Transforming Primary QTS

PRIMARY SCIENCE

FOR TRAINEE TEACHERS

JUDITH RODEN and
JAMES ARCHER

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Introduction

> *A high quality science education provides the foundations for understanding the world through the specific disciplines of biology, chemistry and physics. Science has changed our lives and is vital to the world's future prosperity, and all pupils should be taught essential aspects of knowledge and methods, processes and uses of science. Through building up a body of key foundational knowledge and concepts, pupils should be encouraged to recognise the power of rational explanation and develop a sense of excitement and curiosity about national phenomena. They should be encouraged to understand how science can be used to explain what is occurring, predict how things will behave, and analyse causes.* (DfE, 2013, p.3)

This statement of purpose invites scrutiny and comment and raises questions about how best to implement the 2014 science National Curriculum at Key Stages 1 and 2.

About this book

This book is intended to support all Early Years and primary trainees on all courses of initial teacher training in England and has been tailored to the 2014 science National Curriculum. Newly qualified and more experienced primary teachers may also find this book useful as they begin to make sense of the new science National Curriculum. The Teaching Standards require all teachers to have a secure understanding of the subjects that they are required to teach and an awareness of the strategies that can foster effective learning in science. You may feel that you already have a secure knowledge of the science that underpins the science National Curriculum, but this in itself is insufficient in terms of helping children to learn science at an appropriate level and to encourage them to be scientists. You need to provide an excellent role model to enthuse and inspire the next generation of young scientists.

Scientific literacy

Language and literacy run deeply in the human experience. Within science it has been suggested there are numerous literacies (Webb, 2007). Developing a child's competence and confidence in their ability to converse in the language of science, a language that can be familiar and alien at the same time, is one of the most important tasks of the primary teacher. To do this a level of sophistication in scientific dialect is required. This book aims to support the beginning teacher's quest for conceptual knowledge development through the use of examples and practical guidance in order to enhance the student teacher's scientific literacy.

More importantly, developing a children's scientific literacy involves supporting their emergent enquiry skills in a way that enables them to engage in the scientific process. Just as language acquisition starts with the basic building blocks of listening and turn-taking, developing a child's scientific literacy is firmly rooted in improving the foundational skills of observing and exploring. Through the development of a scientific literacy in this sense children are afforded the opportunity to improve skills such as questioning, critical thinking and evaluating that benefit the wider curriculum.

The importance of science

It is important that the UK has enough well-qualified scientists to meet the demand, but there is much evidence to suggest that there is a shortfall in the numbers of young people coming through into science-related occupations. This explains why science continues to hold core subject status with the National Curriculum. The ASPIRE Project reported concern that women, and working-class and some minority ethnic groups are under-represented in the study of science, especially in the physical sciences and engineering (Archer et al., 2013). Nevertheless, scientists in the UK remain among the best in the world. Schools and universities prepare the most talented and able scientists extremely well, but there is a big gap in achievement between the most able and the least able pupils in terms of success in science subjects. Compared to other countries in the world, many young people in the UK who have potential in science fail to opt for science subjects that would lead them to careers in science. Overall, this situation is very worrying.

Children not only need to perform well in science in primary schools but also need to enjoy science and to recognise that science is important in their lives. Ofsted (2013, p.4) reported that the best science teachers set out first to 'maintain curiosity' in their pupils and that this not only fosters enthusiasm for science, but also helps pupils fulfil their potential. Children must find their science education stimulating and memorable so they continue to study science for as long as possible. Indeed, there is evidence to suggest that many children do enjoy science at primary level (Archer et al., 2013), especially practical work (Ofsted, 2013), particularly when it is well taught and when they have ownership over some of their work. However, despite enjoying science, they do not see themselves as scientists and do not consider taking up a scientific job when they leave education. The ASPIRE Project (Archer et al., 2013) found that only approximately 15 per cent of young people aspire to become scientists. Surprisingly, perhaps, they concluded that at least among the 10–14 year olds in the study, negative views of school science are not the problem. Their findings showed that most young people report liking school science from Year 6 to Year 9 and that 42 per cent of Year 9 students were interested in studying more science in the future. Students also reported positive views of scientists and said that their parents thought that it was important for them to learn science. However, despite these widely-held positive views, the majority of 10–14 year olds do not aspire to become scientists.

The problem seems to relate to children not fully understanding what scientists do, except at a very superficial level. Archer et al. (2013) found that most students and families are not aware where science can lead to and that 'the brainy image of scientists and science careers' puts many pupils off. Children's perceptions of science and scientists have been the focus of research for many years across the world. Although there may be some evidence to suggest that children's perceptions may now go beyond the stereotypical view of the scientist, due to recent changes in the ways that scientists are presented in the media and to Science, Technology, Engineering and Mathematics (STEM) initiatives, clearly there is still a problem, particularly with girls continuing to see science as male dominated.

The challenge for you is to raise your children's awareness of the importance of science in their lives, whether they are male or female, no matter what their socio-economic background. You need to help children not only to enjoy science and to be curious, but also to see the relevance of science in their lives. We hope that this book will help you to achieve this in your teaching.

Further reading

Harlen, H. (ed) (2012) *Principles and big ideas of science education*. Hatfield: Association for Science Education (ASE). Available at: www.ase.org.uk (accessed 11/6/14).

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Department for Education (2013) *Science programmes of study: Key stages 1 and 2* September 2013 London: DfE.

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Webb, p. (ed) (2007) *Scientific literacy: A new synthesis*. Port Elizabeth, South South Africa: Bay Books.

1 Working scientifically

Learning outcomes

By reading this chapter you will develop:

- an awareness of the importance of working scientifically;
- an understanding of the key scientific processes that underpin working scientifically;
- a knowledge of the progression in the process skills that underpin working scientifically;
- an understanding of effective pedagogic strategies for the teaching of working scientifically.

Teachers' Standards

2. Promote good progress and outcomes by pupils

- be aware of pupils' capabilities and plan teaching to build on these
- demonstrate knowledge and understanding of how pupils learn and how this impacts on teaching.

3. Demonstrate good science subject and curriculum knowledge

- have a secure knowledge of science and foster and maintain pupils' interest in science
- demonstrate a critical understanding of the developments in the subject and curriculum area.

Introduction

What is science?

The biggest challenge for you as a teacher in the Early Years or primary phase of education is to understand what exactly science is in the primary school and to have a clear view as to how it should be taught for optimum learning. Science in the primary school is a unique interpretation of what it means to engage in science activity. Roden and Ward (2008, p.6) suggest that there are numerous facets that go to make up the construct of primary science. They encourage us to see science both as a body of knowledge and as a way of working. The new primary curriculum (DfE, 2013) sets out aims to develop knowledge and conceptual understanding as well as children's ability to work in a scientific manner.

Davies and Howe (2003) suggest that science should be both a hands-on and a minds-on activity. At the heart of outstanding primary practice in enquiry is allowing children to construct and investigate their own questions. The Cambridge Primary Review highlights the importance of providing learners with a real sense of autonomy (Alexander, 2010). One child reported in the review that 'we learn things best when we can find out things for ourselves' (Alexander, 2010, p.148). In order to facilitate this it is important, therefore, to be mindful of what counts in terms of 'working scientifically' and how this can be integrated into everyday practice in primary science.

Key scientific concepts

- The process skills in science
- Working scientifically
- Progression in working scientifically
- Types of investigations

Research focus

A recent report undertaken by Ofsted (2013) in 91 primary and 89 secondary good and outstanding schools found the following.

- In the best schools visited, teachers ensured that pupils understood the 'big ideas' of science. They made sure that pupils mastered the investigative and practical skills that underpin the development of scientific knowledge and could discover for themselves the relevance and usefulness of those ideas.
- Science achievement in the schools visited was highest when individual pupils were fully involved in planning, carrying out and evaluating investigations that they had, in some part, suggested themselves.

The report made the following recommendations.

School leaders, including governing bodies, should:

- provide sufficient weekly curriculum time so that individual pupils develop good scientific enquiry skills as well as the knowledge they need.

Science subject leaders should:

- in primary schools, monitor pupils' progress in science regularly to ensure they are supported effectively to reach their potential.

Science teachers should:

- use assessment effectively to plan lessons that build on individual pupils' prior knowledge and provide feedback that genuinely helps pupils to improve their work in science.

Reflection

Given the increased emphasis in the new programme of study on creating opportunities for enquiry and working scientifically, how do these findings and recommendations relate to your experience of primary science? To what extent is there an opportunity for children to work scientifically in the primary schools known to you? What are the implications of the recommendations on your practice and on the weekly timetable of a class?

The process skills in science

As primary science educators our aim is to develop the children's knowledge, understanding and skills. In science the particular skills that help us in working scientifically are known as the process skills. Although there is not as such an agreed definitive list of process skills, these can often be found in curriculum documents. The DfE (2013) programme of study for science lists particular process skills and is very explicit in suggesting that they should be seen as being on equal terms and weighting with that of conceptual knowledge and understanding. The programme of study continually emphasises that knowledge and process skills should always be taught together. Ofsted (2011) highlights, however, that there is a tendency by primary practitioners to focus almost exclusively on conceptual development, often missing opportunities for process skill development. The following section will explore what the process skills are and provide practical examples of how these can be nurtured and developed in the primary phase.

Observation and questioning

Observation is using our senses to explore in a way that assists the raising of questions. It is important that children are taught to identify questions that can and cannot be investigated. Observation and questioning are fundamental process skills from which all other process skills can be developed. Fictional texts such as *Why?* by Lindsay Camp and Tony Ross highlight the inquisitive nature of young children in an amusing and playful way. Questions such as 'Are we nearly there yet?' have become synonymous with our view of young children. Entering a Foundation Stage classroom there appears to be a culture of questioning as children engage in their many activities.

Curriculum links

The Early Years Foundation Stage (EYFS) framework (Early Education, 2012) provides the expectation that all children should be engaged in and respond to questions and questioning and so supports a culture characterised by practitioners responding to children's inquisitive nature. However, while there may well be provision for this kind of approach within many Early Years settings, interestingly, it has been noted that these abilities often do not develop beyond the Foundation Stage and that, indeed, in many cases they regress over a child's career in primary education (Ofsted, 2008; Ofsted, 2011; Ofsted, 2013).

To develop children's questioning ability in science takes time. Questions are often created in response to an individual engaging in exploring and observing a particular phenomenon. Barnes (2012, p.239) suggests that children should be submerged in powerful learning experiences at the start of any new learning. It is essential that children are allowed to engage in exploration at the start of the investigation process. Trying to facilitate the process of children raising productive and relevant questions outside of an observational experience often proves futile. When children have not been given the opportunity to observe a phenomenon they often create questions that seem irrelevant to the teacher. The teacher becomes frustrated by the children's inability to raise questions that can be investigated and so provides the children with questions to investigate. It is often after observing a phenomenon that children are spurred into considering what they have observed and have genuine questions that they wish to explore. Enquiry work that seeks to engage learners and support their discovery must begin with an observational experience.

Case study: Candles

Matt, a third year BA (Hons) student participant, was working with a group of Year 4 children to develop their ability to raise questions about light. He provided them with a single lit tea light on a heat-proof mat. He asked the children to write down as many observations as they could about the candle and its light.

Figure 1.1 Tea light

Some of the observations raised were that:

- the candle made a circle of light on the mat;
- the further away from the candle the fainter the light got;
- as the flame moved the light also moved.

After the children had gathered their observations together Matt spoke with the children about the different type of question words that could be used to raise a scientific question. He encouraged the children to look at the science display where they could see a range of question words including 'why', 'when' 'what' and 'how'. Together as a class Matt and the children worked to create a model question. They asked:

'How can you increase the distance of the light travelled?'

Following this, children in pairs were encouraged to develop as many questions as they could using their observations and the question word. Once complete, the children were asked to use the sorting grid in Figure 1.2. One column was entitled ‘Questions I *can* investigate now’ and the other ‘Questions I *can’t* investigate now’.

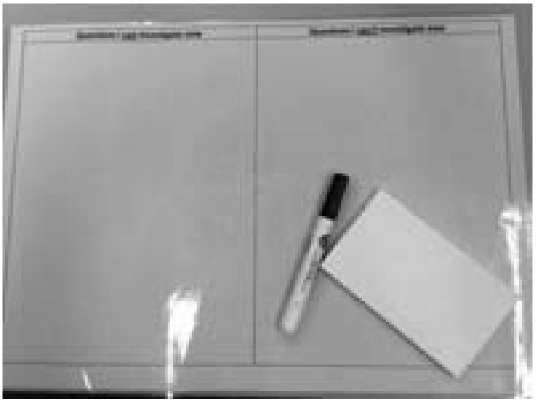

Figure 1.2 Sorting grid

If the children were unsure as to which column their question belonged they were asked questions like ‘Explain/describe the investigation that you could do to answer your question.’ and ‘What equipment do you think you would need?’ If the children were unsure they were encouraged to place the question in the ‘can’t’ column. The children were encouraged to share their ‘can’ questions with another pair. After this they shared their ‘can’t’ questions in their fours. They were encouraged to try to change their ‘can’t’ questions into ‘can’ questions.

An example of this was seen when one group changed:

‘Why does the light get fainter the further away you get from the candle?’

to:

‘What happens to the amount of light there is the further away you get?’

Although through observation the children were able to come to a simple conclusion about the concentration of light the further you get away from a light source, there is still merit in their seeking to carry out this investigation. By finding an answer to their question using accurate measures the children would be able to provide the required evidence to support their findings.

‘Can’ questions were also improved during this time with:

‘Does the distance of light increase if we add one more candle?’

This implies a simple investigation with only two stages of investigation to:

‘What happens to the distance of the light when the number of candles increases?’

This suggests a more complex investigation that should provide richer data that will enable children to come to a more reliable conclusion.

Activity

Take a natural object. Observe it using all of your senses. Draw an enlarged version of a section of the object onto a large piece of paper and label it. Look at your observations. Using your question words turn your observations into questions. Sort your questions into two columns:

- questions I *can* investigate now;
- questions I *can't* investigate now.

Once sorted, seek to turn the 'can't' questions into 'can' questions. Select a 'can' question to investigate and carry out the investigation. You could record the entire process in a floor book and use this as a resource to model to children alternative ways to record the enquiry process.

Figure 1.3 Example of a floor book

Predicting and hypothesising

Predicting is the act of saying what you consider is likely to happen before the outcome is known. However, it is important to realise that predicting is not simply guessing. A prediction is based upon previous knowledge and understanding of the idea under study, i.e. based on a particular hypothesis or a set of findings. Hypothesising is the ability to suggest why an observed phenomenon occurs by applying knowledge, skills and experience. Put simply a hypothesis is a proposed reason for an observed occurrence that is discovered during the enquiry process. A prediction draws on the hypothesis to help suggest what may happen for a new scenario prior to the investigative element of the enquiry process. In the primary classroom this can be further distilled down to 'I think … because', 'I think' being the prediction and an explanation after 'because' becoming a hypothesis.

Within the primary phase these two skills are used as mandatory elements in each enquiry. However, the curriculum introduces prediction at lower Key Stage 2. Why do you think this is? To be able to predict meaningfully a child needs to have had a wide experience in science and previous experience of the concept under study. The child needs to hold relevant knowledge and understanding that can be applied to a new situation. Children of a young age often find prediction difficult. Predictions made by young children are often simply guesses and are frequently not founded on prior scientific knowledge or experience. Asking children at this early stage to make predictions in relation to topics that they have no prior experience or knowledge of can have damaging effects. Children can easily become despondent as their predictions are either incorrect or, worse, deemed as irrelevant by the class teacher. This experience can be extremely off-putting. The emphasis on developing observational and questioning skills in Key Stage 1 should provide the foundation for children to be able to make predictions and hypotheses later on in their primary science career.

Often in the heat of an exciting enquiry older children can miss opportunities to formally record their hypotheses. Using digital recording aids such as electronic thought bubbles and talk buttons can prove an invaluable tool in assisting children in this area. Having the physical resource prompts children to make hypotheses throughout the enquiry experience.

Figure 1.4 Thought bubble

Figure 1.5 Talk buttons

Gathering evidence: recording and presenting

The primary phase offers huge potential for creativity in science. When gathering data, children should be encouraged to use a range of recording strategies that are meaningful to them. Traditional and formal methods that set rigid expectations on outcomes and outputs do not necessarily support understanding. Common practice requires children to write at length prior, during and post the recording stage. This raises two issues. Firstly, when assessing and marking this work the teacher feels obliged to feedback on writing and language conventions as well as the science focus. This equal focus in feedback on science and English can be confusing to children. The child's understanding of science becomes one that perceives science to be inextricably linked to language conventions. In some areas of science the link to language is less obvious and the greater link to number and mathematics is more apparent, such as in aspects of physics. Continually feeding back on language conventions therefore seems to be slightly unhelpful. In addition it has long been reported that children find it hard to read and understand the work recorded in their own books.

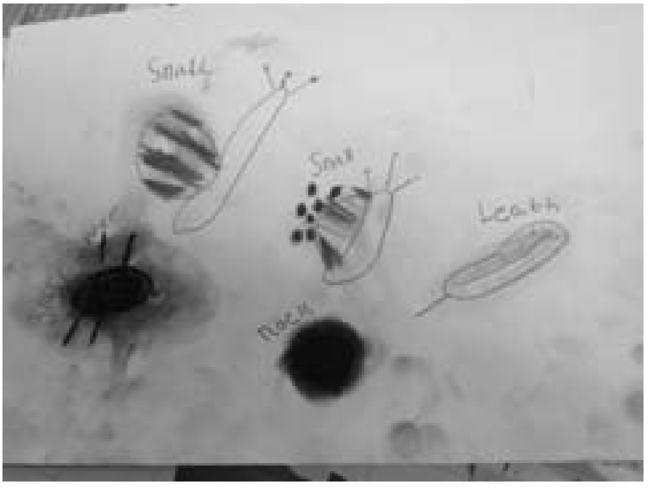

Figure 1.6 Drawings used to record work

In Figure 1.6 you will see that the child has used drawings as a method of recording. There is a greater chance that younger children particularly will be able to recall what they have found through pictures and images than through formal written methods. It is important, however, to realise that the opportunity for assessment with this method should not stop merely with marking the children's drawings. A discussion should be had with the children about the drawings and what they show. This discussion will provide a rich environment in which useful assessment can take place.

Presenting data also provides a range of creative opportunities. Challenging the conventions of graph and chart making is really important. When starting to learn about presenting information children should be able to consider a variety of ways. Arts-based responses such as songs, raps or living graphs (see Figure 1.7), with each child taking a value and presenting it using their bodies, are great examples of this. Other approaches such as using materials or simply placing a scale on their recordings are also beneficial.

Figure 1.7 A living graph – a record of height in centimetres

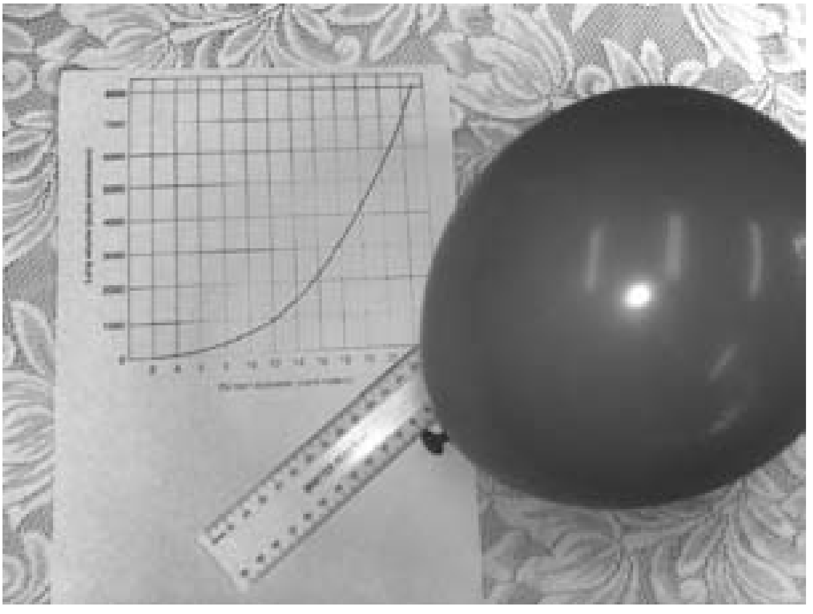

Figure 1.8 A creative approach to recording work

Creative approaches often lend themselves to collaborative work among teachers and children (for example see figure 1.8). Using approaches such as these are not only playful and fun but they also provide a platform for children to build the understanding, knowledge and skills for formal presenting methods.

Activity

Reflect on the ways you have asked children to record their work in science or the way you have seen children record during the science lessons you have observed. To what extent were the methods suggested above evident?

Interpreting findings

Collecting data is relatively easy. Looking at, analysing and understanding what the data is saying is a higher level skill. When interpreting findings children need to organise and/or reorganise data in a way that supports them in exploring and identifying patterns in their data. This leads children to draw conclusions. Giving children already collected data can help enhance their ability to analyse data and draw conclusions. Children need to have an opportunity to focus on this skill alone without having to worry about the other process skills.

Drawing conclusions

The ability to draw conclusions from data is an important skill. Often left to the end of a lesson, this skill is an integral process that should be seen as active throughout an enquiry. Concluding is the act of saying what has been discovered and why this may be, drawing on the evidence gathered. Most children find concluding difficult and often provide a brief descriptive summary of what they have done. Children need this process modelled for them. There are opportunities for shared reading and writing activities here for children analysing conclusions written by others, drawing out the key elements and looking to improve the annotated examples. Getting children to stop what they are doing and to tell each other what they have discovered in plenaries and mini-plenaries should also help develop children's ability to draw conclusions. Using the word phenomenon here can be useful. Playing the Muppets' 'phenomenon' song and getting the children to join in with the song is a good way to introduce this term. After this fun introduction the children should be asked to share what phenomenon they have discovered. As each individual uses the word phenomenon the whole class could sing the song. This is important as it focuses the children on writing conclusions that centre on discovery rather than conclusions that repeat and recount the process.

To develop concluding as an active skill it may be useful to use tools such as dictaphones and computer programmes or applications to provide a tool for regular concluding. Children could be encouraged to begin with to make digital conclusions at regular set intervals until this becomes a natural process for the children to undertake themselves.

Evaluating: identifying barriers and ways forward

Evaluation is an important process skill. At the end of an investigation children need to engage in the process of reviewing what has gone on in order that they can improve future work. Children need to be able to question the validity and reliability of their findings. As time progresses the children need to consider whether their findings are congruent with the wider body of knowledge of science. At this stage the children need to consider why this may be. It could be due to the discovery of new knowledge or, alternatively, it could be that there were issues with the methodology of the investigation. If this is the case children need to identify the potential barriers and limitations that were involved in the investigation. For this to be successful children need to be supported through this process by means of scaffolds such as questions.

Table 1.1 Progression mapping in process skills for Key Stages 1 and 2

Process skill	Key Stage 1	Lower Key Stage 2	Upper Key Stage 2
Questioning	Asking simple questions	Asking relevant questions	Planning different types of scientific enquiries to answer questions
Observation	Observing closely	Making systematic and careful observations	Making systematic and careful observations
Prediction		Using conclusions to make predictions for new values	Using tests to make predictions
Selecting equipment	Using simple equipment Performing simple tests	Setting up simple practical enquiries	Using equipment that assists observing and recording with increased precision, accuracy, and complexity (additional)
Selecting the one mode of enquiry		Using different types of scientific enquiries to answer questions, for example comparative investigations and fair tests	Planning different types of scientific enquiries including recognising and controlling variables where necessary Using tests to set up further comparative and fair tests
Recording	Gathering and recording data	Where appropriate taking accurate measurements using standard units with a range of equipment Gathering and recording in a variety of ways to help in answering questions Recording using simple scientific language, drawings, labelled diagrams, keys, bar charts and tables	Taking measurements, using a range of scientific equipment, increasing in accuracy and precision, taking repeat readings when appropriate Recording data and results of increased complexity using scientific diagrams and labels, classification keys, tables, scatter graphs, bar and line graphs

(*Continued*)

Table 1.1 (Continued)

Process skill	Key Stage 1	Lower Key Stage 2	Upper Key Stage 2
Classifying	Identifying and classifying	Classifying in a variety of ways to help in answering questions	
Presenting		Presenting data in a variety of ways to help in answering questions Reporting findings	Reporting and presenting findings including conclusions, causal relationships
Concluding	Using observations and ideas to suggest answers to questions	Drawing simple conclusions Using straightforward evidence to support findings	Identifying scientific evidence that has been used to support or refute arguments
Evaluating: Identifying barriers and ways forward		Identifying barriers, suggesting improvements and raising further questions Identifying differences and similarities or changes related to ideas and processes	Evaluating the trust/reliability of findings

Progression in working scientifically

It is important for the primary practitioner to be aware of the progression in the skills that assist children in working scientifically. The curriculum document maps the progression in these skills over three phases. Table 1.1 maps the progression in the new programme of study at Key Stages 1 and 2. Scrutiny of the Early Years Foundation Stage documentation, including DfE (2012), shows that the process skills are embedded in Foundation Stage practice.

When planning for progression and curriculum mapping teachers need to take into account process skill development. Teachers need to decide on how these skills are built up and developed in children. Far too often children are expected to use all of these processes immediately as they enter the primary phase and constantly in all science sessions. This is confusing to children and does not allow them to see how these skills are developed. Additionally, children need to be given the opportunity to refine and develop individual process skills. For the majority of science sessions teachers should seek to develop a single process skill that is relevant to the children.

Case study: Planning for working scientifically

Fiona, a part-time PGCE student, was on a course placement in a Year 2 class. She wanted to develop the children's ability to identify and classify. In addition she wanted to develop the children's ability to identify the animal group types.