1 Supporting Young Children's Scientific Learning

Chapter Summary

This chapter considers what 'science' is in terms of young children's learning and development. It looks at the development of conceptual knowledge, the fostering of attitudes and dispositions and the development of science skills. The role of the adult in co-constructing knowledge alongside children, being a source of skills and expertise, asking productive questions, modelling skills, attitudes and language and in observing and documenting young children's learning is looked at in detail.

The processes of science are reviewed and the 'Spiral of Discovery' is used to describe an age and stage appropriate process which will enable practitioners to support young children's exploration and investigation in a structured way.

'Science' consists of a body of knowledge and a range of the skills and attitudes which support and extend that knowledge. Davis and Howe (2003: 102) developed this idea further by defining three types of science subject knowledge:

- Conceptual knowledge: an understanding of, and about, science.
- Attitudinal knowledge: attitudes which underpin exploration and investigation.
- Procedural knowledge: the skills of science.

Young children's experience of science should be less concerned with the development of conceptual knowledge, and more focused instead on those interesting and worthwhile experiences and activities which can enhance their attitudinal and procedural knowledge. Engendering a love of science in young children and awakening the excitement and pleasure of exploration and discovery in them will create the firm foundations on which to build their growing expertise as young scientists.

To be meaningful, children's experiences of science should be based on their interests and preoccupations and should take into account their ages, stages of development and social/cultural backgrounds. Building on children's ideas not only retains the purpose and focus of an exploration, it also leads to some very imaginative and challenging investigations. As children are not encumbered with 'knowing the right answer' they can prove to be the initiators of wonderful ideas, which in turn can be far more interesting to explore than anything most adults would think of.

Developing conceptual knowledge

Many science concepts are complex and require reasoning and mental visualization skills which are beyond the capability of most young children. Indeed, as adults, many of us can find some of these concepts hard to comprehend and certainly very difficult to explain in a straightforward and understandable way. Nevertheless, practitioners need a basic understanding of key scientific concepts if they are to support young children's learning effectively. This will give them the knowledge they need to engage children's curiosity, ask appropriate and challenging questions, manage children's questions confidently and recognize the 'teachable moments' which can lead on to productive and interesting investigations. The background knowledge presented in Chapters 3–13 of this book has been specifically constructed address this challenge.

First-hand interaction with materials, tools and the world around them will give young children a breadth of experience on which to build their understanding of scientific concepts as they get older. Developing a 'correct' concept may take years but it can start with simple activities – like dropping a finger of toast from their high chair, rolling a pumpkin down a grassy slope, dropping pebbles into a dish of water, chasing a shadow or swishing a hand across the surface of a water tray to create waves. 'Doing' and 'seeing what happens' is what is important, although this often prompts questions such as, 'I wonder why … ?' and 'What would happen if … ?'

Practitioners will frequently express their concern about how best to deal with children's misconceptions or incorrect science concepts. Robson (2006: 137) suggests that it is better to think of these as alternative frameworks rather than misconceptions, making the argument that this is more akin to what real scientists do when they invent a new hypothesis to make sense of the world. This view is reinforced by Harlen (2001: 19), who states that 'we must begin to look for a right answer that the children can give with confidence, that depends on their own observations: a right answer that originates from their own experiences. This right answer may fall short of "the truth"'. Probing children's thinking by asking, 'Why do you think that?' or 'How do you think we could test that idea?' may well result in further investigations which can help to clarify thinking. Davis and Howe (2003: 110–17) provide a very useful list of common alternative frameworks with suggestions for questions and interventions which may help to clarify understanding.

Educators in Reggio Emilia, whose philosophy is based on nurturing young children as researchers actively seeking to make meaning of the world, address this issue of conceptual understanding in a very similar manner (Rinaldi, in Filippini and Vecchi, 1997: 182). Working in small groups, with an adult as a fully participating member of each group, children are constantly challenged to re-visit, re-view and re-present their ideas through words, drawings and models in order to deepen their understanding (Thornton and Brunton, 2005: 72). During this process the adult may well put forward the 'correct' scientific explanation as one of a number of alternatives being considered. Once children have arrived at an idea or an explanation which satisfies them, their theories are valued and respected regardless of whether or not they are 'scientifically correct' (Piazza, 1999). As with all aspects of the Reggio approach, it is the quality of the interaction between children and adults as they explore and discuss their theories together which is paramount rather than the final product. As children's experience grows, the original theory will no longer satisfy them and a new one will be formulated.

The words we use to describe scientific concepts can sometimes cause confusion, often because the same word may have a different meaning in everyday life than that which it has in a scientific context. For example, a 'plant' in everyday terminology is usually a fairly small, low growing structure, while in scientific terms it applies to the whole of the plant kingdom – encompassing everything from blue/green algae to trees. Also the term 'animal' in scientific terms includes all vertebrates and invertebrates, not just mammals (see Chapter 3).

Helping children to learn scientific terminology through modelling its correct use will equip them with essential tools for developing their understanding of scientific concepts. For example, it is important to say that sugar has *dissolved* in water, not *disappeared*, and that metals are *attracted* to a magnet, they do not *stick*. This aspect of developing young children's scientific understanding is highlighted in the section 'Developing effective scientific communication' at the end of Chapters 3–13.

When talking about scientific phenomena – puddles drying up in the sunshine or sunflowers turning to face the sun for example – some children will use the phrase 'it happens by magic' to explain what they have seen. Remember, this does not contribute to developing an understanding of what is really happening. Carefully phrased comments and questions will help children to look more closely at the phenomena and begin to develop their ideas about what might actually be happening: for example, 'What do you think is happening to the puddle in the shade?', 'Are all the sunflowers facing the same way?', 'Shall we see if they face the same way in the morning and the afternoon?'

A final challenge to address when helping young children to build their understanding of scientific concepts is the tendency towards anthropomorphism – giving human attributes and emotions to non-human living things and inanimate objects. Worms and snails with mouths and eyes, flowers with faces and talking dogs can potentially create a very confusing world for young children to make sense of scientifically.

Scientific attitudes and dispositions

The attitudes and dispositions which enhance young children's scientific thinking are similar to those which support their overall learning and development. Nurturing desirable dispositions in young children enhances their ability and willingness to apply skills and knowledge. It also fosters their ability to learn how to learn.

Lilian Katz (1993: 16) defines a disposition as 'a pattern of behaviour exhibited frequently … constituting a habit of mind under some conscious and voluntary control … intentional and orientated to broad goals'. Research has shown that children's dispositions are acquired, supported or weakened by interactive experiences with significant adults and peers (Bertram and Pascal, 2002). The younger children are the more important it is to strengthen their dispositions to engage with and closely observe events in their immediate environment and experience (Katz, 2009).

Bertram and Pascal (2002: 248) have identified four key dispositions of effective learners:

- independence – the ability to be self-sufficient, to self-organize and self-manage;
- creativity – using the imagination, being spontaneous and innovative;
- self-motivation – becoming deeply involved in explorations and challenges.
- resilience – the ability to cope with setbacks and to persist with a task until successful.

Scientific attitudes include personal, social and behavioural attitudes such as curiosity, enthusiasm, motivation, co-operation, responsibility, sensitivity, originality, independence of thought and perseverance. Importantly, they also include the reflective attitudes of a respect for evidence, open-mindedness, critical reflection and an ability to accept the provisional nature of knowledge. Significantly, attitudes are 'caught, not taught' (Harlen, 2000: 5) and it is the responsibility of the practitioner to model and display those attitudes which they wish young children to develop.

Encouraging a respect for evidence is an interesting challenge when working with young children. They will have their own theories about why things happen and will tend to look for evidence which reinforces this view of the world and ignore any evidence which contradicts their ideas. Practitioners can help young children to develop a respect for evidence by making sure they always respect it themselves and by using unusual results or observations as a basis for further investigation, rather than as an indication that 'something has gone wrong'. By gently challenging children's conclusions practitioners can draw attention to the need for evidence that is accurate and objective rather than vague and based on opinion.

Science skills

The skills which young children can acquire through investigation and exploration encompass practical, intellectual, communication and social skills. They include:

- practical skills of observation, using all the senses, manual dexterity, fine motor control, hand-eye coordination and construction;
- reasoning and thinking skills such as questioning, speculating and inferring, problem solving, noticing similarities and differences and reflecting;
- communication skills including speaking, listening, discussing, representing, recording and reporting;
- social skills of cooperation, negotiation, leadership, following instructions and behaving in a safe manner.

Handling tools such as buckets, funnels, tubing, magnifiers, tongs, pipettes and magnets and manipulating materials such as sand, water, clay, fabric, wood, plastic and metal will develop young children's fine motor skills in a purposeful way. Achieving this mastery over tools is not only of practical use, it also boosts children's confidence and feelings of self-worth. For example, being able to pour flour back and forth from one container to another without spilling it is a very useful skill for an 18 month old toddler to acquire. Being the 'expert pourer' will also do wonders for that child's self-esteem.

Exploring and investigating using open-ended materials is a valuable way of encouraging young children to utilize their thinking and reasoning skills. As part of the investigative process children will be framing questions, collecting and analysing information, trying out ideas and making evaluations. A baby will do this when he explores what happens when he bangs a metal saucepan with a wooden spoon, a toddler will do this when she 'posts' a ball into the top of a sloping cardboard tube, and a preschool child will do this when he siphons water out of a water tray and onto the ground.

Scientific investigative play provides an ideal medium to support and encourage young children's communication skills. Creating a positive emotional environment in a setting, where children feel confident to put forward ideas and express opinions, will encourage them to talk about what they are interested in and what they have discovered. Exploration is all about finding out – there are no wrong answers so everyone's discoveries are equally valid and important. Yong babies will communicate their ideas and discoveries through movement, expression and body language. Being attentive to these forms of communication and tuning in to the many different languages of communication which young children use are essential parts of knowing and understanding the interests and preoccupations of the children you work with.

Scientific investigation involves the sharing of ideas – observations and discoveries need to be shared with, and verified by, other people. Exploration and investigation can be a good way to encourage children to cooperate with one another, to work together as a team and begin to take responsibility for their own safety and that of others.

All such skills will need to be practised frequently before they can become fully embedded; children need plenty of opportunities to hone their skills through exploration and investigation in a wide variety of different situations.

Role of the adult

Co-constructors of knowledge

The concept of adults and children co-constructing knowledge together underpins the work of educators in Reggio Emilia (Giudici et al., 2001; Malaguzzi, 1998: 49–97) and this has become the foundation on which good practice in early childhood education in the United Kingdom is based (see the Introduction). It implies a very strong image of children as competent and confident, with their own theories about the world and how it works. In co-constructing knowledge children and adults bring their own ideas, theories, experience and knowledge to any situation and then seek to make meaning of that situation as they explore and investigate together. To do this an adult must acknowledge and value the skills, knowledge and experience of the children they work with as well as being comfortable with not having control over the final outcome of the experience (Jordan, 2009).

Working in this way enables practitioners to follow the ideas which children come up with when exploring an adult-initiated activity (Davis and Howe, 2003) and to build on any opportunities that arise from child-initiated play. In the process practitioners can model the scientific attributes of curiosity, cooperation, a respect for evidence, persistence and resilience.

Nobody can be an expert on everything so it is important not to worry if situations arise, or children pose questions, which you cannot immediately answer. Exploring and investigating alongside the children, trying out ideas and seeing what happens, will help to validate these processes as acceptable and positive ways to acquire knowledge. By co-constructing knowledge together both adults and children will experience the pleasure and satisfaction of discovering something new and significant to them. These are the learning moments that stay with us forever.

Source of expertise, skills and knowledge

To act as a co-constructor of knowledge alongside children, the adult must have their own skills, expertise and knowledge in order to capitalize on those opportunities which arise. Having this understanding enables a practitioner to:

- provide interesting starting points which excite children's curiosity and fire their imaginations: try looking a fresh at everyday resources, consider their potential and find the 'extraordinary in the ordinary' (see Chapter 2);
- see the potential in child-initiated play situations and know how to build on them productively;
- carry out realistic risk assessments, know what does and does not constitute a hazard and recognize how to provide children with risk and challenge without exposing them to danger;
- understand the learning they are seeing in different situations and know how to build on this to support individual children's learning and development;
- probe children's thinking with challenging questions which will encourage them to reflect on and review their ideas.

Encouraging children to ask questions

With very young children it is important to remember that questions can be non-verbal as well as verbal. Young babies will be asking questions and expressing curiosity through their facial expression, gesture, stance and posture, through the length of time they spend absorbed in an exploration or by how often they want to repeat the same experience. The attentive practitioner will be alert to these signs of interest and can then use them to provide appropriate experiences to extend young children's learning.

To encourage children to ask questions it is essential to create an emotional environment in the setting which welcomes and values children's questions. Children must feel comfortable enough to put their ideas forward – knowing that they will be taken seriously and that they won't be laughed at or told they are silly. They are entitled to the opportunity to find things out for themselves, guided by a skilful and knowledgeable adult. If, instead, we fall into the trap of giving children 'the right answer' we take away from them the thrill and excitement of discovery, undermining their capability and potentially destroying their interest altogether.

Asking productive questions

Questions can be used to focus children's attention, help them to notice particular features, similarities or differences, find out what they know, pose problems to explore and investigate and challenge them to give reasons and explanations for their ideas and theories.

Closed questions have a right and wrong answer and can often be answered with a very short response. They do have a purpose, in that they can help children to review and recall information they already have, but they do not usually reveal much about what a child is thinking. Fear of being wrong may dissuade some children from attempting to answer a question, while others may feel it is not worth their while to respond if the answer is very obvious.

Closed questions often begin with:

- 'How many … ?'
- 'How much … ?'
- 'What colour … ?'
- 'Is it … or … ?'

Open questions encourage children to express their opinions and share their ideas, explore and investigate and transfer knowledge gained in one context to address problems and challenges in another. These could begin with:

- 'How could we … ?'
- 'What do you think would happen if … ?'
- 'What do you think this might be for … ?'
- 'Can you think of a way to … ?'
- 'What else could we try … ?'

Making these questions person centred, including the pronouns 'you' or 'we' in the phrasing of the question, will encourage all children to put forward their ideas and offer opinions.

Drawing children's attention to features and events by asking, 'Have you noticed … ?' or 'Did you see/hear/feel … ?' helps to build their observational skills.

The association between cause and effect can be pointed out with statements such as 'When you do … , look what happens to …'.

By encouraging children to share their discoveries with others you will be giving them the opportunity to consolidate their understanding and practise new vocabulary. Reflective questions can be used to challenge young children's thinking and help them to refine their ideas:

- 'Why do you think that … ?'
- 'Can you tell me what you were thinking about when … ?'

Modelling and appropriate intervention

Modelling is a very effective and powerful tool to use when developing young children's scientific skills, dispositions and attitudes. This could be as simple as sitting alongside a baby and demonstrating the skills of looking through a sheet of coloured acetate, squeezing clay through a garlic press while sitting with a group of toddlers at the clay table or holding a hand lens in the correct position when exploring flowers with a group of preschool children. Modelling an enquiring mind, thinking out loud, commentating on what you and the children are doing, being interested and enthusiastic and welcoming the joy of the unexpected are all infectious attitudes which children will pick up.

Knowing when to intervene in children's exploration and investigation – and when to stand back – is a probably the most challenging role for any adult. The decision about when and how to intervene will be based on that practitioner's understanding of what he or she can see happening, any experience of similar situations in the past and a swift assessment of the potential direction in which the children's learning might go. There is no simple answer to when or how to intervene, as every situation will be different. Experience suggests that, unless safety considerations demand immediate action, the practitioner will gain more from closely observing what is happening, perhaps by taking photographs and noting down the children's demeanour, actions and conversation, rather than if she or he joins in and affects the outcome of the investigation.

Observing and documenting children's scientific learning

Observing and documenting young children's exploration and investigation are key to tracking individual children's learning experiences, making judgements about what they know and planning what experiences to offer next to deepen their thinking and consolidate their understanding. Observation involves the practitioner being aware of, and valuing, how children explore the world with all their senses and express their ideas and findings in many different ways through the use of the body as well as the brain. This is particularly true with very young children.

The tools of observation and documentation include photographs, video, notes on children's actions and reactions, written transcripts of children's conversations, tape recordings, children's drawings and pictures, models and constructions. Encouraging children to take photographs of what is important to them, and listening carefully to the exact words they use when talking about their discoveries, will give you a valuable insight into what lies behind their thinking and reasoning.

Documentation is an active process which needs to be carried out throughout an exploration or investigation and not just compiled at the end. It is used to:

- plan what resources and opportunities a practitioner should offer children next;
- share ideas and experiences with children, prompting them to review and reflect on what they have been doing and what they have learned;
- share information with colleagues to gain multiple insights and interpretations of the learning that is taking place;
- help parents and family members to share in their children's learning.

Giving children time

Scientific learning demands time. Time to explore resources to find out what they do; time to discover what you are interested in and want to find out more about; time to learn skills; and time to revisit and repeat experiences to consolidate understanding. As children become involved in their explorations and discoveries, they will also become absorbed in what they are doing and will therefore concentrate for long periods. It is important to give children the time they need here by keeping as flexible an approach as possible to support long-term investigations. Children need to feel confident that they are not always under pressure to complete their investigations to a deadline imposed by adults or by fixed routines. Where deadlines must be set, children should be involved in agreeing what these will be so they are then aware of what is going to happen next.

The science processes

The science processes are a set of intellectual skills which define how we gather reliable information about the world around us. It also describes the way in which we carry out an investigation and draw conclusions from it (Harlen, 2001). These are:

- *Observing* using all the senses to gather information.
- *Classifying* organizing objects, experiences and ideas into groupings which make sense to the individual.
- *Raising questions* deciding what one wants to find out.
- *Hypothesizing* using information to explain why something might happen or to explain a set of observations.
- *Predicting* using a hypothesis to decide what might happen.
- *Planning and carrying out an investigation* organizing resources, deciding on what to measure and how to record the information.
- *Interpreting information* looking for patterns and associations, deciding what the data show.
- *Communicating* sharing information, discussion.

Younger children will not necessarily have the experience of the cognitive skills needed to manage all of these science processes. Johnston (2005) uses the term 'exploration' to describe how young children find out about the world. Exploration involves the first four of the science processes – observing, classifying, raising questions and hypothesizing. As children's thinking and reasoning skills mature they become better able to handle the more complex science processes – predicting, planning, interpreting and communicating – and to build their skills in planning scientific enquiries (Goldsworthy and Feasey, 1997).

Spiral of Discovery

The 'Spiral of Discovery' is a term coined by the authors to describe a process whereby practitioners can support young children's exploration

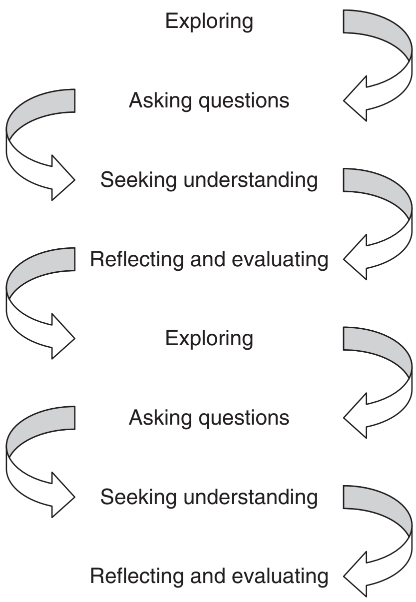

Figure 1.1 The Spiral of Discovery

and investigation in a structured way. It mimics the processes of science, but endeavours to present these in a context which practitioners will recognize in relation to young children's learning and development.

The Spiral of Discovery is made up of four stages:

- Exploring.
- Asking questions.
- Seeking understanding.
- Reflecting and evaluating.

Exploring

Exploring involves children being playful, using all their senses, displaying curiosity and making connections as they encounter a new experience, resource or piece of equipment.

When they are in the exploring stage children will have many opportunities to play with their ideas and develop new understandings of experiences, phenomena and events. By providing open-ended resources and experiences practitioners can support and challenge children's thinking, enabling them to make connections in their learning.

Asking questions

Children build on the information they have gained at the exploring stage by putting forward ideas and theories, posing questions, listening to the ideas of others and thinking about what it is they want to find out.

By observing children closely and engaging them in shared conversations and thinking, practitioners will be able to encourage children to ask questions themselves. Children's enquiry and questioning skills can be enhanced by:

- providing the environment and opportunities for children to ask questions;
- placing value on children's answers;
- giving children time to think, to formulate questions and to respond to those questions which are asked;
- a practitioner modelling a questioning mind themself.

Remember, not all children will use words to ask questions. Some may be too young to verbalize their questions or may lack the necessary communication skills.

Seeking understanding

This stage in the spiral involves children in making choices, looking closely, planning what they are going to do, investigating and recording what it is they have discovered.

Children will need the time and opportunity to investigate, to seek understanding and to find solutions to problems. They learn best through physical and mental challenges which often engage them for sustained periods of time. Their investigations may take the form of quiet solitary activities or they might enjoy the excitement of a shared experience with others.

As children investigate they will develop a wide range of active learning skills including:

- reasoning and thinking skills;
- communication skills;
- social skills;
- practical skills;.

Reflecting and evaluating

This important last stage in the process gives children the chance to revisit their ideas, to reflect on what they have discovered and to evaluate their findings. This will often lead them into new areas of exploration and investigation, continuing their natural spiral of discovery.

Revisiting ideas and discoveries helps to build children's awareness of their own thinking and reasoning processes. Encouraging children to explain their ideas through the use of reflective questions such as, 'Can you remember what you were thinking when … ?' will help to clarify their understanding. In addition, this will often suggest new and productive ways to extend their experience of scientific concepts.

The Spiral of Discovery with babies

Exploring
A baby sitting alongside a light box placed on the floor picks up a piece of blue acetate sheet and investigates it with her tongue to see what it feels like.

Asking questions
The baby looks through the acetate sheet, demonstrating her interest through her gestures, stance and posture. She drops the acetate so it falls on the illuminated surface of the light box. A second baby seated nearby watches what happens and starts exploring the acetate pieces himself.

Seeking understanding
The baby notices that the blue acetate has fallen on top of a piece of green tissue paper on the light box, creating a very dark colour. She picks up other pieces of blue acetate and drops these on the light box to see what happens.

Reflecting and evaluating
The practitioner observes the baby's interests and preoccupations and offers her a yellow acrylic shape to extend her learning.

The Spiral of Discovery with toddlers

Exploring
A small group of toddlers are playing outside at the water tray next to the sandpit. They are filling and emptying beakers and jugs, splashing the water and pouring some of it onto the ground. One of the children starts to talk about going swimming.

Asking questions
One of the children takes a Lego figure out of her pocket and wonders, 'Can he swim?' The other children watch as she drops him in the water.

Seeking understanding
The other children decide to find out which of the small world people and animals can swim in the water tray. They drop them in and the practitioner draws their attention to what they can see happening. Some of the children try to hold the animals up to stop them sinking. The practitioner takes a photograph of what the children are doing.

Reflecting and evaluating
One of the children notices a plastic dinosaur lying on the bottom of the water tray. 'I am going to make a boat for the dinosaur'. He tries various beakers and jugs to see if he can balance the dinosaur inside them and then goes off to look for something else to use as a boat. Meanwhile two of the toddlers have begun to explore new possibilities about what happens when water is poured onto sand.

The Spiral of Discovery with preschool children

Exploring
A group of children are outside looking for invertebrates in the garden. They have set up a role play scenario involving an outdoor laboratory complete with collecting trays, magnifiers and clipboards. They turn over a stone, discover some woodlice and run off to fetch a magnifier and a collecting tray. When they get back the woodlice have disappeared.

Asking questions
The children have many suggestions about where the woodlice might have gone: 'Into the ground', 'They flew away'. They discuss where they might look for them and search for other likely stones.

Seeking understanding
The children decide to catch some of the woodlice so they can track the journeys they make. They discuss this plan with the practitioner and negotiate who will do what. It is agreed that the practitioner will

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find a large piece of paper and will take photographs while the children tip the woodlice on to the paper and use crayons to track the movements of the woodlice. The woodlice move very fast – one child uses his crayon to draw a circle around one woodlouse in an attempt to contain it.

Reflecting and evaluating
The children recapture the woodlice and put them back under their stone. They talk about the way one woodlouse stopped momentarily inside the circle and then moved on. They discuss different ways they could contain the woodlice – string, pencils or wooden blocks – and wonder if they could repeat the same exploration with snails.

Further reading

Davis, D. and Howe, A. (2003) *Teaching Science and Design Technology in the Early Years*. London: David Fulton.

Johnstone, J. (2005) *Early Explorations in Science* (2nd edition). Maidenhead: Open University Press.

Nutbrown, C. and Page, J. (2008) *Working with Babies and Children from Birth to Three*. London: SAGE.

Thornton, L. and Brunton, P. (2005) *Understanding the Reggio Approach*. London: David Fulton.