CHAPTER 7

PLANNING AND ASSESSING CHILDREN'S SCIENCE LEARNING

Do not train children to learning by force and harshness, but direct them to it by what amuses their minds, so that you may be better able to discover with accuracy the peculiar bent of the genius of each.

(Plato, 427–347 BCE)

Well-planned science lessons provide engaging learning opportunities. Planning involves deciding which strategies will best develop children's understanding. The ideas that children bring to the classroom are the basis for learning and can be assessed to inform planning. This chapter examines approaches to planning and assessment which can be integrated into the three-stage framework for organising science learning.

Topics discussed in the chapter

- The nature of formative assessment
- The nature of summative assessment
- Planning children's science learning
- Planning the exploratory stage
- Planning the re-describing stage
- Planning the application stage
- Across the stages

The nature of formative assessment

There are two purposes for assessment. The first is to check children's progress towards a learning goal and to evaluate what needs to be done to promote learning. This is assessment *for* learning or formative assessment. The second purpose of assessment is to create a snapshot or summary of children's progress at the end of a topic or over a period of time. This is assessment *of* learning, or summative assessment, used for formally reporting children's progress to parents and others.

The key characteristics of formative assessment are that it is ongoing, dynamic and progressive (Bell and Cowie, 2001). It also has to be responsive – something has to happen as a result of it. The following teacher's comment highlights the progressive and responsive nature of formative assessment:

> **If you do something to find out where they (children) are at, and then you do something from that to change your teaching or what you are doing, then it is formative (assessment).**
>
> (Bell and Cowie, 2001: 544)

Formative assessment may be informal, without written records being made, and can be used to inform teaching and learning in all stages of a lesson. In practice, it is often opportunistic, taking place as teachers listen to children's conversations and respond to their queries and comments. When planned, assessment activities may be carried out at the beginning of a lesson and again at the end to measure changes in understanding. Information can be used to inform what is taught in subsequent sessions.

Teachers and children can collaborate to ensure effective formative assessment. From the child's perspective, formative assessment can help them to understand what learning is possible and how it can be achieved. It should also clarify what they have done well and what they need to do to improve (Black and Harrison, 2000). Teachers often share their learning intentions with classes of children, usually towards the start of a lesson. By sharing learning intentions and deciding on indicators of children's progress (success criteria or 'steps to success'), children are better aware of the aims and purposes of their classroom activity (Clarke, 2008).

Although formative assessment can be carried out through different activities, it is by nature dialogic because it requires children to communicate their ideas. Questions such as: 'What do you imagine is going on here?', 'What do you think?', 'What do you mean by that?', 'Can you say a bit about …?', 'Can you explain more about …?', 'Why do you think that?' or 'What words would you use to explain …?' provide tools to mediate assessment activities and to probe more deeply into children's thinking. Having discovered what the child already knows, we can use the information to respond appropriately.

Something to think about

Is it always possible to plan for formative assessment? What formative assessment opportunities provide the sort of information that can be used to support planning?

Aspects of effective formative assessment

Learning needs: Essentially, the purpose of formative assessment is to gather information about children's ideas and to use it to help create new and appropriate learning opportunities. In science classrooms, development is dependent on finding out, and addressing, the difference between a child's existing ideas and a more scientific point of view. The ideas in question may concern understanding natural phenomena or events, or they may be to do with attitudes or ways of working scientifically. The difference between the children's way of thinking and ways of thinking from a scientific point of view can be defined as the 'learning needs' of the children (Leach and Scott, 2002). The concept of 'learning needs' helps us to target teaching strategies for different children, to identify next steps and to hold focused discussions with classes and individuals.

Teachers' questions: Teachers ask questions to stimulate discussion and help children to articulate their current ideas. Teachers' questions are meant to engage children by appealing to their personal memories and their willingness to contribute. They are used to ensure that all children are attending and to generate common knowledge. But some questions are more useful than others. Teachers may slip into asking questions to which children have to guess the right answer, that is, find out what the teacher wants them to say. For example:

T: OK, who can tell me what magnets do? Katy?

K: Stick to the fridge.

T: Um, yes, fridge magnets – but if you have two magnets, what happens?

And so on for many more turns until the class have come up with the required phrases, 'Like poles repel; unlike poles attract'. Teachers' questions require a lot of hand-waving on the part of the children and the teacher may have to manage some off-task behaviour created by boredom. This sort of interaction is the source of such phrases as: 'Listening ears on, everyone!', 'Let me see, who is sitting beautifully?', 'I can't ask you because you haven't got your hand up' or 'Can you repeat that, Josh? I couldn't hear because some people are just not listening' and so on. Episodes of interminable questions leave the class and the teacher quite baffled by one another and do not help children to understand anything. Less experienced teachers may copy this style from those who have had years of practice at handling children this way. Children, having little choice, rapidly learn the rules and then spend much of their time finding ways to subvert them.

In the story 'What seeds need', the teacher is starting a topic on growing plants with Year 5. Here the deadening impact of 'teachers' questions' is evident.

Example: What seeds need

T: Right. Now. What do seeds need to grow? *(hands go up)* Alice?

Alice. Sunlight and […] water.

T: Hmm, sunlight and water, you think. What else? *(fewer hands)* Bryce?

Bryce: Earth.

Kieran: Compost.

T: Put your hand up. You might be chosen to talk if you put your hand up. *(Kieran puts up his hand.)* Hmmm, come on, someone different. Muj?

Muj: Something to grow in.

T: Yes, something to grow in, but what else? To grow?

Chloe: Blue pellets to keep away slugs.

T: That's not vital. What else does it have to have? What other vital things? We've got sunlight, water and soil.

Denes: Can worms help them grow? On my Gran's allotment, right, she has worms, they […]

T: *(dismissively)* Worms!

Denes: *(nodding)* Yes, she lets me pick them up, I can pick up worms.

Alice: Yes, in the soil, they make holes in the soil.

T: Um, yes, help the soil. Absolutely. Worms. Right, now I want you to put together a role-play for me …

Comment

The teacher had not decided whether to stick to talking about germination (seeds usually need water, air and some warmth) or to talk about plant growth (plants usually need light, water, air and some warmth and sometimes a growing medium such as soil). She asks six 'teachers' questions'. She accepts the children's suggestions, sunlight, water and soil – although not sounding too confident about it – but has another idea in mind and prompts the children to keep guessing what it is: possibly warmth or air. The interesting idea of slug pellets reminds Denes of soil creatures and he asks a question about worms, which is dismissed as nonsensical by the teacher but picked up by his classmate Alice. Alice's idea that worms make holes reminds the teacher that worms do help plants – which is what she asked – by aerating soil. But this is slightly too complex an idea to fit in the simpler narrative that plants need sun, water, soil and … air? Warmth? She covers up the slight muddle by rapidly moving on. This cannot happen to teachers who are asking genuine questions, which by their very nature indicate a quest for information or understanding. Teachers do better when they take up answers positively and make it clear what they do not know or what is new to them; clarifying their role as part of the enquiry rather than the complete solution.

The children have no chance to share what they genuinely know or understand. It is evident that Alice seems to understand what plants require, Denes has experience of allotments, Chloe has learned about keeping slugs at bay, Kieran offers the suggestion of compost as a different medium than soil and Muj may be summing up what soil and compost are or is aware that plants need a habitat, even if it's simply a plant pot. These ideas are not what the teacher wants. Each suggestion is taken as a slightly wrong end point rather than an opener to a wider discussion. But what is she trying to teach? The learning intention for this session was 'to be able to say what seeds need to grow into plants.' It would be more productive to hand out some seeds and ask the children to tell each other everything they can think of about how to help the seed grow into a big plant. The teacher can then invite children to share what they have heard or nominate a classmate who they think has something interesting to offer. Having listened to the children's ideas, the teacher can consider their 'learning needs' and then manage the next step in their learning accordingly.

The responses we get from children depend on the types of question we ask. From a question such as 'What will happen to the plant if we stop watering it?', the teacher may be expecting a factual answer: 'It will die'. The teacher is only interested in one answer. But if we show the children an unhealthy-looking plant and ask what they think is wrong with it, we are more likely to hear a range of views. To engage children in learning conversation, we need to ask questions which show an interest in their experience or require them to express a point of view, giving their reasons. In the three-stage framework, interesting questions or puzzles are introduced in the exploratory stage and this sets the scene for children's learning in the re-describing stage. Children's responses to puzzles and questions provide us with insight into their existing understanding. Planning questions and puzzles is crucial if we are to determine, and subsequently address, children's 'learning needs'.

The 'Blue Earth puzzle' provides an example of formative assessment in practice in a class of 8-year-old children:

Example: Blue Earth puzzle

Joe's class was shown a picture on the interactive whiteboard of the Earth taken from space. The children were asked to think about why the Earth looked blue from space.

Joe was convinced that the Earth looked blue because the sky was blue. He held firm views about the reasons for the colour and he was not ready to change them. He asserted that the picture from space was taken through the sky so it had to look blue.

When another child suggested that the Earth looked blue because of the seas and oceans that covered it, Joe became quite agitated. He walked up to the whiteboard and said that he was worried about this idea. He used his hands to explain that if the blue was water then the water on the sides and bottom of the Earth would run off and we would have no seas left. He knew that we have seas and oceans; he insisted that the only possible explanation was that the blue had to be the colour of the sky.

Comment

Joe's response revealed learning needs which the teacher had not expected. Here on Earth we constantly live with the effects of gravity, so that intuitively it makes sense that water would fall down and off the sides and bottom of the Earth. We need to recognise the explanatory power of Joe's reasoning. He has seen water running downwards. As teachers, we have to make the decision: in what way do we want Joe to change his understanding of the Earth and gravity? Once we decide this, we can plan and organise teaching strategies to help him to understand a more scientific point of view.

Something to think about

Read the 'Blue Earth puzzle' and assess Joe's learning needs. Think about how you might address them.

Self-assessment and peer assessment

Children can be involved in assessing their own progress. To do so, they need to be clear about what they should be able to do as a result of their learning, which they could not do before. Setting children a puzzle to solve provides them with an insight into what they are trying to achieve. Finding solutions to puzzling events brings not only measurable intellectual rewards but can also provide emotional satisfaction which can positively influence children's attitudes to further learning (Chapter 1).

Just as children need to be taught to talk and think together in scientific ways (Chapter 5), they need to be taught the assessment skills to monitor and manage their own learning. Children may need input in the language of judgement and assessment. For example, 'understanding' can mean being able to explain an idea clearly to someone else or being able to put an idea into practice or help solve a puzzle. Simple systems to record self-assessment include the use of 'traffic light' icons to signify whether children perceive they have achieved the learning goals, putting thumbs up or drawing smiley faces on work to show how confident individuals are in their learning.

Whatever strategies are used to promote self-assessment, children need to learn to question and reflect on their learning. Asking themselves particular questions can help shape children's thinking and understanding: What needs to be done next? How can I best find an answer to that question? Is there any other way to find an answer to that problem? Is there another way of looking at the problem or puzzle? Are there any other words I can use to explain my view more clearly? What reasons do I have for my belief? Do I really understand the meaning of that word?

These types of questions require children to reflect on the nature of their own learning and understanding. Children should be encouraged to communicate and justify their judgements to their peers and teacher, and make suggestions about how to proceed with their learning.

Peer assessment can usefully support self-assessment (Black et al., 2002). Strategies for peer assessment may not be immediately obvious to children. Asked to look at one another's work, they may take the stance of a very harsh and unyielding teacher! Effective ways to assess work and communicate helpful ideas really need to be made explicit. Exploratory talk (Chapter 5) between children has an important role to play in peer assessment. Learning takes place as children listen and respond to each other's ideas, and discussion can focus on how to achieve their learning goals collaboratively. Children need to be taught to offer supportive formative comments and suggestions, to query ideas and note what they have found new or interesting, and that it is not their role to make summative judgements about whether their classmates' ideas are right or wrong, 'good' or 'bad'.

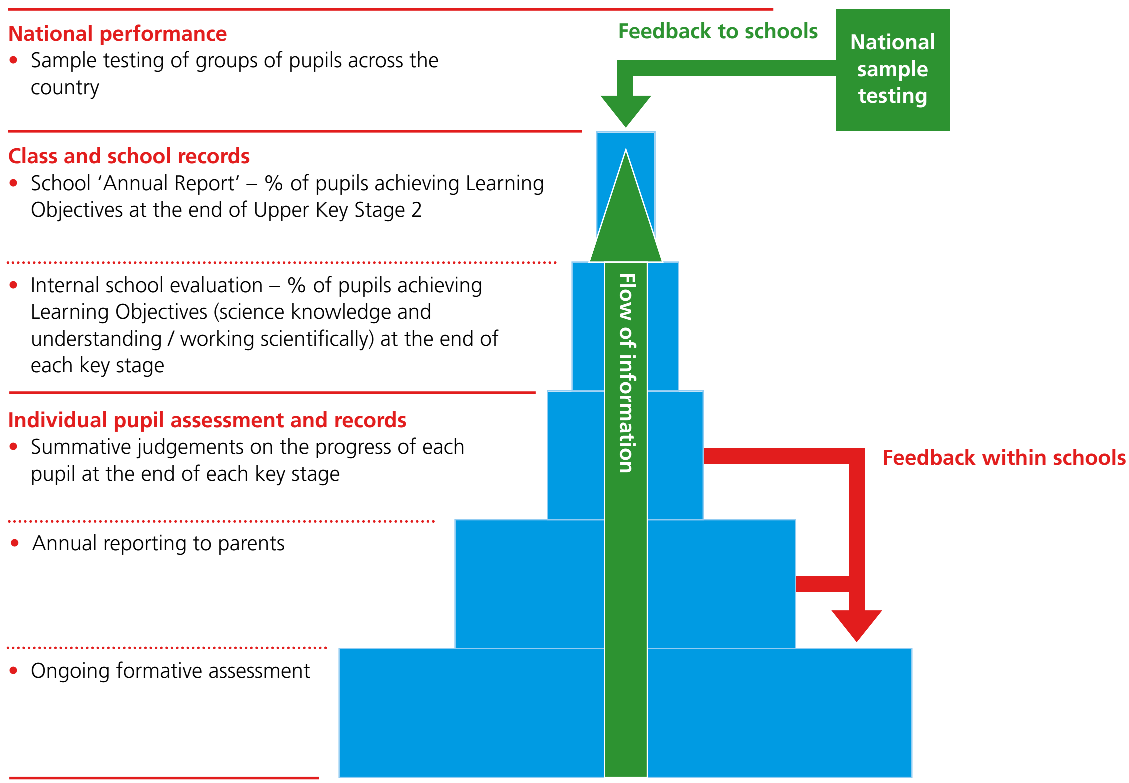
In summary, a key purpose of formative assessment is to provide information for managing children's learning. It is also important for children's awareness of their own developing ideas, helping them to be better motivated by giving them a stake in their own learning. For teachers, the chance to talk to children about their understanding is always a source of interest, and one of the profoundly satisfying aspects of our role.

The nature of summative assessment

The purpose of summative assessment is to summarize children's achievements at particular points in time, such as at the end of topics or terms. Outcomes of summative assessment are recorded and used for various purposes including planning, reporting to children, reporting to parents and governors, and reporting to other teachers during transition from class to class or school to school. All forms of assessment should be used to improve learning. Whereas formative assessment is an ongoing and active process which influences children's learning as they learn, summative assessment involves the collection of a range of evidence from which judgements are made about their progress over time. For summative assessment to influence learning, it needs to be shared with the children and used to inform planning.

Traditionally, pencil-and-paper tests are used to collect evidence of what children have learnt over a period of time. Although these types of tests can be useful if well designed, they are often limited in scope by focusing on the recall of facts rather than eliciting children's points of view.

The Nuffield Foundation (2012) published a report which argues that there is no need for separate types of assessment for formative and summative purposes. It suggests that the rich and extensive descriptions of each child's achievements, which are provided by effective formative assessment practices, can be summarized and used to create a narrative-style annual report to parents. The report should indicate the child's progress regarding the learning outcomes for the year and indicate where support is being provided to ensure the expected learning can be achieved by the end of the key stage. The transfer from formative data to summative judgements at the end of each key stage should be subject to internal moderation and referenced to national exemplars.



Individual, class and school assessment: A wide range of assessment processes provide a rich and extensive source of information on individual pupil's learning, which is used to report on achievement. Information on individual pupils is then summarised to provide summative judgements which can be collated at the level of class or whole school. Class and school level data can be used for internal reporting and the School Annual Report. Feedback from internal evaluation and summative judgements informs future improvements of teaching and learning.

National performance: Sample testing of groups of pupils across the country provides data on the national picture which in turn provides feedback to schools.

Figure of the flow of assessment data through the school published in the Nuffield Foundation report (2012).

Source: Nuffield Foundation, 2012. *Developing Policy, Principles and Practice in Primary School Science Assessment.* [Accessed June 2017]

The flow of assessment through school

The Nuffield Foundation produced a pyramid model (described above) which indicates how assessment information can flow from ongoing formative assessment in the classroom to whole school reporting. The Teacher Assessment in Primary Science (TAPS) project team worked with schools and other professional organizations to consider how the Nuffield model would work in practice. As a result, they produced a comprehensive model of school assessment with its foundations firmly embedded in shared understanding of good classroom practice. The model provides a structure containing examples from a wide range of schools, which can be used as a source of ideas for teachers or as a whole school self-evaluation tool to identify strengths and areas for development. The resource is especially rich in ideas which exemplify the many ways formative assessment practices can be integrated into the curriculum. The TAPS pyramid and reports are available for download from the Primary Science Teachers Trust website (https://pstt.org.uk/).

Planning children's science learning

Teachers manage the learning of large numbers of children with a diverse range of ethnic backgrounds, social behaviours, talents and interests. Sometimes, general teaching and learning theories do not easily translate into effective classroom practice (Lijnse, 2000; 2004). It can prove difficult for teachers to apply the outcomes of science education research in their classrooms.

In this book, educational theory is translated into classroom practice. The theory chapters in Part 1 provide examples of how research-based ideas can be applied in the classroom. These ideas are brought together into the three-stage framework which can help to organise science learning and which provides a structure for planning. In Part 2, 'Ideas for practice' exemplify how the three-stage framework can be used to teach specific concepts and skills.

The scientific view

When planning a science topic start by trying to picture in your mind the scientific view which you want to share with the children and then think about the best way of communicating that view. Take care to choose words which are familiar to the children. Avoid presenting scientific knowledge as a collection of facts and definitions because they do not help children create useful pictures of the scientific ideas in their minds. Eminent scientist Richard Feynman called scientific definitions 'mystic formulae' because for many children they are just empty, meaningless words (Chapter 1).

By starting with a clear view of the science in your own mind, you will be able to talk about and describe the key scientific ideas in language children will understand. A crucial part of teaching science is interpreting scientific ideas in ways which enable children to talk about and make sense of them. Children need opportunities to use spoken language to make ideas explicit and to appreciate their value. If we describe scientific ideas using everyday language, we can help children re-describe and re-think their experiences of the natural world from a scientific point of view.

When planning a topic think carefully about how you want to influence children's understanding of the world. The small ideas which we teach children can enable them to begin to see some of science's big ideas. For example, a topic on the feeding relationships in a garden, starting with a study of snails, can provide a way into grappling with big ideas such as interdependence and adaptation. Similarly, topics on light and sound provide opportunities not only to explore how we sense the world but also to find out how different animals and plants sense the world, providing a window on diversity and adaptation.

Something to think about

Reinterpret and expand the statement that 'light is reflected from surfaces' into a point of view accessible to children. What experiences could help children to think through the ideas?

Planning the exploratory stage: choosing strategies to elicit children's ideas

In the exploratory stage, activities should be planned to provide opportunities for children to communicate their ideas through appropriate means such as talking, drawing, modelling and writing. Bearing in mind the ideas and experience the children already have, decisions can then be made about what needs to happen in the children's minds to move their thinking towards the scientific view (Asoko, 2002).

Asking the right questions is the key to finding out what is going on inside children's minds. A 'big question' or 'puzzle' sets the scene for the children's learning and helps to stimulate curiosity and discussion (Chapter 1). Children's responses to the puzzle, and the information and questions which emerge from their discussion, provide feedback on children's existing understanding. In this way the puzzle is an important tool for formative assessment.

Examples of puzzles can be found in 'Ideas for practice' outlined in Part 2 of the text. Other strategies for eliciting children's ideas include the following.

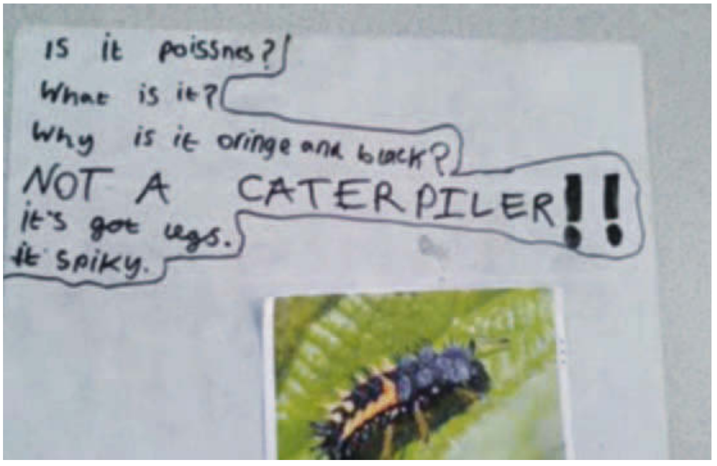
Talking points

Talking points (Chapter 5) provide a focused stimulus for children to talk together and to raise their own questions. Talking points are statements relevant to the topic and the puzzle that provoke thinking and the exchange of ideas. Listening to others and offering their own ideas help children to establish their current thinking and to reflect on alternative ideas (Dawes, 2004). For example, we might offer children the following puzzle: 'What do you think of this idea: An acorn has an oak tree inside it?' Talk to your partner to decide whether this is true or false and why …' This is likely to bring out more ideas than holding up an acorn and asking questions such as: 'Who can tell me what this is? What has it got inside? What will it grow into?'

Concept Cartoons, created by Brenda Keogh and Stuart Naylor, provide stimulating talking points. Simple cartoon-style drawings present children with their own misconceptions and generate discussion and argument. They are remarkably easy to use in the classroom as a part of normal teaching. Concept Cartoons are available as a book or CD-ROM from Millgate House Publishers.

Unusual pictures and objects

The TAPS pyramid model (2015) provides a variety of activities for eliciting children's ideas. A stand-out activity is the use of pictures of 'challenging creatures'. Children can be asked what the unusual creature might be, where it could be found and how it is adapted to its habitat. Of course, the questions can be guided by the intended learning. It is important that children give reasons for their views hence providing a window into their thinking.



Example of a 'challenging creature' from the TAPS project.
Source: TAPS / Bath Spa

All kinds of thought-provoking pictures and photographs can be used in all areas of the curriculum. Interesting objects can be used in the same way. For example, small pieces of Moon rock and meteorites can be borrowed from the Science and Technology Facilities Council (STFC). More down-to-earth objects such as crystals, igneous rocks, fossils, unusual toys and even unfamiliar fruits and vegetables can stimulate curiosity and discussion. Many fascinating objects can be borrowed from museums.

Children's drawings

Annotated drawings can help to externalise what is going on inside children's minds. For example, we can ask them to draw how they think light enables them to see an object or what they think electricity looks like inside a wire. The diagram and, crucially, the child's written annotations are a resource for assessment.

The following example illustrates this. Thinking about the movement of particles of a gas, a Year 4 class were asked to sit very still. A perfume bottle was opened in a corner of the room. The class were asked to raise their hands when they could smell the perfume. After this activity, they were asked to draw a picture of the classroom, annotating it to show the movement of the scent and saying how they think that this movement happened.

Children's drawings can be compared and discussion focused on the reasons for the differences. Working collaboratively children can produce a drawing which they agree on and which represents their shared understanding.

Scientific enquiry

The value of practical enquiry is often seen as providing opportunities for children to develop scientific skills. In addition, enquiry creates puzzling events which arouse children's curiosity and provide contexts for discussion in which thinking is articulated, shared and clarified. For example, when enquiring into changes of state, children are often surprised to find that water expands when it freezes.

A puzzling event is the starting point on a quest for knowledge which begins with the sharing of children's ideas in the exploratory stage. Listening to children's ideas and responding to their questions provides insights into their *learning needs*, which can be addressed by looking at the puzzle from a scientific point of view in the re-describing stage.

Modelling through drama

Modelling through drama involves placing children in thought-provoking situations where they need to use their scientific understanding to decide how to act. The activities include: spontaneous role-play, hot seating, mind movies, miming movement, freeze frame, modelling concepts and phenomena, and acting out mini historical plays. The techniques are described in full in McGregor and Precious (2012; 2014).

Each of these activities requires children to act on their ideas and hence provide windows into their thinking. A teacher involved in a study of drama techniques reported:

> **I think the benefits of using the drama – the techniques are easy to use, it's a very effective learning tool and I think it's an effective teaching tool because you can see how children are thinking, where they are in their learning. It's really good as an ongoing assessment tool.**
>
> (McGregor and Precious, 2012: 13)

Storytelling

Children's storytelling is a key part of learning science because it features the children's voices as opposed to the authoritative voice of the teacher. It enables children to talk about the science in their own words; hence it can capture the nature of the children's understanding and reveal its influence on the way they think and feel. Children's stories can provide valuable formative assessment information which can inform the basis of self and peer assessment, so the children can have a say in what they need to do next.

Something to think about

What strategies have you seen or used in school to elicit children's ideas? Can you think of any strategies which are appropriate for particular science topics you may be planning to teach?

Planning the re-describing stage: choosing strategies to help children make sense of the scientific view

Scientific concepts are ideas which have been created over time by many people. Scientific ideas may be abstract and can be represented and communicated through words, symbols, gestures, actions, pictures, diagrams, physical models and mathematical formulae (Asoko and de Boo, 2001). They are often counter-intuitive and to make sense of them children need to be able to construct clear and useful mental models of them (Chapter 4). Below we provide some examples of strategies which teachers can use to help children visualise scientific concepts.

Analogies

Analogies can help children make sense of scientific ideas because they make the unfamiliar familiar (Treagust et al., 1992). Analogies work because they enable children to use familiar experience and existing knowledge to construct useful mental representations of the scientific concept. For example, when we ask children to imagine electricity in wires to be like water flowing through a pipe, we are helping them turn an abstract idea into something which they can visualise. Because electricity and water are not the same things and wires are not the same as pipes, this analogy has limitations and, pushed too far, will break down. All analogies have limited explanatory power. However, they can provide useful ways of seeing and talking about concepts which we want the children to learn. Asoko and de Boo (2001) is a good source of analogies for different topics. (Part 2 also provides examples of some useful analogies.)

Role-play

Children can model a concept through role-play. For example, during teaching about how simple electric circuits work, children can play the part of the current which transports the energy from the battery to the bulb. If they understand the model of the current as a transport system for energy, they can model what happens to the energy as the current travels through the filament in the bulb. They can role-play how difficult it is for current to pass through a filament wire. Role-play is based on analogy and hence has similar explanatory limitations.

Physical models

Physical models can be useful because they enable children to visualise a concept and to talk about how it works. Models provide children with something concrete to talk about. For example, in teaching about how we digest our food, it is not possible to have a real digestive system to explore. Physical models encourage children to hypothesise about what each part does. This is a form of scientific enquiry. The same applies to the use of models to make sense of more abstract concepts. For example, the motion of the balls inside a Lottery machine help children imagine the particle nature of a gas. The Lottery machine is both a three-dimensional model and an analogy.

Interactive models and simulations

Interactive simulations can be used to help children to investigate and make sense of scientific concepts. Simulations can be found on a variety of websites including the BBC Bitesize video clips. Popular ones include models for electric current, change of state, germination, photosynthesis and the Solar System. We need to be aware that children can interpret these models in ways which are different from what we may expect (Sutherland et al., 2004) and to make sense of the scientific ideas involved, children will need to talk about the simulations with each other and the teacher. Simulations that allow the children to alter variables, such as changing the shape or size of a parachute to see the effect on how it falls, can help children to explore possibilities and design investigations. Others can be used to speed up the impact of changing conditions, such as growth in plants, to support hypothesising. However, these virtual investigations are no substitute for hands-on practical work whenever possible.

Use of information sources

ICT in schools is used most often as an information source. Online illustrated texts, animations and videos can provide a rich source of information on science topics. Children enjoy finding things out for themselves and this can result in a change in the way that they perceive the world (Chapter 1). However, finding suitable websites can be difficult. Searching websites for information can be frustrating for children when most of the information has been written for an adult audience. Even websites designed for children can present ideas in ways which are complex and uninteresting for the intended age group. Time is well spent by teachers in building up a catalogue of the most interesting and useful websites for particular topics.

The BBC Bitesize websites are usually good starting points, while specialist websites such as 'The Space Place' and the 'NASA Kids' websites provide amazing imagery and up-to-date information. When it comes to wildlife projects, the 'Arkive Education' and the 'Woodland Trust' websites are full of useful information and when exploring the weather, the Met Office's 'Weather for Kids' website is the place to go.

A good science library stocked with both electronic and hard copy resources can play a vital part in children's learning. Multimedia products provide rich learning experiences for children. Footage from television programmes made by David Attenborough and Brian Cox for example, provide inspirational images of the natural world. Dorling Kindersley provides a wide range of science-based digital material including illustrated books for all ages. For young children, there is a series of big books covering science topics, which can be read by teachers and children together.

Links to relevant information and teaching resources are provided for each topic in the 'Ideas for practice' sections, in the second part of the book.

Something to think about

How would you decide which is the best way to represent a particular concept? Are there some criteria which you can use to help you? For example, would the Lottery machine model be useful when teaching 7- or 8-year-old children about evaporation? What model would you use to help them visualise what is happening? If we can't think of a suitable model, does this suggest that the ideas are too complex for the children?

Planning the application stage: choosing strategies to promote the usefulness of the scientific view

Our ability to talk about and explain an event or phenomenon depends on the model of it we hold in our minds (Chapter 4). If the model is powerful and reliable, it can be used in a wide range of contexts and may even help us explain events we may not have previously experienced. Children need to experience the explanatory power of their newly acquired scientific ideas. In making purposeful use of a scientific point of view, they can appreciate its value and may be persuaded to assimilate it into their thinking (Chapter 4). Below we provide some examples of the types of activities which can provide opportunities for children to make use of scientific ideas. For details of specific activities, refer to the 'ideas for practice' sections.

STEM activities

Included in the application stage are activities designed to support the STEM agenda (Chapter 9), which aspires to making science more relevant to the children's lives. In these activities opportunities are provided for children to apply their scientific knowledge to solving problems in real-life situations and to involve them with science-based professions.

Redesigning nature

'Redesigning nature' is a creative problem-solving exercise in which children use their scientific understanding to design imaginary plants and animals which live in particular habitats. For example, after learning about pollination, children could design an imaginary flowering plant which is adapted to a habitat where there is little wind and no insects. The children have to work out how the plant will reproduce. Alternatively, after teaching about habitats, children could design an 'undiscovered' type of animal which lives deep inside the rainforest. It is important that children explain how their design has been informed by their scientific knowledge. As part of a D&T project, children can design and make moving models of their imaginary animals.

Something to think about

Imagine that you have just taught 6- and 7-year-old children about plants. What redesigning nature task could you give them?

Designing and making physical systems

Design and technology projects can provide opportunities for children to use their scientific skills and understanding to solve practical problems. For example, children can use their knowledge of electrical circuits when designing twin headlights for a model car (Chapter 19) or their understanding of friction and the properties of materials may prove useful when designing a pair of non-slip slippers (Chapter 20). The scientific ideas taught in science lessons are not necessarily useful for informing children's designing and decision-making. Research shows that if ideas are to be useful, they must be taught in ways which relate specifically to the D&T project (Layton, 1993).

> **Something to think about**
>
> List four D&T projects which would benefit from the application of scientific knowledge. Explain how the science underpins the projects.

Drama and debate

Children can play a part in a performance which involves the use of scientific ideas to inform a debate. For example, an environmental theme could be developed around a scenario where a company are seeking planning permission to build houses on a local wildlife area. Children can take on different roles to debate the relevant issues. Examples of other subjects for debate which can be informed by scientific knowledge include waste management, pollution and global warming.

Creative writing

Creative writing can provide children with opportunities to make use of their scientific knowledge in enjoyable and satisfying ways. Examples of creative writing include:

- science fiction stories based on contemporary science;
- writing and performing plays which involve famous scientists, past or present;
- writing science-based newspaper articles or blogs;
- creating poems based on scientific themes.

Painting and 3-D modelling

Children can depict scientific themes in painting, collage and by constructing 3-D models. For example, having learnt about the phases of the Moon, children can paint what they think the Earth looks like from the Moon and make 3-D models of the moon's surface.

A popular modelling activity is to make 3-D moving models of animals using programmable robots to control their movement. For example, working on the theme of adaptation, children paint pictures of camouflaged animals in their habitats. They then make 3-D models of their animals, which can be attached to programmable robots so they are able to move around in a model of their habitat.

Video modelling

Children can enjoy making animations using a digital camera or camcorder. Using simple materials such as Plasticine to make the objects, they can use stop motion techniques to create simulations of events such as plant growth, dissolving, electricity flowing in a circuit, the Earth moving around the Sun, how blood flows around the body and other scientific phenomena. Making animations based on scientific ideas requires children to have a clear understanding of the science and to be able to visualise how it applies to the model they want to create.

Scientific enquiry

Children can use their scientific understanding to raise questions and to make predictions about the behaviour of living or non-living things. For example, after learning about pollination, children plan an enquiry to find out whether bees are attracted to particular types of flowers. This can lead to other questions about whether it is the colour of a flower which attracts bees, or whether they are attracted to its fragrance.

Across the stages

1. *Safety*

   Risk assessments should be made for every lesson no matter what is being taught. They can be as simple as making sure all the furniture is safe, there are no obstacles in the classroom which children can fall over as well as focusing on the safe use of science equipment. The ASE publication *Be safe!* (2011) is a useful source of information to help assess risks associated with primary science activities.

2. *Organising talk*

   Since effective learning is linked to the ability to think and talk about the relevant ideas, we must provide children with opportunities to discuss and express their thoughts. Meaningful discussion can take place during small-group work or whole-class contexts. Children require clear guidelines to work collaboratively in both small-group and whole-class situations (Chapter 5). They should be aware that their talk together is an important part of their work and they need to be taught the strategies and skills which will help every child take an active part in exploratory talk.

3. *Worksheets*

   The choice of resources can have a profound effect on the quality of the children's learning and their attitudes to the topic. The disheartening phrase 'death by worksheet' describes the dull nature of the learning experiences which such resources may provide. But well-designed worksheets can be a very useful way of organising some activities. Worksheets should not be overused to the point where children's activity is just focused on 'filling them in'. Whatever resources are used, practical or otherwise, they need to provide the children with something interesting to talk about.

Summary

Assessment is used to inform planning, and planning should outline how assessment will be carried out. Lesson plans should include key questions that can help children to articulate their knowledge and understanding. Questions should help children to think and share experience and should not simply require children to guess facts. Children should be actively involved in the assessment process. Knowing the learning objectives and knowing the steps needed to achieve them can help children to engage with their learning, but the main motivating drive is children's curiosity. By helping children to ask their own questions and by ensuring they realise there is something interesting to discover, we can foster children's natural inquisitiveness and satisfy their wish to learn.

Further reading

ASE journals:

- Primary Science 140 (Nov/Dec 2015). *Introducing the TAPS Pyramid Model* by Sarah Earle.
- Primary Science 132 (March/April 2014). *Just Imagine: Using Drama to Support Science Learning with Older Primary Children* by Deb McGregor and Wendy Precious.
- Primary Science 123 (May/June 2012). *Dramatic Science: At Key Stage 1* by Deb McGregor and Wendy Precious.
- Primary Science 123 (May/June 2012). *Using Models to Promote Children's Scientific Understanding* by Jane Maloney and Sheila Curtis.
- Primary Science 123 (May/June 2012). *Making Movies* by Zoe Crompton and Emma Davies.

Books:

- Asoko, H. and de Boo, M. (2001). *Analogies and Illustrations: Presenting Ideas in Primary Science*, Hatfield: Association for Science Education.
- Association for Science Education (2011). *Be Safe! Health and Safety in School Science and Technology for Teachers of 3- to 12-Year Olds (4th edn)*, Hatfield: Association for Science Education.
- Clarke, S. (2008). *Unlocking Formative Assessment*, London: Hodder & Stoughton.
- Harlen, W. and Qualter, A. (2014). *The Teaching of Science in Primary Schools*, London: Routledge.
- Naylor, S., Keogh, B. and Goldworthy, A. (2004). *Active Assessment*, London: David Fulton.

Reports:

- Davies, D., Collier, C., Earle, S., Howe, A. and McMahon, K. (2014). *Approaches to Science Assessment in English Primary Schools*, Bristol: Primary Science Teaching Trust.
- Harlen, W. (2014). *Assessment, Standards and Quality of Learning in Primary Education*, York: Cambridge Primary Review Trust.
- Nuffield Foundation (2012). *Developing Policy, Principles and Practice in Primary School Science*. www.nuffieldfoundation.org/primary-science-assessment
- Primary Science Teachers Trust (2015). The Teacher Assessment in Primary Science (TAPS). https://pstt.org.uk/resources/curriculum-materials/assessment

Peer-reviewed journals:

- Earle, S. (2014). Formative and Summative Assessment of Science, in English Primary Schools: Evidence from the Primary Science Quality Mark, *Research in Science & Technology Education*, 32(2): 216–228.
- Loughland, T. and Kilpatrick, L. (2015). Formative Assessment in Primary Science, *Education 3–13*, 43(2): 128–141.