Understanding misconceptions – teacher guidance with additional notes for EAL learners

The original teacher guidance for this aspect has hyperlinked resources and can be accessed from the same bookcase in the 'Local school' that this one came from. Or accessed from the Grouped Resources.

This strand is about recognising that pupils come to lessons with ideas about the world around them that can often be different from the accepted scientific ideas. Pupils need to develop some understanding of what these misconceptions are. They should begin to explore the idea that some scientific explanations can be counter-intuitive and how misconceptions or alternative frameworks might arise.

It is important that potential misconceptions are identified in the scheme of work and some suggested activities are provided for teachers to begin to address these. (The word 'misconceptions' as used throughout this document may be taken to mean 'alternative frameworks' or 'alternative conceptions'.) A misconception can be defined as a view that does not fully coincide with the scientific view.

Some features of misconceptions are that they:

- may be linked to everyday use of language;
- are constructed from everyday experience and are usually adequate for everyday life;
- can be personal or shared with others;
- explain how the world works in simple terms;
- are often similar to earlier scientific models (e.g. 'the Earth is flat');
- may be inconsistent with science taught in schools;
- can be resistant to change;
- may inhibit further conceptual development.

It is worth noting that in many cases pupils can hold both the 'misconception' and the scientific idea at the same time and may use different ways of explaining events in different situations. Some misconceptions may persist despite teachers' best efforts. Even when presented with new evidence pupils may modify it to fit into their existing model; for example, some pupils, having been clearly shown that current is not used up in a circuit, responded a few weeks later by saying that the ammeters were not working properly.

It is important that pupils' ideas are challenged in a non-threatening way and they feel reassured and safe when exposing and exploring their ideas. Pupils need to be able to test out their ideas to experience the 'conflict'. It is not enough just to tell pupils their ideas are wrong and this is what they should think.

It is all too easy to underestimate what pupils can achieve in science, simply because they are new learners of the English language. The expectation should be that they progress in their scientific learning at the same rate as other pupils of their age. Addressing misconceptions is essential for all learners; however, for EAL (English as an additional language) learners, the origins of misconceptions might not just be in scientific concepts (which can be addressed in the same way as for other learners) but in their understanding of text.

Such misunderstandings might occur at text, sentence or word level.

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Potential barriers at text level

- **Level of formality** – it may seem counter-intuitive, but many EAL learners, particularly those who have experience of schooling overseas, will find more formal language easier to access than a less formal register. It is important, therefore, not to 'dumb down' text but to teach pupils strategies for accessing texts with a more formal register.
- **Cultural context** – each culture has shared understandings of ideas and the way they are presented and organised which may cause problems if not taken into account. Contexts for learning should be relevant, motivating and culturally inclusive. This can mean that some 'common' metaphors and analogies are not helpful.
- **Tone of a text** – for example, an EAL learner might not detect irony in a text and so read it literally.
- **Layout of the text** – pupils need to understand how different parts of a text – particularly features such as diagrams (cross -sections, 3D and 2D), graphs and models – contribute to the overall meaning.
- **Lexical density of a text** – this refers to the number of content words that are 'packed in' to each clause. Lots of extended noun groups, such as 'lung cancer death rate', make the text harder for EAL pupils to read.

Potential barriers at sentence level

- **Use of the passive voice (who did what to whom?)** – EAL learners will have to be taught that they will often need to use skills of deduction in order to work out 'who did what to whom'.

  In everyday spoken English we tend to talk about what people do. However, when scientists are writing about their work, they are less interested in what individual people do. Scientific writing is usually impersonal. We don't need to know who carried out the action. Compare 'Miss Patel heated the test tube over a bunsen burner' with 'The test tube was heated over a bunsen burner.' The second sentence is more typical of scientific writing – we don't need to know who carried out the experiment. This style of writing is achieved by using the passive voice. For example, 'the embryo is implanted'; 'blood is oxygenated', 'rocks are eroded'.

- **Collocation and idiom ('It's just an expression')** – these are commonly used expressions such as 'The issue of GM foods is a political hot potato' (idiom) and words that frequently appear together such as 'high probability' (collocation). Teachers should be aware of these in texts and, whenever they are encountered, challenge pupils not only to explain, but to think of alternatives. Other examples include 'rocket science', 'blind with rage', 'bad blood' and 'by the skin of your teeth'.

  Some idioms can lead to misconceptions, for example, 'looking daggers at you' can make pupils think seeing happens because light comes from the eyes or 'dry as a bone' can make pupils think bones are dead.

  There is also a high probability that some words will appear together in a sentence. 'High probability' is itself an example of this. Other examples are 'do a test', 'strong acid' (rather than 'powerful acid') and 'adverse reaction'. This is called 'collocation'.

- **Degrees of comparison ('the bigger they come the harder they fall')** – in a sentence such as 'The higher the temperature, the faster the reaction' EAL learners will need to be taught that this is showing a dynamic relationship between the temperature and the reaction.

  A crucial aspect of science is identifying relationships between variables. To do this, pupils need to be able to understand and use a particular sentence pattern: 'The …er the X, the …er the Y'. For example, 'The thicker the metal, the longer it takes to dissolve'.

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Remember that often words of three or more syllables take 'more' or 'less' rather than the comparative form of '...er'. For example, 'The more acidic the solution, the less explosive the reaction'.

The expression of degrees of comparison is an important aspect of drawing conclusions from investigations and should be specifically taught through modelling.

- **Using pronouns ('this and that')** – pronouns are words such as 'he', 'she', 'it', 'they', 'this', 'that', which all refer to a noun elsewhere in the text. In guided or shared reading sessions, teachers should ask pupils to identify the nouns to which the pronouns refer.

  As pupils' writing in all subjects develops they learn how to make their writing flow by avoiding repetition. Compare 'John went to the park. John played on the swings' with 'John went to the park. He played on the swings.' 'He' is a pronoun and refers back to 'John'. In scientific writing there are many examples of the use of pronouns such as 'this', 'that', 'these' and 'those'. For example, 'Elements cannot be broken down into anything simpler. When these combine together they make compounds.' 'These' and 'they' are both examples of pronouns and in this sentence refer back to 'elements'. This will not necessarily be obvious to some pupils with EAL. Particular attention needs to be given to pronouns and the words to which they refer.

- **Modal verbs ('should have', 'could have', 'would have')** – these express doubt, certainty, possibility, probability, obligation or permission and EAL learners might not understand the subtle distinctions between them. For example: 'the results might indicate that…' and 'the results show that…' – how certain is the writer in each case?

  At the heart of science is the use of evidence to reach decisions, but science is also about identifying what is doubtful, certain, probable or possible. In investigations and problem-solving activities pupils start off tentatively saying, 'It might be X…it could be Y'. Then after finding appropriate evidence they decide that 'it can't be X because…' or 'it must be Y because…'.

  To do this they need to understand and use modal verbs. These include 'can', 'could', 'might', 'may', 'should', 'ought to' and 'would' and their negative and question forms, as well as different tenses. For example, when looking back at an investigation they might want to consider what 'might have happened' or what 'should have happened' or what 'could not have happened'. Modal verbs should be specifically taught through modelling and through relating them to ideas, hypotheses and conclusions.

Potential barriers at word level

- **Delexical verbs** – these are common verbs such as 'do', 'make', 'give', 'put' and 'get' that can be used in many different contexts. These verbs have different meanings depending on other words they are combined with or the context they are used in; consider 'give out' (emit, break down) or 'put down' (place, humiliate, suppress, write). Verbs such as these are often used incorrectly by pupils with EAL.

  It is preferable to teach pupils the science-specific verbs rather than using the more common delexical verbs which can cause confusion.

- **Specialist use of everyday language** – teachers should draw attention to the specialist use of words such as 'cell', 'tissue', 'mass', 'volume', which can have different meanings in everyday contexts.

  Science has its own subject-specific vocabulary, for example, 'evaporation', 'sodium chloride', 'transpiration', 'oxygenated'. In general, teachers are very good at drawing attention to these words and teaching them explicitly.

  There are also many scientific words which are used in other curriculum areas and in ordinary English with different meanings: 'conductor', 'tissue', 'host', 'property', 'value', 'attract', which can cause problems unless the different meanings are made explicit to pupils.

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Apart from subject-specific vocabulary in science texts, there are many other examples of more formal language not normally used in spoken English: 'represent' (show), 'container' (beaker), 'method' (how to do it), 'direction' (way), 'complete' (finish).

Moving from step 1 to step 2

Step 1 – pupil characteristics

Pupils:

- use everyday experience to explain scientific ideas;
- show common misconceptions in their written and oral work.

Step 2 – pupil characteristics

Pupils:

- are aware that some scientific explanations are counter-intuitive and that this can be because of differences between everyday and scientific explanations.

Strategies to ensure progression from step 1 to step 2

A) Use Concept Cartoons™ (concept mapping or annotated drawings) with pupils to raise awareness that alternative ideas exist.

- Use a Concept Cartoon™ and give pupils time to discuss any points with which they agree and to justify their decisions, explaining how they know. Share these views with the whole class to explore whether different pupils hold different views. If all pupils think the same then ask them to try to give at least one idea or reason why other characters might think differently.

  The aim of this exercise is to reinforce the idea that there are often seemingly legitimate reasons why people think certain things and hold particular ideas. A Concept Cartoon™ can be used to create some cognitive conflict that will be developed further on.

  The Ideas, Evidence and Argument in Science (IDEAs) project[1] has materials to support the development of argument in the classroom.

- Use concept maps – these may be constructed by pupils or devised by the teacher where some of the links are based on current scientific knowledge and understanding and some are not.

  The aim of this exercise is for pupils to work in small groups to identify links with which they agree and those that they think are wrong. They share their ideas with another group and look for similarities and differences in their ideas. Pupils can use this to produce a list of questions or ideas about which they are less secure. It is important to have a climate for learning that enables pupils to feel safe enough to admit that they do not know.

  Use annotated drawings – these may be ones drawn by pupils in other classes, taken from various science sources or drawn by the pupils. Annotated drawings might be produced in response to:

  - a question, such as: 'What does a plant need to grow?' or: 'How do clothes dry?';
  - a simple practical activity such as placing an ice cube in a metal container and observing the changes, or watching a Cartesian diver.

1 The Ideas, Evidence and Argument in Science (IDEAS) project was developed by Jonathan Osborne, Sibel Erduran and Shirley Simon and published by King's College, London (2004)

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Working in small groups, pupils identify any annotations with which they do not agree and make changes in a different colour. These are passed to another group who make further changes in another different colour – these changes might be to the original or amended annotations. The drawings are then returned to the original group for further discussion before the three groups join together to explore any differences in their ideas.

B) Identify some misconceptions held by the pupils and explore with them which of these statements seem counter-intuitive and why.

- Use the true/false/unsure sheet from the 'Misconceptions in science' handout to identify quickly some misconceptions across a range of concepts.

  Or use the card sort activity from the 'Misconceptions in science' handout and ask pupils to sort the cards into those with which they agree, those with which they do not agree and those about which they are not sure. (Note: They are all false!)
- Use the 'Identifying misconceptions questionnaire' with small groups of pupils to explore their understanding.
- Ask pupils which areas of science they find the easiest to understand and see if they can say why.
- Explain the idea of the counter-intuitiveness of science to the pupils. Allocate some misconceptions to groups of pupils and ask them to find out what the scientific explanation is.
- Ask them to decide if this explanation seems counter-intuitive and what makes the misconception more believable.

Moving from step 2 to step 3

Step 2 – pupil characteristics

Pupils are:

- aware that some scientific explanations are counter-intuitive and that this can be because of differences between everyday and scientific explanations.

Step 3 – pupil characteristics

Pupils can:

- explain how some common misconceptions might arise;
- recognise that it is possible to have and use conflicting models.

Additional guidance

In some areas of school science, there are big overlaps between everyday and scientific ways of knowing (for example, skeletons) which are the ones pupils generally find the easiest to understand because of the similarity of the explanation. However, in other areas, science offers an alternative to the everyday view – one that pupils may find implausible. For example, most people will describe drinking through a straw as 'sucking'; the scientific explanation is that there is a difference in air pressure inside and outside the straw. You remove some particles of air from the straw, thus reducing the air pressure inside the straw, and the greater air pressure outside pushes the orange juice up into your mouth. The scientific explanation can seem counter-intuitive.

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Strategies to ensure progression from step 2 to step 3

A) Use Concept Cartoons™ with pupils to promote the discussion of alternative iewpoints, for example, explaining why they do not agree with certain characters' viewpoints.

- Use a Concept Cartoon™ but this time ask pupils to explain why they do not agree (wholly or partly) with the other characters' ideas or statements.
- Set up a debate with different pupils taking different roles to justify why their view is correct. English and humanities departments often have expertise that can be drawn on to organise this well.
- Use a variety of group work activities to enable pupils to explore different viewpoints. See the handout 'Successful science discussions'.

B) Discuss with pupils how some of the different representations of scientific phenomena can lead to misconceptions, for example, diagrams or models of particles, seasons, gas exchange.

- Ask pupils to look through textbooks to find pictures of:
  - diagrams of particles, for example, in solids, liquids and gases; osmosis; diffusion;
  - gas exchange in leaves and air sacs;
  - day and night; seasons; phases of the Moon;
  - respiration (usually only animals and not plants);
  - elements and compounds;
  - light ray diagrams;
  - the reproductive system.

  Select one of these and explain to pupils how it might cause misconceptions. For example, the diagram showing the seasons generally has a noticeably oval orbit with the Earth much closer to the Sun in autumn and spring.

  Ask them to look at the other diagrams to see if they can identify how any of them could lead to misconceptions.

Additional guidance

Models and analogies are useful to help pupils visualise abstract ideas and objects or processes that are too small to be seen. Different pictures can be used to explain different ideas or aspects of ideas. However, no one model can explain everything and sometimes models break down. Models can be 'good enough' for the particular purpose, for example, a 'billiard ball' model is good enough for solids, liquids and gases but not for chemical reactions. Yet in many books this is what is shown. Pupils need to be made aware of the 'good enough' model and its shortcomings.

C) Create the opportunity for pupils to discuss which of the common misconceptions could arise because of everyday ways of speaking, for example, 'plants get food from the soil'.

- Give pupils some examples of common everyday expressions that could cause misconceptions. For example:
  - 'I'm looking right through you.'
  - 'Turn the switch off and save power.'
  - 'Shut the door and keep the cold out.'
  - 'Come a bit closer – I can't hear you.'
  - 'The ball stopped because it ran out of force.'

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  - 'I've used up all my energy.'
  - 'Astronauts float because there is no gravity in space.'
  - 'Just going to buy some plant food.'

  Ask pupils to discuss how these could lead to misconceptions and if they can they think of any others.

- Give pupils the 'Everyday meanings sheet' to discuss and complete. How do these words lead to misconceptions?
- Ask pupils to search the internet for any old sayings or myths that might lead to misconceptions, for example, the idea of taking flowers out of a hospital ward or bedroom at night. Ask whether they have been told any of these by parents, carers or grandparents.

Moving from step 3 to step 4

Step 3 – pupil characteristics

Pupils can:

- explain how some common misconceptions might arise;
- recognise that it is possible to have and use conflicting models.

Step 4 – pupil characteristics

Pupils can:

- explain how insight into the ways misconceptions can arise has helped their understanding of science.

Strategies to ensure progression from step 3 to step 4

A) Use Concept Cartoons™ with pupils as a stimulus to enable them to think about why the characters might have those ideas and where they might have come from.

- Pupils are given a Concept Cartoon™. The aim of this exercise is to develop an awareness of how the misconception might have arisen and to extend this to include an explanation of what is fundamentally wrong with the idea. Pupils should have already considered how misconceptions can arise from everyday terminology or expressions and when the scientific explanation feels counter-intuitive. Other reasons may be as a result of:
  - the scale of the topic – either giant scale, for example, the Universe, or tiny scale, atoms, means that it cannot be observed directly;
  - the statement being based on opinion rather than scientifically accepted fact, or opinions based on atypical observations such as: 'All plants reproduce like the Mexican hat plant, where little plants form round the edge of the leaves, drop off and grow in to another plant.';
  - it being an abstract concept;
  - relying on another concept being fully embedded.

  This list may be used as a checklist for pupils or made into a table.

B) Create the opportunity for pupils to compare some of the common misconceptions to the scientifically-accepted explanations and consider what evidence they would need to disprove the misconceptions.

- Pupils could devise their own Concept Cartoons™ to illustrate possible areas of confusion in a topic. Then give this to another group to decide what activities they would ask younger pupils to undertake to begin to challenge some of the misconceptions.

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- Pupils identify and discuss examples where they think it would be difficult to challenge the misconception, and explain why.
- Give pupils some examples of how scientists came to a view that was contrary to the beliefs of the time; for example, Galileo, Darwin, Wegener and the role of the scientific community in validating new models.

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