consider how and why attitudes vary.

Activity 1 Popular views about science

Allow about 10 minutes

Consider the following questions, and note down your thoughts. You don't need to respond to every point, or to comment in great depth.

What is the popular media view about science? Has this changed over the last few decades, or even in recent years? How do you think general attitudes to science might affect science teaching and learning in the primary years? What about the attitudes of educational practitioners and children?

Consider your own position too. What is your attitude to science, and what has influenced this?

Many people view science as 'difficult', 'boring', 'irrelevant' and only for the 'clever' students. Why do you think people might feel this way about science?

Provide your answer...

Comment

Those who influence attitudes towards science and how scientific knowledge develops include researchers, government, industry and religious and lobby groups. Attitudes change – for example, over recent years there has been a growing interest about science related to medicine and the environment. There has also been much cynicism in some quarters about some scientific evidence and theories – for example, in relation to climate change. These attitudes impact on science teaching and learning: the topics that are included in the curriculum, how science is portrayed, children's engagement and how children 'do' science.

Whatever the content and conception of science presented in the science curriculum, the role of adults in mediating the science curriculum and in engaging and enthusing young learners is critical. Your attitude to science will have been influenced by your own experiences including in:

- education (formally at school, and beyond that, informally through actions including visiting museums or sites concerned with environmental education, reading, watching television and using the internet, via finding out about health, diet and environmental issues)
- work (for example, in roles in education, medicine or in industry)
- hobbies (finding out about weather for holiday plans, the soil if you are a keen gardener, habitats and migration if you are a birdwatcher).

Some people associate science with high-level specialists and feel that science does not actively influence their lives (Metcalfe, 2014). Others may have been put off by lacklustre teaching that failed to engage them or help them to see the relevance of science to their lives and interests. When asked to describe 'a scientist', some trainee teachers depicted a scientist as a stereotypical 'boffin' – a bespectacled man with wild curly hair, dressed in a white coat and exhibiting eccentric behaviour – as shown in Figure 1 below!

Figure 1 Professor Boff

A challenge for those working in primary education is to address these stereotypes, and to make science appealing and relevant to children who have different interests and views.

1.2 The nature of scientific knowledge

The nature of scientific knowledge is closely tied to the nature of science itself. The scientific method tries to eliminate biases, subjectivity and idiosyncratic ideas from its body of knowledge, in order to produce objective paradigms or theories.

Activity 2 Theories

Allow about 5 minutes

Science develops theories. But what is a theory? What purposes do theories have in science? Answer these questions below, illustrating your explanation with some examples of scientific theories.

Provide your answer...

Answer

A scientific theory explains some aspect of the natural world. A theory is well-substantiated and widely accepted because it will have been tested and confirmed through observation and experimentation. Theories are used to make predictions and explain observations. Examples include the theory of natural selection and evolution, atomic theory and the theory of gravity. It should be noted that though these examples are 'theories' this is not meant to imply doubt – the evidence to support them is so substantial that they are often treated as 'fact'. Nevertheless, scientists work on the basis that a theory can never be proved absolutely, because it would only take some additional evidence to disprove it. Knowledge is constructed through human senses – a process that will always involve an element of subjectivity. So, scientific theories are not infallible, and even when there is robust evidence, human values, ethics and beliefs may result in competing views. We are left to judge which theory or finding is valid.

Metcalfe (2014, p. 11) found that some primary school children believed that scientists 'got things right the very first time because they are clever and never make mistakes'. He argued that helping young people to recognise that scientific knowledge is incomplete and may be wrong, and giving them a 'genuine experience of science' where they can experiment and develop their own enquiries, will help to develop their tenacity and creativity.

Figure 2 Genuine experiences of science

1.3 Seeing the bigger picture

Science encompasses a wide range of topics, theories and ideas. When developing subject knowledge in science, it is useful to think about such knowledge (yours and children's) in terms of small and big ideas. As in other curriculum areas, children normally start by learning about specific events or features that have limited application (small ideas) so that they develop an understanding of big ideas over time.

Activity 3 Big and small ideas

Allow about 10 minutes

From your own experience, whether as someone who works with children or has children, or just from your own scientific subject knowledge, can you think of a small idea that children might focus on in science and suggest how it relates to a bigger idea? You could think about small ideas that a four-year-old might learn about, and contrast them with what an eleven-year-old would learn.

Provide your answer...

Comment

There are many examples that you may have identified, including:

- Young children might plant stones and seeds in soil to see if they grow, to identify living and non-living things (small idea), while older children might learn about cellular structures that are unique to living things (big idea).

- Children may observe that the sun appears to 'move' during the day and that stars 'appear' at night (small idea). Later on, this will develop into an understanding of the fact that the Earth turns on its axis and that our planet is part of a wider solar system (big idea).
- Young children may play with parachutes and observe that they 'slow down' a falling object (small idea). Older children will learn about the gravitational and air resistance forces involved in this interaction (big idea).

Children can develop 'small ideas' as steps towards the bigger ones. Braund and Leigh (2013) argued that in this way, adults can make science accessible and meaningful for young children.

Figure 3 shows one representation of big ideas from the European Commission Go-Lab project, which aims to support school science learning. Harlen (2010) argued that:

- science teaching and learning should start with small ideas
- big ideas should not to be taught directly
- relevance to big ideas should be a reason for children spending time learning about scientific phenomena, and about science itself
- adults should know how the small ideas fit in with big or powerful ideas.

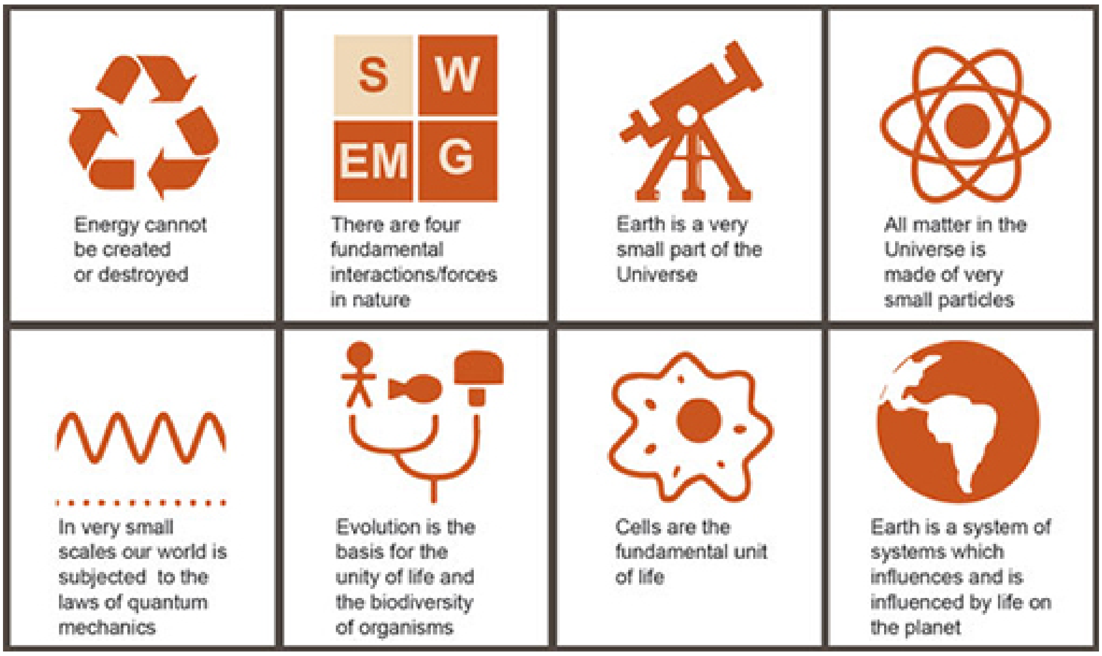

Figure 3 Go-Lab's big ideas of science (Go-Lab, n.d.)

Right click on the following link to open the video [Building the Science curriculum in Millersneuk primary](#) in a new window. Listen to how school staff explain their approach to supporting progress in children's conceptual knowledge and understanding. Note the emphasis on conceptual development throughout the primary years.

You can read a transcript of the video here: Millersneuk Primary transcript

2 Subject knowledge and teaching and learning

In the following sections, you should answer the questions and complete the activities related to a range of science subjects. The surrounding commentaries focus on issues to consider when supporting children's science learning.

2.1 Getting a sense of scale

In spite of 'joined up' planning in schools like Millersneuk Primary, children learn about different science topics in school as distinct blocks of work. One result of this is that the relative sizes of the things they're learning about are not immediately clear to them. For example, consider how the girls in Figure 4 would know how the ladybirds in their 'bug hotel' compare to other objects such as a plant cell or the Earth in terms of scale.

Figure 4 Observing the 'bug hotel' in the school bug garden

Activity 4 Scale

Allow about 10 minutes

Put the following in order of magnitude, from smallest to largest:

Table 1 Placing objects in size order

ladybird	bacterium	the Earth	flea	galaxy
human being	atom	molecule	plant cell	proton
red blood cell	solar system	star	universe	virus

Provide your answer...

Answer

The objects should be listed in the following order:

(smallest)

- proton
- atom
- molecule

Note: A micrometre (micron) is 1 millionth of a metre (note the English spelling). Protons, atoms and molecules are too small to be measured in this way.

- virus
- bacteria
- red blood cell
- plant cell
- flea
- ladybird
- human being
- the Earth
- star
- solar system
- galaxy
- universe

(largest)

Learning about these things as separate topics means children don't get a sense of the size of things that cannot be seen by the naked eye, or are so large that size is just a number (a very large one). You can help children to get a sense of scale by including opportunities for them to think across topics, and supporting them to make meaningful comparisons.

2.2 Scientific vocabulary

The same word may have different meanings depending on the context in which it is used. Those supporting children need to be aware of these different meanings. Children's ideas may become partly or completely misconceived due to confusion about vocabulary.

Activity 5 Everyday and scientific meanings

Allow about 10 minutes

Consider the everyday meanings and the scientific meanings of these words. If you're unsure of their scientific meaning, look them up. There's a space provided for you to note down any observations you make.

Table 2 Words with different meanings

atmosphere	space	dense
reaction	energy	reflection
solution	cells	tissue

Provide your answer...

Comment

In everyday language, these words are regularly used in ways that can vary quite a bit from their scientific meaning. For example, you might hear 'she's got so much energy' or 'I caught my reflection in the shop window', while these words are used for quite specific purposes in biology and physics.

It is possible for children to use scientific words correctly in scientific conversations, but then find it difficult to express all the complex ideas behind the concept when asked to define or explain what they mean. Exploring their ideas through talking and observing can help to dispel some of their confusion or identify under-developed ideas. As you answer the questions in this course, consider whether scientific vocabulary is a barrier for you. Are you able to provide good definitions that would support primary-aged children's learning? Or could some of your definitions mislead children and actually be unhelpful, as illustrated in the following activity?

Activity 6 Atoms and molecules

Allow about 20 minutes

For each of the definitions provided in Table 3 for an atom (definitions 1-6) and a molecule (definitions 7-10), decide whether:

it is **right**
it is **wrong**
it could be **potentially misleading**

AND decide whether:

it **would be helpful** to an eleven-year-old learner
it **would not be helpful** to an eleven-year-old learner

Note your decision in the boxes beside each definition – and explain your reasoning if you can.

Table 3 Definitions of atoms and molecules

Definitions of 'atom'

1. The simplest structure in chemistry. It contains a nucleus with protons and neutrons, and electrons moving round in shells.	*Provide your answer...*
2. The smallest part of an element that can exist as a stable entity.	*Provide your answer...*
3. The building blocks of life, the LEGO® of nature.	*Provide your answer...*
4. The smallest particle of an element that still shows the chemical properties of the element.	*Provide your answer...*
5. The smallest particle that can be obtained by chemical means.	*Provide your answer...*
6. The smallest particle that can be found. It is made up of protons, neutrons and electrons.	*Provide your answer...*
Definitions of 'molecule'	
7. The smallest particle of matter that can exist in a free state.	*Provide your answer...*
8. Something that is formed by two atoms bonding together.	*Provide your answer...*
9. The smallest portion of a substance that is capable of existing independently and retaining the properties of the original substance.	*Provide your answer...*
10. Group of two or more atoms bonded together. A molecule of an element consists of one or more like atoms; a molecule of a compound consists of two or more different atoms bonded together.	*Provide your answer...*

Answer

Table 3 Definitions of atoms and molecules

Definitions of 'atom'	
1. The simplest structure in chemistry. It contains a nucleus with protons and neutrons, and electrons moving round in shells.	Whether it is the simplest structure in chemistry is debatable and potentially confusing. The reference to electrons moving round in shells is not helpful because children will have different ideas about 'shells' than those that apply to atoms.
2. The smallest part of an element that can exist as a stable entity.	True, but not helpful because of the use of the term 'stable entity'.

3. The building blocks of life, the LEGO® of nature.	True. This is probably the most helpful for younger primary children because it avoids other complicated words and uses something they are more likely to be familiar with.
4. The smallest particle of an element that still shows the chemical properties of the element.	True, but this explanation requires an understanding of chemical properties.
5. The smallest particle that can be obtained by chemical means.	True, but not useful because 'by chemical means' adds complexity.
6. The smallest particle that can be found. It is made up of protons, neutrons and electrons.	True. This explanation is useful, even though it includes protons, neutrons and electrons. They are easier concepts to understand than expressions like 'chemical means' or 'stable entity'.
Definitions of 'molecule'	
7. The smallest particle of matter that can exist in a free state.	True, but not very useful because of the use of the term 'free state'.
8. Something that is formed by two atoms bonding together.	True and useful because it is put in simple terms.
9. The smallest portion of a substance that is capable of existing independently and retaining the properties of the original substance.	True, but not useful because it is too complicated.
10. Group of two or more atoms bonded together. A molecule of an element consists of one or more like atoms; a molecule of a compound consists of two or more different atoms bonded together.	True, but takes the definition into elements and compounds.

Extending children's scientific vocabulary will help them to build on their understanding, develop their thoughts and to express ideas. However, just because a child uses a scientific term, this does not necessarily mean that they understand it! Through questioning, their level of understanding can be assessed. Embedding new scientific terminology within meaningful texts, or giving children the chance 'to use them in discussion, debates and their own writing' will make them more likely to understand and retain learning (Kearton, 2011).

2.3 Classification: order or confusion?

Classification is used to bring some order to scientific knowledge, but as with all human constructions, there are debates and contentious issues surrounding the topic. For example, the concept of whether something is living or not is central to the study of biology. It may seem obvious to us, but it's much more complicated than you might think. Children learn about the criteria for 'living' and 'dead' through experience as well as formal learning, and the criteria they use to identify living things change as they develop their conceptual frameworks. Children under six are unlikely to have any concept of 'living'. At first, children associate 'living' with something being active in any way. In the next stage, living is associated with movement. Around the age of nine to eleven years, children start to view living things as those organisms that move by themselves. You will explore this in the next activity.

Activity 7 Living, non-living or dead?

Allow about 25 minutes

1. What are the seven characteristics of living things? Explain how each applies to a plant.

Provide your answer...

Answer

A common acronym to remember the seven characteristics is MRS GREN.

M	**- movement**: this may be obvious movement or internal movement of substances such as sap.
R	**- respiration**: the process of releasing energy from food, not to be confused with breathing. Like all living things, plants need to respire.
S	**- sensitivity**: detecting changes in the environment. Plants respond to light, gravity, and some respond to touch (e.g. the venus flytrap).
G	**- growth**: this is not just growing bigger, but also includes the replacing of cells that die, and the repair of wounds.
R	**- reproduction**: passing on of genetic information to new individuals. Plants produce seeds (sexual reproduction), or reproduce vegetatively (asexual reproduction) with the new individuals being identical to the parent plant.
E	**- excretion**: the process of getting rid of metabolic waste products. Oxygen is a plant waste product, released during photosynthesis.
N	**- nutrition**: all living things need nutrients to make new material and drive the living processes. Plants take in nutrients and the energy needed to drive these processes. Plants also take in micronutrients, usually dissolved in the water taken in by the roots.

2. Look at the list of objects in Table 4. Classify them as ‘living’, ‘non-living’, ‘once lived (dead)’ or as ‘other’. Note your classifications in the table along with any potential causes of confusion for primary-aged children, and outline any misconceptions you think they might have.

Compared to children, you will have a more sophisticated view of the definition of ‘living’, and you may start off thinking that this question is very straightforward. However, the examples in the list may get you thinking and questioning your decisions. For example, children seeing a lump of coal are unlikely to classify this as ‘once lived’, but if you know how coal is made, you may be less sure. Although coal is made from things that once lived and have undergone tremendous pressure and heat over time, coal as a substance has not ‘once lived’. This is an example of how a little bit of knowledge can actually confuse matters.

Table 4 Classifying living and non-living items

Object:	Living / non-living / once lived (dead) / other:
Fire	*Provide your answer...*
Tree	*Provide your answer...*
Mushroom	*Provide your answer...*
Seed	*Provide your answer...*
Bird's egg	*Provide your answer...*
Milk	*Provide your answer...*
Egyptian mummy	*Provide your answer...*
Bottle cork	*Provide your answer...*
Ammonite fossil	*Provide your answer...*
Virus	*Provide your answer...*

Answer

Table 4 Classifying living and non-living items

Object:	**Classification:**	**Notes:**
Fire	non-living	Children may classify it as living because it moves.
Tree	living	Plants are often not classified as living by children, because they are not obviously active and moving.
Mushroom	living	Even when children categorise plants as living, fungi such as mushrooms may not be included. (If the mushroom has just been picked and is still respiring it's still living. When it stops respiring, it's dead.)
Seed	living	Whether a seed is living or dead is hard to tell until they are planted or tested to see if they are respiring. Seeds start off as living – if they didn't, the world would be in deep trouble!
Bird's egg	living	Like the plant seed, it can be hard to tell if the egg is dead or alive. If it's been bought from

		the supermarket, it has probably never been alive because it will not have been fertilised. The embryo in an egg that has been fertilised will die if not kept warm though. Like seeds, fertilised eggs start off as living.
Milk	non-living	This is an animal product, produced by a living thing, but not in itself alive or once alive.
Egyptian mummy	once lived	Of course, the movies would have you believe that they can still get up and about!
Bottle cork	non-living	This is an interesting one, because it conflates material from a once living thing that has been crafted into an object. Would you say a wooden table once lived? The material it is made from came from a tree that once lived, but tables and bottle corks have not once lived. So, the bottle cork was part of a living tree once, but as an object it was never alive. To add to the conundrum, much like hair, cork bark is made of dead cells.
Ammonite fossil	non-living	This is another interesting one that leads to arguments. To classify it, you need to have a clear idea of what a fossil is. An ammonite was a living thing, but any traces of the living cells have long gone and been replaced with rock. Essentially, the fossil ammonite is a mould made of rock.
Virus	other – viruses cannot be clearly placed in any of these categories	They meet some of the biological requirements for being defined as living, but not all of them. This shows that imposing such definitions on the world is not as simple as we would like to think. Human constructions of 'living' are philosophical as well as biological, and where to draw the line is the source of much debate.

2.4 Conceptual development

Concepts are generalisations based on particular features relating to different objects or events. They allow us to 'use past experience in dealing with new experience' (Harlen and Jelly, 1989, p. 69). Some concepts are concrete, such as 'plant' or 'beach', while others are abstract, such as 'biodiversity' or 'erosion'. Watts explained that:

> We each have a 'mental' store in which our ideas and experiences are organised, so that similar ones are grouped together. In such a group there will be a general definition of the topic, some specific related pieces of knowledge and an idea of the contexts in which it is applicable. These broad, organising groupings are known as concepts, and are an essential aspect of developing understanding.
>
> Watts (1998, p. 51)

Children can become confused when they are introduced to new scientific concepts. The constructivist theory of learning explains that children have pre-existing ideas about the world and how it works. These ideas and conceptual frameworks will have developed through their experience (both in and outside of school), from the way ideas are talked about by their family and friends, and how they are portrayed in the media. This can result in children developing 'alternative frameworks' or 'misconceptions'.

Because prior knowledge and intuitive ideas are 'anchors' for conceptual development (Pine et al., 2001), children need time and opportunities to explore and develop their conceptual understanding (Mooney, 2013). Across the curriculum, teaching should ensure that children reconstruct 'faulty alternative' frameworks and change their conceptual understanding, to restructure what has been previously learned. This is particularly the case in science, as Vosniadou et al. pointed out:

> … scientific explanations of physical phenomena often violate fundamental principles of intuitive physics, which are confirmed by our everyday experience. For this reason learning science requires the radical reorganization of existing conceptual structures and not just their enrichment, and the creation of new, qualitatively different representations.
>
> Vosniadou et al. (2001, p. 384)

2.5 Constructivism and science

Linking new ideas with old, adapting and modifying ideas to inform thinking and ways of working are all in keeping with a social constructivist view of learning. This involves connecting learning with children's prior experience and building on their existing skills. If insufficient account is taken of children's existing understanding (including ideas that may be incorrect), children are unlikely to see the relevance or make connections with their own experience.

Questions that ask a child to remember something or apply a rule are unlikely to reveal their conceptual understanding. Various techniques can be used to find out what ideas a child holds about a topic or scientific concept. For example, you could use a concept cartoon depicting a situation, with two or three statements about what is happening. Children then look at the cartoon, decide which statement(s) they agree or disagree with, and say why. Engage with the example below to see this technique in action.

Activity 8 Using concept cartoons

Allow about 5 minutes

In Figure 5, children are building a snowman. They want to keep it for as long as possible. One child wants to put a coat on it, but the other isn't sure this will help preserve it. Do you think the coat will delay or speed up melting or have no effect? Why? Add your thoughts to the box below.

Figure 5 Concept cartoon. Adapted from Keogh and Naylor (1997)

Provide your answer...

Answer

The coat would delay melting because it would reduce the energy being transferred from the external environment. It is the same principle as using cooler bags to carry frozen food when shopping. However, coats are associated with keeping warm, so it is not unusual to reach the wrong conclusion that the coat would increase the rate of thawing.

3 Discovering children's ideas

If we are not aware of the ways in which children think, then leading them towards ideas that are accepted as scientific fact becomes a difficult task. Children can be very tenacious in holding onto ideas from their prior experience. Their 'alternative frameworks' may work alongside or, in some cases, be in opposition to accepted scientific ideas, preventing the development of scientific understanding. Thus, it is necessary to elicit children's prior learning and alternative frameworks so we can help them to progress.

From your own experiences, can you think of any instances of such 'alternative frameworks'? For example, some children think that as the Sun moves in the sky through the day, it is the Sun that orbits the Earth.

After you've considered these frameworks, move on to the next activity below.

Activity 9 Techniques to discover children's ideas

Allow about 15 minutes

In addition to using concept cartoons, what other approaches could you use to help you to discover children's ideas?

Provide your answer...

Comment

The techniques described below can all help.

1. Using pictures

Drawing or annotating diagrams does not rely on language skills and can reveal understanding that cannot be revealed through questioning.

For example:

- Draw what's inside your body or what happens to food after you have eaten it.
- Use arrows on this diagram of a flower, the Sun and an eye to show how we see objects.
- Draw a plant to show how it gets its food.
- Draw what happens to a drop of blood leaving the heart, visiting the big toe on its journey.
- Use arrows to indicate the forces acting on a ball after it has been kicked; compare this to a ball rolling across the floor.

Activities that involve sorting or selecting pictures can be employed with all children, but may be particularly useful for younger children or pupils with some special educational needs (SEN).

2. Creative writing or drama

For example:

- Pretend you are a water particle, and describe what happens to you as you go from being in frozen water to evaporating.

- What would happen if we got our food like plants get their food? What would happen if friction was switched off?
- Pretend you are a drop of blood, and describe what happens to you as you go around the body.

3. Sorting activities

These activities are useful to find out what criteria children use to classify objects. Real objects or pictures can be used. For example:

- Sort these things/pictures of things into living, non-living, once living.
- Sort these things/pictures of things into solid, liquid, gas.

4. True/false statements

True/false statements can be used to reveal misconceptions. To use these, you will need to know what the common misconceptions or confusions are and ensure they are included in the statements.

5. Predict and explain

Give children a situation, and ask them to predict what will happen next, explaining their reasoning. For example, you might ask young children to predict what will happen when objects made from different materials are placed in water. This will reveal what ideas they hold about floating and sinking.

6. Exploratory play

Allowing children to play and explore can engage them and help us to identify children's knowledge, understanding and skills prior to adult-led learning. For example, playing outside, looking for evidence of seasonal changes, or playing with soil and seeds.

When trying to discover children's understanding of scientific concepts, the most suitable approach to use will depend on the age of the children and the concepts you want to find out about (Pine et al., 2001).

3.1 Children expressing their ideas

One of the most important things an adult can do is listen to children, and give them opportunities to express their ideas in different ways.

Activity 10 Listening to children

Allow about 10 minutes

Watch the following two video clips, and observe how children are given opportunities to express their ideas at the start and end of a topic. What roles do you think the adults have played? Note any thoughts in the box.

Video content is not available in this format.

Video 1: Observing seeds

Video content is not available in this format.

Video 2: Christopher explains about friction

Provide your answer...

Comment

In the first film, the teacher has created an environment where young children share their ideas as they start their observations in pairs. Time, space and resources have been organised and the children are encouraged to touch and look at the seeds. The teacher stands back and gives the children time to explore the seeds and to share their existing knowledge as they start the topic, with one girl sharing her belief that one of the seeds is a bean.

In the second clip, it is clear that much of Christopher's learning has taken place as a result of observing or measuring, and then discussing what his observations might mean with the other children and adults. Being able to put what he has seen into his own words, and indeed 'teaching' someone else, helps him to articulate what he knows. He might need some prompts but, crucially, his ideas are valued as someone listens to him. Although we do not see the teaching prior to Christopher's interview, it is evident that he has had opportunities for extended investigation and exploration.

It's become widely accepted that language plays a key role in learning science, and Bruner (1978) stressed the importance of language as a way of learning how to think. If we are given opportunities to communicate our ideas, we begin to examine and perhaps question our preconceptions, and to develop our conceptual understanding.

3.2 Concept mapping

Another way to find out about children's existing knowledge is to use concept maps. These are not the same as brainstorms, spider diagrams or flow charts. Concept mapping is concerned with the organisation of ideas and the relationships between concepts (the term 'concept' is used to mean any term or phrase that has a scientific meaning). They are more sophisticated than mind maps because they reveal the conceptual understanding of the person devising the map. Pairs of concepts are connected by words and phrases along an arrow that shows the direction in which each pair should be read. An example is given in Figure 6.

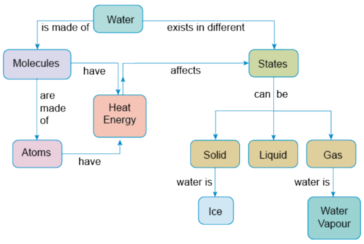

Figure 6 An example of a concept map

Concept maps are not flow diagrams. Although a concept might be linked to several others, the reading of a relationship is between pairs of words only. You do not link three concepts to make a longer phrase, for example. Each pair of linked concepts stands independently from the other pairs.

3.3 Constructing a concept map

There is no one right way to construct a concept map. However, there are some key steps and principles that need to be kept in mind. Read the following example before making your own concept map.

Identify the concepts or key terms

Focus on a few key concepts. Single words should be used to represent each concept, so for example, the chemistry of water might include 'molecule(s)', 'water', 'electron(s)', 'charge', 'polar', 'atom(s)', 'bond(s)', 'oxygen' and 'hydrogen'.

Concepts can be represented by pictures. When working with children you might provide them with a list of concepts or generate them with children through a brainstorm activity.

Sort through the concepts

Write the concept words or draw pictures on small pieces of paper so they can be moved about. Sort through the concepts and leave out ones you do not know or do not think are related to the other words (Figure 7).

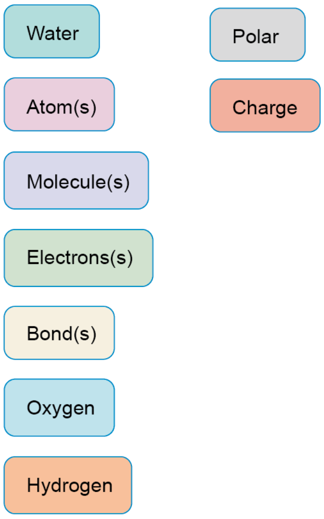

Figure 7 Sorting concepts

Forming the map

Put the remaining concept words on a sheet of paper. Arrange them in a way that makes sense to you, so that words that you see as closely connected are near each other (Figure 8).

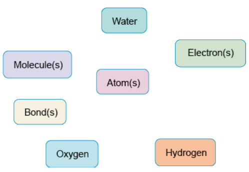

Figure 8 Arranging concepts

Sticking down the terms

When you are satisfied with the arrangement, stick them down or write the concepts on the sheet, surrounding each with a box to denote that it is a concept.

Linking the pairs

Next, identify pairs of concepts that you see as being directly connected (Figure 9).

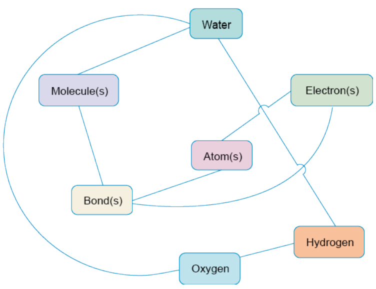

Figure 9 Linking concepts

Remember that in a concept map, only pairs of concepts are linked – each line is a separate, independent link and can be read forwards or backwards.

Adding the connecting phrases

Writing in the link words and adding arrows are crucial steps. Without these, concept maps are of little value (White and Gunstone, 1992).The arrow indicates the direction in which to read – which word is first in the 'sentence' (Figure 10).

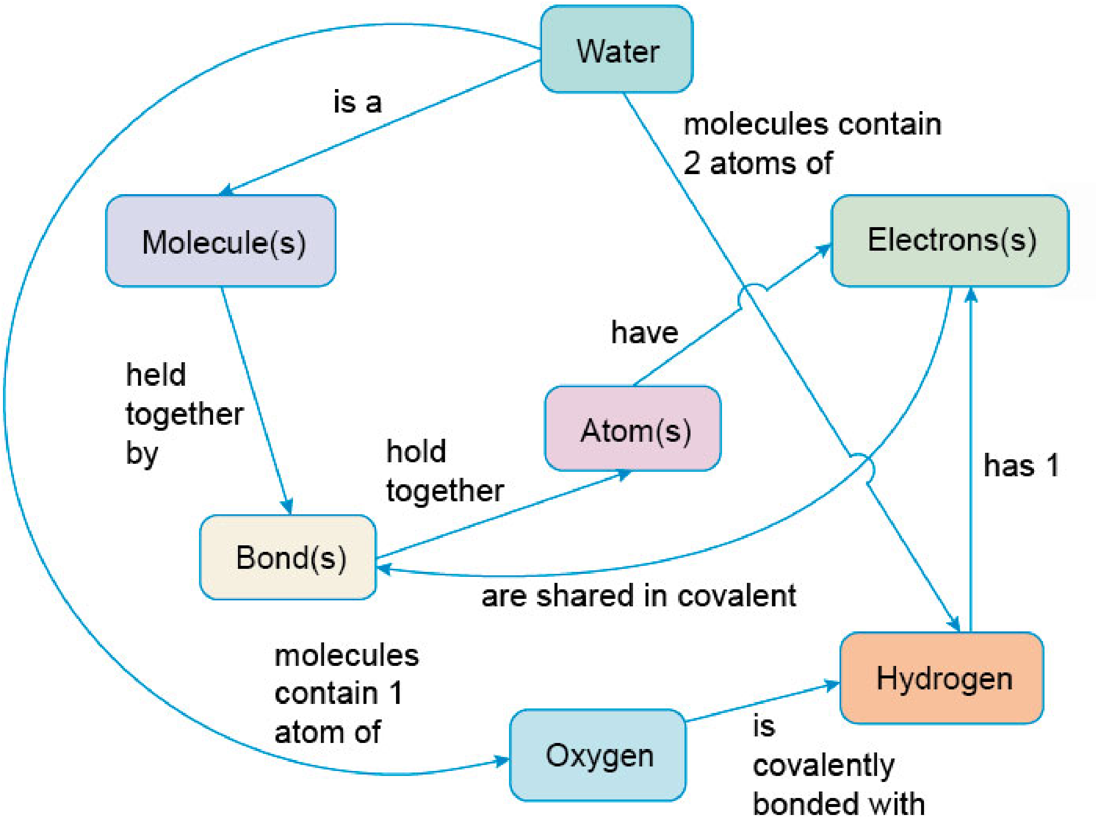

Figure 10 Adding details

Final checks

Go back to any concept words that you did not include in the first step, and see if you can include them in your map.

3.4 Uses of concept mapping

Concept mapping is a useful technique for assessing understanding. Not only do the linkages show how a person understands concepts, but words not used or with poor connections suggest a weaker understanding. Concept maps can be used to support learning as well as to assess understanding. For example, completing a concept map as a group to consolidate new work enables children to discuss their ideas (socio-constructivism) and by listening to the conversations, you can assess children's understanding. Concept maps can also be useful for adults in revising their own understanding.

Concept mapping is used across all age groups and phases of education. However, it takes some time to learn how to construct them. A variety of methods have been suggested to teach the technique to individuals, but all rely on practising with simple examples first. Concept maps are particularly appealing to visual learners, but all children can benefit from using them. Remember, that as concept maps are personal, there is no one 'right' map.

Activity 11 Making a concept map

Allow about 30 minutes

Follow the previous instructions to produce your own concept map. You can choose your own subject and concepts or use those listed below for plant nutrition.

- food
- green plant
- chlorophyll
- carbon dioxide
- oxygen
- water
- soil
- micronutrients
- glucose
- light
- respiration.

Once you have completed the concept map, spend 5 or 10 minutes researching the subject and the concepts. Would you change anything in your map?

4 Using models in science

Science develops and uses models which are simplified representations of the real world. Concept maps are a type of model that aid and show our understanding. Other models allow us to make predictions. In the following activity, you will think about models in general, before revising some of your subject knowledge about electricity and evaluating two models that could be used with primary-aged children.

Activity 12 Scientific models

Allow about 15 minutes

1. What purposes do models have in science? Give some examples of scientific models to illustrate your explanation. Can you identify some limitations of the models you identify?

Provide your answer...

Answer

Possible examples include:

- A scale model of a wind tunnel to test the impact of an aeroplane's shape on its flying efficiency.
- A crash dummy enables us to examine the impacts of a crash on a human body.
- Computer models used to predict the weather.
- Animals used as models for testing medicines.

Models have limitations though. For example: animals are not the same as humans and do not always react in the same way; car crash dummies don't move and are not constructed like humans.

2. Briefly explain what is meant by the following terms.

Table 5 Key terms related to current electricity

electric current	*Provide your answer...*
conductor	*Provide your answer...*
insulator	*Provide your answer...*
series circuit	*Provide your answer...*
voltage	*Provide your answer...*

resistance	*Provide your answer...*

Answer

Table 5 Key terms related to current electricity

electric current	An electric current is the flow of electric charge, often carried by electrons in wires.
conductor	A conductor is a material that will carry an electric current. Metals are good conductors.
insulator	An insulator is a material that will not carry an electric current. Plastics, wood, ceramics are good insulators.
series circuit	A circuit has a set of components linked by wires which allow an electric current to pass through them. A series circuit is one in which the bulbs and other components are in line and the electric current passes through each, one after another.
voltage	Voltage, also called electromotive force or potential difference, is the size of the difference in the charge between two points in an electrical field. It's a measure of how much 'push' there is. A 9V battery provides more push than a 1.5V battery.
resistance	Resistance is a measure of how much a material or system, such as a circuit or device, reduces the electric current flow through it. Resistance is measured in units of ohms (Ω). The higher the resistance, the more the current is reduced. A commonly used analogy is water flowing through pipes. The resistance is bigger when the pipe is thinner, so the water flow is decreased. Resistance also increases as the length of the conductor (wire) increases.

3. Here are some statements about current electricity. Are they true or false? Note your answer in the box, along with any relevant thoughts.

Table 6 Statements about electricity

	True or false?
Electricity is the flow of electrons in a circuit.	*Provide your answer...*
Positive and negative charges move in opposite directions in an electric circuit.	*Provide your answer...*
Batteries push electrons around a circuit.	*Provide your answer...*
Electricity is made in a battery when it is connected to a circuit.	*Provide your answer...*
Electricity is used up as it goes through a lightbulb in a circuit.	*Provide your answer...*
When you switch off a light in your home, the electricity is still in the wires connected to the bulb.	*Provide your answer...*

Answer

Table 6 Statements about electricity

Electricity is the flow of electrons in a circuit.	False.	This statement highlights the confusion caused by the word 'electricity' and it is best to avoid using it when possible. The correct way to describe the flow of electrons is to use the term 'electric current'. It is important to use precise language consistently.
Positive and negative charges move in opposite directions in an electric circuit.	False.	Only the electrons move in an electric circuit. Although it is possible to model a circuit on the idea that positive charges move one way while negative charges move the other way, this is not the case at an atomic level.
Batteries push electrons around a circuit.	True.	This is a useful way to imagine the role of the battery. The electrons are already in the circuit and the battery provides the electromotive force (emf) that pushes the electrons around the circuit. The common misconception is that the electrons originate in the battery.
Electricity is made in a battery when it is connected to a circuit.	False.	Batteries do not make electricity. Being connected to a circuit or not in this case is irrelevant.
Electricity is used up as it goes through a lightbulb in a circuit.	False.	This is a common misconception. The electric current (electricity) continues to flow around the circuit, so it cannot be 'used up' in the bulb. Energy is transferred to components in the circuit. The current carries this energy.
When you switch off a light in your home, the electricity is still in the wires connected to the bulb.	False.	Using the word 'electricity' in this sentence doesn't make sense – the flow of electrons in the wires is the electric current. Once the light is turned off, the electric current stops, though the electrons are still in the wires.

4.1 Modelling electricity

Some of the ideas you have encountered are challenging because they are abstract in nature. Building and using circuits will help children to develop their understanding.

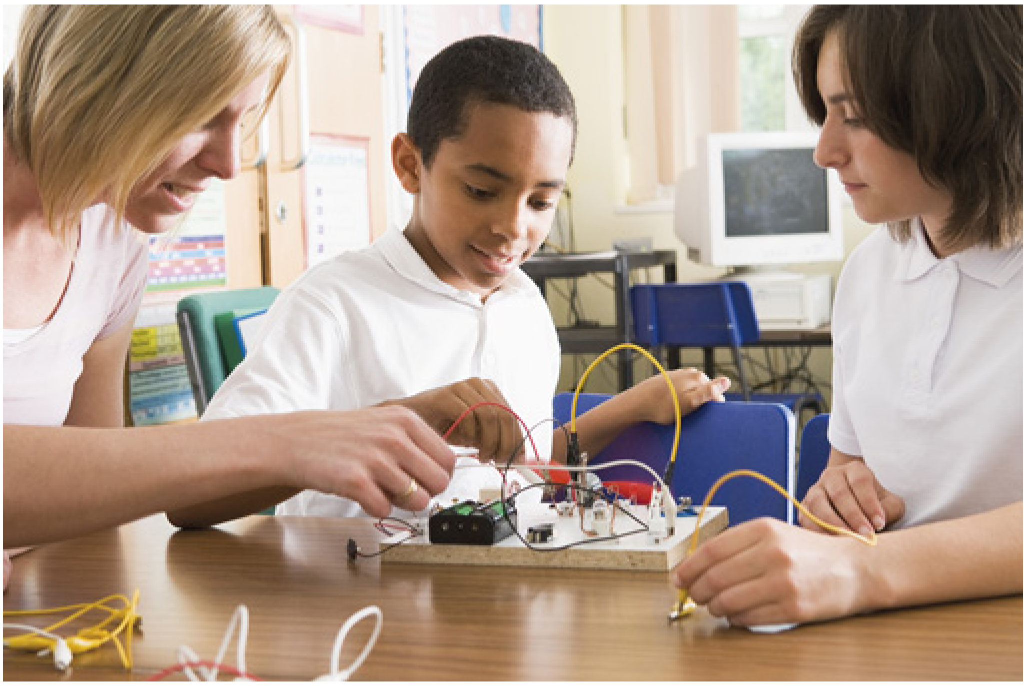

Figure 11 Making circuits

We can also use models and analogies to help children relate new abstract ideas to familiar situations. Two models are outlined in the following sections. Read about and evaluate each model.

4.2 Sweets and cups model

Read the instructions and imagine using the model. Answer the questions and consider how effective this model would be in helping children to relate new abstract ideas to situations they are already familiar with. How closely do the equipment and the process model an electric current moving through a circuit? What benefits would there be in using this model? Do you foresee any problems?

Activity 13 Modelling a circuit (1)

Allow about 15 minutes

What you need:

- a packet of wrapped sweets
- two boxes
- two paper cups.

What to do:

Before you start, choose one person from the group to read out the instructions and the 'applying your knowledge' questions.

- Start with everyone, except one, in a circle. The one outside the circle is an observer.
- One person has a box with some wrapped sweets in it (the 'battery'): they pass one sweet every second to the person on their right, who immediately passes

each sweet to the person on their right, and so on. (It may help to have someone outside the circle keeping time by tapping the table once a second.)

- One person in the circle has a cup to represent a lamp/resistor. When a sweet arrives, they hold it in the cup for a second before they pass it on. Soon, all the sweets in the box are moving steadily around the circle. The observer stands behind the person on the left of the 'battery' and claps every time the person they are standing behind passes a sweet back to the battery. The rate the sweets are moving around is the current. Allow the sweets to go round several times, so that everyone settles into the rhythm before you make any changes.
- Now give a cup to a second person, so there are now two lamps/resistors in the circuit. What happens to the rate that sweets pass round the circuit (how often the observer claps) now?
- Now give someone else in the group a box, and half of the sweets. They also pass one sweet a second, so now there are two people passing sweets to the rest of the circle (so there are two sweets a second being passed). This increases the rate that sweets pass round the circle, and the observer claps twice as fast.

Applying your knowledge:

The following prompts will help you and children to evaluate this model:

What forms the circuit in this model?

What represents the current moving round the circuit?

What represents energy in the circuit?

Where does the current collect energy?

In what ways is this model similar to your own ideas about electricity? In what ways is it different?

Provide your answer...

Answer

The circuit in this model is the circle of children. The current is the rate of moving sweets. The energy is the number of sweets. The current collects energy from the battery (box).

4.3 Rope model

The rope model is another model that demonstrates electric current moving around a circuit. Once more, read the instruction, answer the questions and consider how effective the model is for helping children to develop their conceptual understanding.

Activity 14 Modelling a circuit (2)

Allow about 15 minutes

What you need:

- a (large) loop of rope, ideally with a pattern or marks on it every metre, so you can see how fast it is moving.

What to do:

Before you start, choose one person from the group to read out the instructions and the 'applying your knowledge' questions.

- Everyone in the group stands in a circle and holds the rope so that the loop is not pulled too tightly, but does not sag anywhere either.
- One person pulls the rope around **steadily**, i.e. with a steady amount of pull.
- Everyone else should grip the rope very lightly as it passes through their hands.
- Everyone should grip more tightly and notice what happens. Be careful though, not too tightly! (This is not a tug of war game: the person pulling is meant to give a constant amount of pull, and should not start pulling harder and harder as everyone else grips more tightly.)

Applying your knowledge:

The following prompts will help you and children to evaluate this model:

What forms the circuit in this model?

What represents the current moving round the circuit?

What represents energy in the circuit?

Where does the current collect energy?

In what ways is this model similar to your own ideas about electricity? In what ways is it different?

Provide your answer...

Answer

The circuit in this model is the children's hands. The current is the moving rope. The energy is the rate of the rope's movement. Energy comes from the person pulling the rope.

Conclusion

Achieving and maintaining confidence in relation to personal subject knowledge is a challenge for all primary education practitioners. In science, the challenges include:

- rapid advances in knowledge, understanding and technology
- shifting views in science and attitudes to science
- the breadth of 'content' across the main sub-disciplines.

No matter how good your science subject knowledge, to effectively support children's learning, you must understand the ways children think about science, and you need to 'be able to evaluate the thinking behind students' own methods, and identify students' common misconceptions' (Coe et al., 2014, p. 2). You will also need to challenge stereotypes about science, and make science learning experiences engaging and relevant to children.

This OpenLearn course is an adapted extract from the Open University course E209 *Developing subject knowledge for the primary years*, relevant to anyone interested in the education of 3 to 11 year old children.

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Further reading

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Acknowledgements

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