EXPLORING SCIENCE WITH YOUNG CHILDREN

A DEVELOPMENTAL PERSPECTIVE

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The nature of early years science

Chapter overview

This chapter discusses the thinking and history behind science being introduced to children in primary and early years education, and some of the difficulties that practitioners and teachers encounter if they lack confidence in their science background. The authors' stance is to encourage working from existing professional strengths rather than to focus on deficits, including a consideration of using starting points such as narrative fiction. In the search for progression in the development of children's science thinking – also known as 'conceptual trajectories' – the skills that lay the foundations for scientific thinking are discussed.

Science education in the early years

Science as a subject alongside the 'three Rs' in the primary curriculum is a fairly recent, mid-twentieth century, phenomenon (Harlen, 2008), well after it had established its place in the secondary phase of education. It took a paradigm shift in educational thinking to recognise that young children's learning is in large part an active, self-directed activity. Enquiring young minds do not wait for adults to decide when they are ready to start making sense of their world. Sense making began to be seen as a biological necessity, a drive towards intellectual adaptation to the environment within the broader process of human evolution. This radical change in outlook displaced the passive, adult-driven process satirised in Dickens' *Hard Times* (1996) in which the schoolmaster Thomas Gradgrind's pedagogical style embraced only the cramming of facts. The emergence of cognitive developmental psychology as a discipline raised awareness of children's scientific and mathematical reasoning processes (Isaacs, 1962). Using a new framework to guide research ('genetic epistemology' or the developmental construction of knowledge) it was possible to describe, even from infancy, how intelligent behaviour emerges. This developmental perspective was informed by empirical investigations that included listening to children as they dealt with various logical or mathematical problems. This was a radical foray into what previously had been the territory of philosophers.

The exact nature of the science appropriate for young children was not an immediately settled matter. For a number of years, there has been debate about the precise qualities of science thinking behaviour to which we should aspire for children in primary education. From early in the introduction of science as a school subject, there has been a debate that has see-sawed back and forth: should we prioritise the 'what' (science concepts) or the 'how' (science processes) of science? The proponents of the 'what' side wished to lay the foundations for the big ideas that have shaped modern culture (evolution, the solar system, electricity, chemistry, energy, etc.), while the 'how' advocates favoured introducing children to science processes (the ways of experimental enquiry practiced by scientists). This fluctuating debate has matured into what is currently a more nuanced position.

The major guiding principles of science education

In more recent years, the process–concept dichotomy has become refined into a more elaborated structure and set of expectations (see, for example, Duschl et al., 2007, p. 36). There tend to be four major concerns that, though interacting, have separately identifiable features.

1. **Conceptual understanding**: the 'what' of science, knowing about the subject matter, the concepts or scientific ideas that are widely accepted and used by scientists to explain the natural world.
2. **Science processes**: the 'how' of science, to know about and engage in practical scientific enquiries as the principal mode for generating and putting to the test scientific evidence and explanations.

3. **The rules associated with the acceptance of science knowledge**: how science knowledge is unique and differs from other kinds of knowledge; how knowledge claims are made and supported, more formally stated as the 'epistemic nature of scientific knowledge'.
4. **The nature of science discourse**: how scientists arrive at agreed (provisional or disputed) understanding through talking, writing and doing science. This implies being aware of the 'rules of the game' of participation in scientific exchanges; knowing what counts as evidence and the acceptable ways of making and challenging claims.

With varying degrees of prominence, these principles guide the scope of science education, applying to a much wider age range than our focus on 3–7 year olds. While primary or elementary science has a minority stake in that larger enterprise and 'emergent science' an even smaller and more recent presence, the same guiding principles apply. The perspective adopted, as throughout this book, is that early years educators must look both to earlier and later events to establish firm foundations and a consistent trajectory. The challenge is to frame expectations in age-appropriate form. To this end, the narrative set out in this book elaborates the guiding principles in each of three chapters: Chapter 4 deals with conceptual development; Chapter 5 examines working scientifically; Chapter 6 discusses children engaging in scientific discourse by giving reasons for their ideas and increasing their capability to use evidence to support those ideas.

Science in the early years context

Science educators must be sensitive to the interface with the broader context and principles of early years education. That wider context assumes an important role for practitioners and teachers in partnership with parents in nurturing children's understanding, reasoning and science skills. Science is one area amongst the many that are important in every child's development. Early years education rightly adopts an integrated or holistic approach to the all-round development of every child. Providers and consumers expect high-quality learning, with demonstrable progress towards early learning goals, both within the fundamental underpinning capabilities and in specific areas of learning. Science, as with other specific areas of the curriculum, is expected to be encouraged within approaches that focus on the individual and foster positive relationships. The entire learning environment must be one that is enabling and acknowledges children's differing needs and rates of progress.

The expectations for science-related provision are introduced for the most part within the broad expectation that children should learn to understand the world and the objects and events that they are likely to encounter within it, either directly or indirectly. This is a broad agenda, but the lack of detailed specification allows local circumstances and special interests to have their place. In England, the major themes include people, communities, environment (including animals and plants) and materials – again, a very broad agenda. Other themes relevant to science can be discerned in every area of the curriculum, as we stress throughout this book, so our advice is, if you see a spark of interest, pursue it and fan it into flames.

Following their starting school (at approximately 5 years of age in the UK), children are expected to become increasingly ready to access the science-specific requirements of the curriculum. While most schools share some of the concerns of early years educators to develop the whole child, science can be expected to form a more discrete element of teachers' planning once children are attending school. But not all science activity needs to be planned. Allowance should be made for exciting but unplanned serendipity. The range of explorations and enquiries fostered within pre-school settings can be extended and modified to fit with the early demands of 'working scientifically'. Children's developing capabilities to express their ideas and to reason orally will enable interactions centred on ideas and evidence to flow more readily. Group interactions can give rise to exchanges of discourse that are recognisable as early forms of 'argumentation' (discussed in Chapter 6). Science developed in the pre-school will provide the foundation for children to construct new understandings. With children's overall development will arrive an increasing range of age-appropriate science topics.

Confidence and competence of educators

Although only a minority of people use science (or more broadly, science, technology, engineering and mathematics – 'STEM') directly in their income-generating occupations, it touches all of us in our daily lives. This impact reaches beyond consumer products and technical applications to ways of thinking, knowing, finding out, evaluating and discussing. These 'logico-scientific' behaviours are critically important not just for science education but because they impinge on many other subjects in the curriculum as they are encountered throughout lifelong learning. Little systematic evidence is available about the science backgrounds, qualifications and training of early years staff.

A review of childcare training (the 'Nutbrown Review', DfE, 2012) recommended minimum entry requirements and improvements in the criteria for early years qualifications. Insights into the professional development needs of early years teachers in relation to science (Copley and Padron, 1999) describe how early childhood educators view maths and science as difficult subjects, 'ones they felt unable to teach'. Increasing attention is being paid to the more general training and qualifications of early years professionals in England. New criteria for early years educator qualifications (DfE, 2013b) and new standards to be achieved by early years teachers (DfE, 2013c) aim to bring about more general improvements in the accomplishments of early childhood educators. Evidence of educators' confidence, qualifications and training in relation to science has tended to refer to teachers of the 5–11 age range. For example, Murphy and Beggs (2005) reported a lack of confidence and competence in the teaching of science in the primary phase of education, particularly physical science:

> Teachers felt that their overall lack of science background knowledge, confidence and training to teach science effectively was the most significant issue currently facing primary science. (Murphy and Beggs, 2005, p.7)

Harlen's (Holroyd and Harlen, 1996; Harlen, 1997) explorations through interviews with primary teachers in Scotland (n=55) reported how this group coped with a subject many found problematic. Teachers' reporting of defensive strategies remains particularly interesting and is likely to resonate with some educators today. Avoidance included teaching as little science as possible and eschewing practical work that might 'go wrong'. Physical science would be sidestepped, with more confidence shown in biological topics. Work cards offering step-by-step structure and exposition would be favoured as offering a handrail. Teachers saw emphasising a process approach as a positive coping strategy – that is, using science methods rather than addressing science subject matter content. As science educators, we can infer that the consequence would be a neglect of any deeper consideration of conceptual issues requiring science content understanding.

We can be sure that misgivings about the sufficiency of their own science knowledge still pertains amongst the educators of young children. Many adults who manage the science learning of young children are likely to be employing various coping or defending strategies to maintain their professional self-esteem. In the face of doubt, it seems entirely legitimate to utilise wider pedagogic skills when teaching science. The more general professional teaching techniques of planning, listening, questioning, evaluating and so forth apply to science as much as to any other subject. The thinking and reasoning skills that pervade the language and mathematics curricula have definite relevance to science learning. This survival strategy is not ideal, but does offer a first-aid sticking plaster, though it is important to appreciate the disadvantages. The benefit of educators' enhanced science background knowledge is not to enable the transmission of facts in a top-down fashion. Rather, conceptual science knowledge allows educators to use the insights available from their science understanding to interact with children more knowledgeably. It allows them to deploy pedagogical content knowledge or 'PCK' (Shulman, 1987). PCK requires knowing not just what science to teach but how and when to teach it. It confers an overview, a broader perspective, a map of any particular domain that includes the byways into which learners are likely to stray as well as the more direct routes to understanding. PCK will include knowledge of the experiences, resources and scaffolding techniques having proven effectiveness. Understanding the subject matter in greater depth will also enable more effective formative assessment judgements to be made.

Children's attitudes towards science

Attitudes and beliefs are complicated. Children's science attitudes can be thought of as a disposition towards learning and engaging in the subject; views about the impact of science on their own well-being and that of the planet; beliefs about the kinds of people that scientists are and how closely they might identify with them (and thus, their career choices); and beliefs about the nature of science (NoS) as a discipline. It is the first of these that is especially important and within the scope of early years experiences, where a positive attitude of mind towards science is going to be subject to the influence of the adults around children and the kinds of science activities they experience. Throughout education, science should be associated with curiosity and wonder about every aspect of the world. The subject should inculcate inquisitiveness and excitement about the unfamiliar while dispelling apprehension about the unknown. Science is about finding out. It offers myriad chances for exploring, for observing novel objects, materials and events. It is possible that children bring attitudes towards science along with them to their educational context, influenced by others, either positively or negatively. But the inspiration and imagination of teachers is a key factor in introducing creativity to science explorations and will influence children's outlook towards STEM subjects. Stylianidou and Agogi (2014), drawing on data from a study of creativity in early years science across nine countries, describe some of the teaching approaches associated with creativity in early years science as including planning motivating contexts linked to children's interests and physical exploration of materials.

Approaches including questioning and fostering curiosity were judged to be enabling of creativity. Frost (1997) emphasises the creativity entailed in teaching generally and in planning science experiences in particular. Planning means drawing together personal and professional experience, making imaginative use of available and relevant resources and co-ordinating everything within time constraints. As with any organised group activity, when science activities are productive, positive and pleasurable, the work put into planning is invisible.

Open-ended interactions tend to exploit children's interests, engage their attention and encourage persistence and curiosity. They are thus the bases for developing positive dispositions towards science learning. Fostering positive attitudes towards learning by engaging children's interest generally and science activities in particular has been found to be associated with their later achievement in science. In a longitudinal study following 4–8 year old children, Leibham et al. (2013) found that early science interests shaped the development of children's self-concept and influenced their later school science achievement. Interest in and attitudes towards science do not develop in isolation. The behaviours and values of the family and wider community can be expected to be influential. There is some evidence of children maintaining a long-term interest in science where parents have cultivated activity in science-related contexts in the home. Alexander et al. (2012) probed parental support for science learning at home in a longitudinal study and found sustained interest among children whose families created activities with contexts for science learning.

Holistic and subject-specific practices

Early years educators rightly think of their responsibilities as being to the whole child and their all-round needs, viewed within the framework of the whole curriculum. The implication is that pedagogical content knowledge relevant to the age range is closely linked to the theory and practice of child development. The teaching and learning agenda must always be mindful of the development of the whole child. Only gradually is subject-specific expertise a requirement and an advantage. It makes no sense to think of an 'on–off' switch tripped by administrative contingencies that compels teaching to abandon holistic concerns at a particular age or juncture in a child's education. The determining factor in any shift in practice must be considerations of children's development: are they performing at an average level, accelerating ahead or revealing evidence of developmental delay? The conceptual demands of science need to be introduced into the curriculum very gradually, from a broad, everyday context. In this light, less than completely assured subject-specific knowledge need not be detrimental. It will not be the cause of irreparable damage. On the other hand, educators having an enthusiasm for STEM subjects, as in any other area of the curriculum, are likely to be in a position to bring more dimensions and greater stimulation to their interactions with children.

The enormous complexity of science can be overwhelming to non-specialist educators. Being clear about the particular expectations for the early years group will introduce some reassuring realism. All educators should expect to grow in their chosen profession and this can happen alongside and through interacting with children. Science is a subject that feeds on curiosity and a desire to discover. This attitude can and should be a mutual experience between adults and children. The further children move through primary and into secondary education, the greater the need for specialist science conceptual knowledge becomes. In working with younger children and emergent science, the processes of thinking and behaving scientifically will be of pre-eminent concern rather than accumulating science factual knowledge. While we recommend a holistic approach as entirely appropriate for the needs of children in the lower end of the 3–7 age range, we intend to be very clear about what we mean by this. A statement to the effect, 'we cover science as it comes up in other subjects', without accompanying explicit objectives could be a self-deluding and defensive posture that lacks substance. Positive links with other subjects can and should be made, with advantages in both directions. Links with mathematics and literacy are easy to discern, but no less so also with history, geography, physical education, drama and art and design. For example, painting could touch upon the materials that can be painted on and different kinds of paint, sources of pigment, papermaking, colour mixing and light as well as how paintings change over time – colours fading, paper curling and becoming brittle. This 'Renaissance' attitude is closer to the impact of science in everyday life than the narrow boundaries defined by examination syllabi. Our advice to educators is to enjoy the freedom offered (albeit tacitly) by the early years (DfE, 2014) framework and the very broad latitude implied by the KS1 (DfE, 2013d) curriculum by offering children a broad and balanced science experience.

Stories and emergent science

Narrative fiction is a staple of early years education and one that may offer a starting point for science enquiries. We all love the sharing of other worlds that stories invite. They cost little, if anything, beyond some time and personalised attention that the favoured among us have experienced from our earliest awareness through bedtime stories. Active listening and participation in the action – dressing up, wearing masks or make-up, holding symbolic objects to fit the plot – seem to be adopted naturally by children. Involvement is contagious and like pantomime routines, draws on an intuitive sense that needs no drama school training. So it is that the early years scene of children closely packed on the carpet around the adult, attracted to the picture book like paper clips to a magnet, is a familiar one. The spell emanates from the narrative and images, enhanced by their artful deployment by the narrator to draw in children's involvement. Such a powerful device warrants a closer analysis for its science education potential.

In presenting stories of various kinds to non-readers (or those at the early stages of acquiring the skill), educators have at their disposal a technique that offers far more than entertainment or recreation. There is an enormous range of high-quality picture books and non-fictional expositions of science-relevant information available, accompanied by high-quality graphics. Adults can introduce these, or make them available to children. There are also biographies of eminent scientists, simplified to ensure accessibility. These widen children's awareness, broaden their geographical horizons and excite interest, respect and possibly personal ambition to be involved in STEM. In recent years, there have been efforts to redress the ethnic and gender imbalance that might have been orthodox in earlier times.

Some science educators acknowledge the possibilities of using a narrative form to communicate science to the public in a more meaningful and accessible manner (Avraamidou and Osborne, 2009). Norris et al. (2005) developed a framework for distinguishing narrative explanations from other kinds. They define eight elements that are present in a narrative:

1. events
2. change of state
3. narrative appetite (in the listener or reader)
4. passage of time
5. structure
6. agency
7. purpose, and
8. a listener or reader who is actively making meaning.

By closely defining narrative and the quality of explanation it supports, they suggest it should be possible to examine the claims made for narrative science explanations. They neither accept nor reject claims of 'improved memory for content, enhanced interest in learning, and greater comprehension of what is learned' (Norris et al., 2005, p. 552) and conclude:

> We are all *agents* with *purposes* of some sort whose lives inevitably consist of a series of *events* situated in *time*. This being the case, and these being the fundamental properties of narratives, it is not a large leap to the notion that the 'narrative' experience of our lives would make narratives in general easier to comprehend or recall than the content of some expository texts, which may be much less related to life experience. (Norris et al., 2005, p. 554)

This research debate has tended to be in the context of older students and adults where there is an unfortunate lack of suitable science narrative texts upon which to base research enquiries. The arguments have equal weight in the context of young children, for whom there is the advantage of an abundance of texts available for teaching and research.

Finding science-relevant content and contexts as springboards for practical enquiry in the early years is a fairly well-established approach. The wisdom of the choice of building materials used by *The Three Little Pigs* has been subjected to forensic scrutiny. The straw, wood and bricks used by the piglets as building materials can be integrated easily into an exploration of the properties of materials – in this case, their response to the blowing ('huffing and puffing') forces exerted by children (rather than a 'big, bad wolf'). The story has the critical features of narrative described by Norris et al. (2005), the plot concerning the universal theme of using ingenuity to outwit a dark, life-threatening force. The anthropomorphism allows the addition of life-threatening tension to the plot with which children readily identify. Authors use anthropomorphism for different effects. For three little children to be eaten by a wolf might be too gruesome! Yet children often enjoy the tension of dangerous 'cliff hangers' and the comeuppance of sinister villains that can be expressed more acceptably through animal characters.

Reflection

How would you explore children's views of anthropomorphism in children's literature? When, and in what circumstances, are children able to distinguish between fact and fiction in animal characterisations? Do children show awareness that some friendships portrayed would, in nature, be predator–prey relationships? You could think of some examples and talk to children about them.

Some educators may feel that narrative fiction risks introducing 'misconceptions' to children. By contrast, some science education researchers are adopting a different, more analytical approach to children's fiction. Blanquet and

Picholle (2012) explored a story with 4–6 year olds (*Plouf!* by Corentin, 2003). ('Plouf' is onomatopoeic in French, the sound of a pebble dropped into water.) The tale has features in common with Jean de La Fontaine's (2014) *The Wolf And The Fox In The Well*, in which a fox descends a well in a bucket in pursuit of a reflection of the Moon in the water that he has mistaken for cheese. Having discovered his mistake, he lures a wolf into descending in a second bucket from the top at the other end of the rope. The wolf, in pursuit of the same illusory cheese, acts as a counterweight to the fox. The wolf's descent lifts the fox out of the well, leaving the wolf at the bottom as the victim. Corentin's version is more complex, involving a wolf, a pig and a family of rabbits, but the avoidance of being eaten by using a pulley and counterweight remains the central device of the plot. (If English readers wishing to replicate the enquiry find French too great a challenge, de La Fontaine's version is available in translation: www.readbookonline.net/readOnLine/20106/.)

Figure 2.1 Science enquiry stimulated by narrative fiction

Supported by their teachers, children built models to replicate the arrangement in the story. They then compared the predictions of the model within the story with their own empirical observations, commenting on any discrepancies. In fact, Corentin's physics uses artistic licence: it is as fictional as the speech of the animals and cannot be reproduced empirically. As the researchers put it, 'special laws, different from real-world natural laws, govern the fiction'. The children were able to distinguish between the 'two worlds' of fiction and non-fiction and could be readily supported to 'cross the gap between a literary fiction and a real-world experiment' and 'use the results of the latter to confront the predictions of the former' (Blanquet and Picholle, 2012, p. 1908). The researchers suggest that children's capabilities to distinguish between fact and fiction is a key feature of science; their strategy of marrying fiction with science enquiry offers an imaginative way of bringing such distinctions to children's attention.

It makes good sense that the French curriculum explicitly advises the use of children's literature for 'the organisation of interpretative debates' that stimulate imagination and thinking. In another example, Bruguière and Triquet (2014) explored the potential contribution of children's literature to science conceptual understanding by reference to 6–7 year olds' response to *The Tadpole's Promise* (Willis and Ross, 2003). This tale of romance between a tadpole and a caterpillar ends tragically. Although the tadpole promises the caterpillar never to change, once each has metamorphosed into adult form the dénouement sees the frog consume the butterfly. The ostensible tale of romance thinly veils an underlying science narrative of predator–prey relationships, metamorphosis and pond ecology! Once again we see an interaction of fictional and non-fictional frameworks as fertile ground for exploring children's science thinking.

Reflection

What, as science educators, would we want children to take away from the story of *The Tadpole's Promise*, when the love between the caterpillar and tadpole characters grows into a predator–prey relationship? What might children actually derive? Can you envisage how the tale might be used as a jumping-off point for children's further science thinking?

Christopher Wormell's *One Smart Fish* (2011) uses a science framework more deliberately and possibly with a more scientifically didactic intent than the other examples discussed. The tale is of a fish that is clever enough to leave its watery habitat and the company of other fish to venture onto land and learn to walk. Admiration motivates others to follow this lead. The book ends with a double page graphic illustrating myriad creatures evolving in diverse forms to colonise the land, in effect, an image of Darwin's 'Tree of Life'. This story is not a science exposition, but a work of fiction with scientific resonance. In a few pages, the plot draws on roughly 350 million years of the evolutionary history of life on Earth.

Background science

Evolution

Our planet Earth is estimated to be about 4.5 billion years old, with life in the form of the first single-celled organisms emerging roughly 3.8 billion years ago. A landmark event occurred when air-breathing fish moved from shallow water onto land, about 375 million years ago. These vertebrates (animals with backbones) gave rise through very slow evolution over many, many generations to diverse forms: amphibians (needing to return to water to breed); reptiles (including the dinosaurs from which birds later evolved); and mammals, with modern humans in evidence about 0.2 million years ago.

Pause for thought

Science through fiction

Children in the 4–7 year age range engaged with the story of *One Smart Fish*, excitedly suggesting ways that the fish might change as the teacher told the story. Following the story, some 6 and 7 year olds made sequenced drawings to show the fish as it gained the capability to walk on land, followed by further evolutionary changes. Figure 2.2 shows a 6 year old's ideas of how gaining feet was accompanied by changes to the overall body shape, changes to movement from slithering to crawling, and reptiles capable of walking on land.

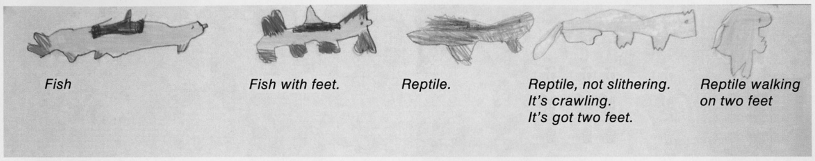

Figure 2.2 A drawn sequence of creatures' evolution from water to land dwelling

Should we, as science educators, feel disquiet that the narrative unfolds with the rules that actually govern the working of the world suspended? Do we need to quickly ensure that children appreciate that, 'Things don't really happen like that! It's just a story!'. As Norris et al. (2005, p. 560) point out, science discourse uses exposition and argumentation to convey reasoning effectively, honestly and with the precision that allows results to be tested through replication by others. Fiction takes liberties, but gets the message across by painting with broad brush strokes.

The justification of narrative fiction as a means of introducing science is irresistible. It can serve to set up a context and stimulate children's interest. Rather like releasing an 'ear worm' into listeners' brains, a work of fiction can initiate a curiosity that might provoke pondering over years to come. Even those uneasy about this use of fiction will need to accept that children will be exposed to these highly successful and popular narratives regardless. As educators, we must come to terms with the fact that explorations in science do not always offer closure. What should we do with a story that takes liberties with the passage of evolutionary time or the physical laws that govern the universe? We take comfort from the reality that it is educators who mediate these stories. Skilled educators 'tell' rather than 'read' stories with inflections of voice, facial expressions and gesture, together with the possible use of props. Adults who know the audience they have captured engage children, pausing to question and confirm understanding. They invite children's predictions, hypotheses and explanations about the words they hear and the images they are shown. Nor need the audience be 'hit cold' with a narrative. Rather, stories can be selected as integral to an educator's wider planning strategy. The possibilities for incisive interventions such as investigations, drawing and modelling activities and supportive interactions during and subsequent to the narrative can be rehearsed. This planning allows the educator to inform her or himself, to identify supporting sources of information: reference books, video, perhaps models or images and background science. Only then do children take possession of the information and transform it so it becomes their own. This is the procedure that gave rise to the child's own image reproduced in Figure 2.2, following a reading of *One Smart Fish*. And of course, there is the motivation that is aroused to explore secondary sources that develop the theme with a more scientific emphasis.

If we find the discrepancy between fact and fiction too troubling, there is the option of avoiding such works altogether, but this would be to overlook the enormous potential of narrative. Jerome Bruner offers some interesting insights into the interface between fact and fiction:

> There are two modes of cognitive functioning, two modes of thought, each providing distinctive ways of ordering experience, of constructing reality. The two (though complementary) are irreducible to one another. Efforts to reduce one mode to the other or to ignore one at the expense of the other inevitably fail to capture the rich diversity of thought. (Bruner, 1986, p. 11)

An example of the 'logico-scientific' mode is a well-constructed logical argument that draws on formal or mathematical systems to explain and describe. An example of the 'narrative' mode is a well-told, convincing story that uses characters who act in various ways to achieve their intentions. The first is universal, the second more about particular connections between events. Either mode can be used as a means of convincing another person of a claim, a truth or an argument. 'Yet what they convince *of* is fundamentally different: arguments convince one of their truth, stories of their lifelikeness' (Bruner, 1986, p. 11).

So here we have it: in teaching science, narrative credibility might serve to orientate children in the direction of factual truths. This strategy is justifiable, but demands a parallel discussion between educators and children as to the distinction between fact and fiction. We feel that it would be a mistake to regard science in the early years curriculum as a discrete, separate and independent subject when the skills developed in the language curriculum clearly have so much to offer to the development of scientific thinking.

The emergence of science-specific capabilities

In the course of the development of a Child Development Assessment Profile designed to be used to record 'whole child' development (3 to 5 years), the authors invited practitioners to collect data pertaining to 1,195 children across about 270 settings. An important feature of the survey was that the data were collected during and as part of practitioners' and children's usual day-to-day interactions. Analysis of this large body of general developmental data enabled the identification of children's emergent science skills within the contexts of wider and more general early years practice (Russell and McGuigan, 2016). The merit of this approach is at least two-fold. Firstly, an overview of general practice can help to identify likely developmental trajectories in science thinking that are so important in a formative pedagogy. Secondly, in identifying educators' existing strengths in their practices, we avoid treating a lack of confidence in teaching science as a professional deficit. We would prefer to build on the positives as growth points. In the early years, all science conceptual understanding is best treated as provisional because that is exactly what it is: interim understanding, temporary and most certainly subject to later elaboration. Understanding will inevitably grow in scope and complexity, so concerns about inadvertently introducing 'misconceptions' lack force (Allen, 2014). All of us who are not professional scientists splash around in our personal oceans of misconceptions but survive and improve our knowledge. Many of the skills deployed by educators and many of the imperfect emerging capabilities shown by children can be thought of as aspects of a progression towards more science-specific understanding. The later science capabilities do not suddenly and spontaneously emerge. By working closely with practitioners, observing, discussing and interpreting practices, we were able to identify antecedent behaviours and, subsequently, routes towards more mature manifestations of the science skills we were interested in nurturing. Working with non-specialist educators and taking into account all aspects of children's development served to support the generation of a number of insights when we reviewed our data using a science education perspective. The qualities of behaviour that could be considered to be precursors of the emergence of science proper we identified in the order 'general developmental', 'science-enabling' and 'science-specific'.

'General developmental' capabilities encompass the familiar 'milestones', including the social, physical and emotional aspects expected of all children. For example, 'attention' tended to be high on the list of practitioners' concerns, particularly for new entrants, and would be a priority from the point of view of a child's socialisation and safety as much as being a necessity for any progress with cognitive skills.

'Science-enabling' behaviours are those judged to have relevance to science because of their generally logico-mathematical nature, but might be equally important to many other subjects and activities. They would tend to support science-relevant activities incidentally rather than with a science focus in mind. Examples would be aspects of numeracy such as measurement (essential to making comparisons in many science activities) and oracy (critical in presenting or interpreting ideas in speech or derived from text).

'Science-specific' behaviours were self-evidently capabilities that the science education literature and science educators describe as such. They would be in evidence when deliberately promoted. However, there were some instances of activities nominally associated with other curricular areas that offered a close correspondence to the requirements of a science curriculum. For example, while all sorting, classifying and measuring activity could be regarded as 'science-enabling', the use of particular set labels such as 'alive', 'was once alive' and 'never alive' tipped the balance into 'science-specific' behaviour. Similarly, some examples of oracy that required clear presentation with reasons of a point of view suggested very close links with the antecedents of argumentation (presenting and defending a point of view with supporting evidence).

Combinations of, and relationships between, these discrete behavioural criteria suggested potential developmental sequences relevant to emergent science. Table 2.1 (adapted from Russell and McGuigan, 2016) includes just some of the criteria and illustrates how some behaviours suggest incremental development (or 'threads' of progress as we named them) as we move down through the right-hand column.

To make sense of and impose order on this complex set of behavioural criteria, we referred to the major guiding principles of science education at the beginning of this chapter, in a form suitable for the early years. This resulted in the summary of behaviours in Figure 2.3: (i) conceptual development (with origins in observation and recording); (ii) enquiry skills (starting from direct experiences); and (iii) science as discourse (beginning with the expression of ideas and moving through 'ideas and evidence' towards argumentation). These are the three areas discussed in greater detail in Chapters 4, 5 and 6. Although discussed individually, the three aspects interact very closely. Opportunities for engaging in them should be recognised as arising in many contexts, including other subjects in the curriculum. They are presented in Figure 2.3 in a manner that confirms their inter-relatedness. In the base tier are the means by which information is acquired once an investigable question has been posed. (Not all children's questions start out as being investigable, but many can be tweaked into a form that can be explored in the real world, rather than only imaginatively.)

Table 2.1 Examples of clustered 'threads' and links with emergent science

Relevance to emergent science	Threads of behaviour and linkages between threads	Example behaviours
General developmental	Paying attention, increasing concentration span and persistence	Listening to and engaging with fictional narrative and imaginary starting points
	Naming and labelling concepts and instances	Naming objects and phenomena accurately
	Expressing ideas	Self-generated ideas expressed with some degree of autonomy and confidence; general language and vocabulary development
Science-enabling	Concrete operational experiences and manipulations; multimodal opportunities	Many of the 'stations' made available in settings (e.g. sand, water, dough, etc.) are designed to ensure basic experiences and particular language and vocabulary development. Opportunities for observation, change and control of materials and events
	Logical operations	Classifying; ordering; comparing similarities and differences; comparing the magnitude of objects and durations of events
	Exploring the nature of materials and making things	Bricollage; experiencing the relationship between the physical and conceptual demands of making
Science-specific	Early explorations and investigations	Children's explorations and more systematic teacher supported enquiries
	Recording outcomes and results	Lists, charts, tables writing, audio, photographs, maps, models, collages, etc.
	Early argumentation	Expressing ideas (a.k.a 'making claims'), drawing conclusions, with justification

Source: Russell, T. and McGuigan, L. (2016). With permission of Springer.

On the left of the base are the secondary sources of evidence that include experts (including teachers), books, films, video or the internet, perhaps even folklore. On the right of the base layer are the (empirical) enquiries that gather data or information using direct techniques such as observation and measurement, including 'fair tests' and other procedures used in enquiries (see Chapter 5). In the central triangle is shown the step in which evidence is appraised for the support it offers, or fails to offer, for the question or problem children have posed (Chapter 6). The question

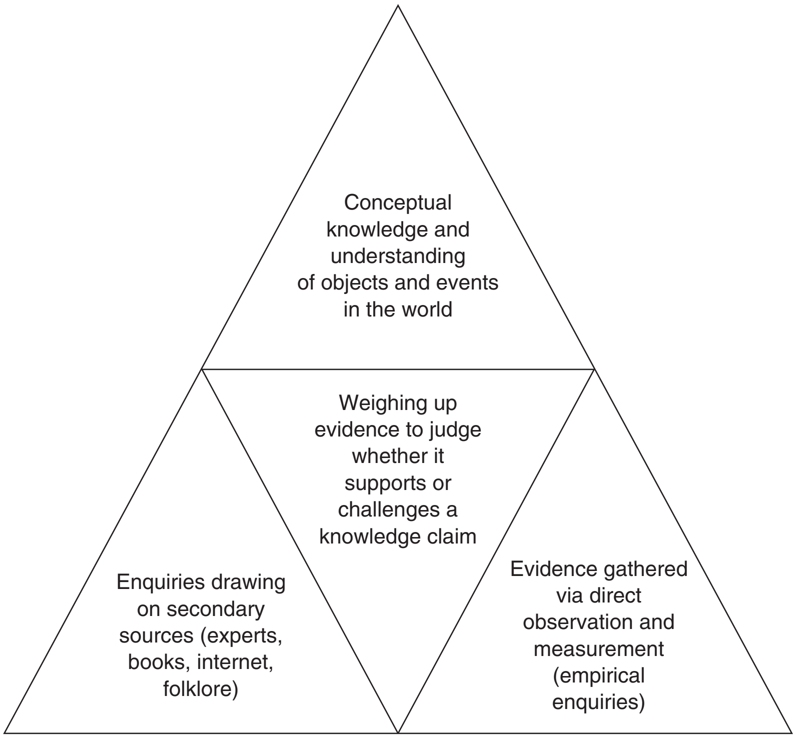

Figure 2.3 How different kinds of knowing in science are inter-related

that is the subject of the enquiry can be considered to imply a claim or proposition for which the enquiry provides evidence that may or may not support it. Conceptual understanding is shown in the apex (see Chapter 4) and will exist both prior to and subsequent to some form of enquiry.

Summary

This chapter has reviewed briefly the background to science for the early years together with some of the important developments in the manner in which it can be addressed.

- The importance of early learning in science for individual achievements and for society in general is a relatively recent innovation dating from around the mid-twentieth century.
- The need for improvement in the science qualifications and training of early years educators is acknowledged by all stakeholders.

- Links between curricular areas should be identified as positive opportunities and explicitly nurtured.
- Narrative story introduces science contexts to early years children in non-threatening, creative, imaginative and meaningful ways, commensurate with children's development.
- Science-specific capabilities can be fostered within the more generalist and holistic practices of early years.
- An increasingly science-specific focus can be planned and implemented as children progress towards the upper age range of the early years phase.