# Science for Children

## Developing a personal approach to teaching

3rd Edition

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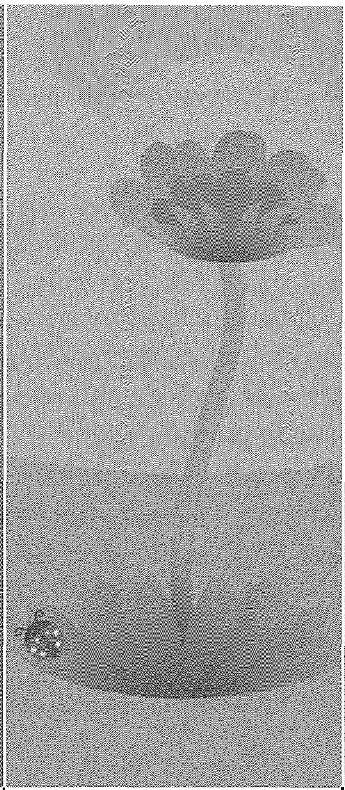
# Researching children's understanding and ways of learning



## Chapter 2

## Introduction

**Rowan:** Who will be Father Christmas when he is dead?
**Adult:** Umm . . . he is not going to die.
**Rowan:** Why doesn't he die?

Rowan's thinking about the mortality of humans is extended to something important to him—Father Christmas. We can find out a lot about children's thinking by listening to them (Fleer & Robbins 2003; Robbins 2005). This chapter provides insights into children's scientific thinking. We provide examples from our research and the research literature to illustrate not only children's thinking but also ways in which you can get to know how children think and learn. This section is followed by a brief discussion of student border-crossing between school science and everyday science (including multiple world views or cultural orientations) in order to demonstrate the sensitivities needed by teachers working with young children. In addition, we see how broadly scientific literacy can be defined when we look at school science and everyday science.

## Children's understanding

Children's understanding of the world is influenced by their daily experiences, as well as by direct encounters with information from books, parents, teachers and other children. Knowing what children think is important for understanding how concept formation in science can take place.

**Rowan:** If I ever die and someone pokes it, it will be gone.
**Adult:** Pokes what?
**Rowan:** The bubble in my head.

### >> Research orientation 2.1: How do you find out what children think?

Before proceeding, record what you make of these comments and those in the introduction. *What is occurring here in terms of Rowan's understanding? How could you research what children think in relation to a range of science concepts?* For instance, consider the drawings shown in Figures 2.1 and 2.2, which were done by Stephanie (age four years) and Zach (age eight years), who were learning about their bodies.

**Figure 2.1** Stephanie's (age four years) drawing of what is inside her body

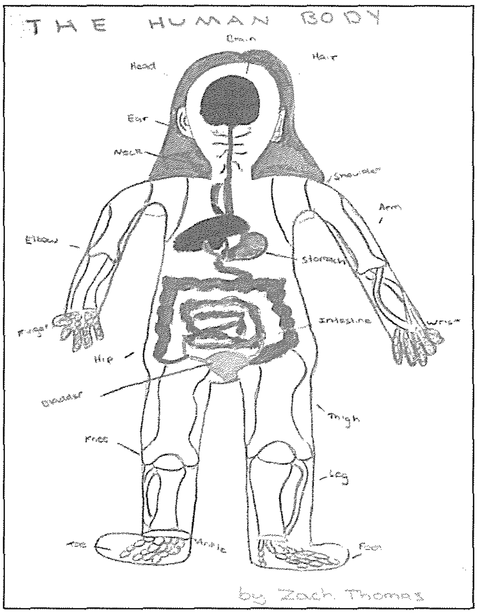



**Figure 2.2** Zach's (age eight years) drawing of what is inside his body

## Hollow legs?

In the teaching sequence on children's understandings of the body (see Figures 2.1 and 2.2 above), the teacher invited the younger children to draw around their bodies and then to draw what they thought was inside themselves. For the older children, the teacher asked that they draw a picture of themselves and what they thought they looked like from the inside. Not only did the children not know about the organs in their bodies, but they also believed that food, after being swallowed, floated around in any area of the body (perhaps the expression 'hollow legs' does little to assist children with developing scientific understandings of themselves). In addition, their everyday experiences with cuts, scratches and bruises tend to reinforce a view that blood is below the surface of the skin, filling the spaces inside the body (like a bag of blood). The primary function of blood and how it travels throughout the body, being dispersed and collected, were ideas not considered by many of the children. Ideas about how to teach a unit on the body that takes account of children's everyday understandings can be found in Fleer and Leslie (1995).

Many studies have been done that examine children's understandings of particular scientific concepts (Fetherston 1999; Gabel 1994; Rahayu & Tytler 1999; Thomas 1999). These studies reveal that children between the ages of seven and 15 have many different views about almost every scientific concept considered in school. Less is known about children below the age of 7 (Cummings 2003; Fleer 2000; Fleer & Robbins 2003; Segal & Cosgrove 1992; Robbins 2005). The volume of research that has been conducted since the mid-1970s on young children's understandings of scientific phenomena (Novak 2005) tends to lead to two conclusions: first, that children have different views about scientific concepts (Cummings 2003; Fleer 2000; Sharma, Millar, Smith & Sefton 2004); second, that those views influence how they interpret the scientific experiences that are organised by the teacher (Darby 2005; Fensham 1998; Ritchie 1998; Roth 2000; Sprod 1998).

Twenty years of research have shown us that:

- children develop mini-theories about their environment, based on their own cultural or everyday experiences (often called 'everyday explanations', 'alternative views' or 'misconceptions');
- children's existing ideas may or may not match those of school science;
- children make sense of science ideas or lessons in relation to the existing ideas they hold;
- differences in children's everyday or cultural ideas and school science cause variations in how children make sense of science lessons (see further the discussion on cultural border-crossing later in this chapter); and
- some children's ideas do not change as a result of science instruction.

Consequently, it is paramount that, as a teacher, you find out what children think about the scientific concept that you have decided to introduce, before you start teaching (Skamp, Boyes & Stanisstreet 2004). The children probably hold quite different views from those you expect.

# Finding out children's understandings

## When is an animal an animal?

The following is an example of Tim Hardy's interview with a five-year-old boy (Nicky, his son) about his understanding of animals, based on seminar research reported in Osborne and Freyberg (1985: 172–3) and others (e.g. Kallery & Psillos 2004; Novak 2005). Note the way the interviewer focuses the child's attention and draws from Nicky his view of whether or not the item in the picture is classified as an animal. In the second section you see that the adult goes back to each card and tries to elicit, once again, from the child more information about his criteria for 'animal'.

**SECTION ONE**

**Tim:** Now see those six pictures, Nicky . . . Now I want you to tell me whether you think they are an animal or not an animal. What's that, do you think?
**Nicky:** A cow.
**Tim:** Would you say that's an animal?
**Nicky:** Yes.
**Tim:** That's an animal. What do you think that is?
**Nicky:** Grass.
**Tim:** Is that an animal?
**Nicky:** No.
**Tim:** It's not an animal. What's that?
**Nicky:** A spider.
**Tim:** And what would you say that is? Is that an animal or not an animal?
**Nicky:** It's kind of an animal.
**Tim:** It's kind of an animal is it?
**Nicky:** Yes.
**Tim:** Why do you say 'it's kind of an animal'?
**Nicky:** I just do.
**Tim:** I see. Okay. And what's this animal here do you think?
**Nicky:** A whale.
**Tim:** Is that an animal or not an animal?
**Nicky:** An animal.
**Tim:** What's this here?
**Nicky:** A worm.
**Tim:** Is that an animal or not an animal?
**Nicky:** It is an animal.
**Tim:** And this is a boy, is that an animal or not an animal?
**Nicky:** Yes, it is an animal.

**SECTION TWO**

**Tim:** That's an animal. Now you say that a cow is an animal, why do you say a cow is an animal?

**Nicky:** Because it gives milk.

**Tim:** Yes. What else about a cow, why is it an animal?

**Nicky:** Nothing else.

**Tim:** Now grass, what did you say about grass?

**Nicky:** It's not an animal.

**Tim:** Why did you say it's not an animal?

**Nicky:** Because it doesn't have eyes . . .

**Tim:** Yes . . . It doesn't have eyes.

**Nicky:** And it doesn't have ears.

**Tim:** It doesn't have ears, yes.

**Nicky:** And because it has roots.

**Tim:** It has roots, and animals don't have roots?

**Nicky:** No.

**Tim:** And what about the spider, is that an animal or not an animal?

**Nicky:** Kind of an animal.

**Tim:** Kind of an animal, yes.

**Nicky:** Because it feeds through its mouth.

**Tim:** Yes, and that makes it an animal, does it?

**Nicky:** A kind of animal.

**Tim:** Umm, but a cow is an animal, but what did you say about the spider? A kind of animal, is it really an animal or not?

**Nicky:** A kind of animal.

**Tim:** Umm, and what about the whale, you said that's an animal didn't you?

**Nicky:** Yes.

**Tim:** Why did you say that's an animal?

**Nicky:** Because it has eyes.

**Tim:** Yes. It has eyes does it? What else does it have that makes it an animal?

**Nicky:** It has fins.

**Tim:** What about this thing here, you said that was a worm. Why is that an animal?

**Nicky:** Because it goes on the ground.

**Tim:** Yes, and do all animals go on the ground?

**Nicky:** No. This one doesn't go on the ground (points to spider).

**Tim:** Spiders don't go on the ground?

**Nicky:** No.

**Tim:** Do they sometimes go on the ground?

**Nicky:** Yes.

**Tim:** And what about the boy? Is a boy an animal?

**Nicky:** Yes, 'cause people are animals!

**Tim:** Are they?
**Nicky:** Yes.
**Tim:** Why do you say they are animals?
**Nicky:** Because you say they are.
**Tim:** Oh I see, but what do you believe?
**Nicky:** You.
**Tim:** But what do you think, are they really animals?
**Nicky:** Yes.
**Tim:** Why do you think they are animals then?
**Nicky:** Because they are just a kind.
**Tim:** Just a kind, a kind of animal then?
**Nicky:** Yes.

Nicky's response to the task is quite sophisticated for a five-year-old child. Mobility and human-like characteristics, such as ears and eyes, are most important in his categorisation of what is an animal. The absence of these features means it is not an animal. He also knows that people are animals—although in everyday language the term 'animal' is not usually associated with humans (e.g. 'no animals allowed on the freeway'). As a result, scientific taxonomies often cause confusion for children. Strategies for interviewing children can be found in Osborne and Freyberg (1985) and for an overview of different techniques see Novak (2005).

**Figure 2.3** There are lots of opportunities for finding animals in the school grounds

**Figure 2.4** Investigating animals leads to important observations about animal behaviours

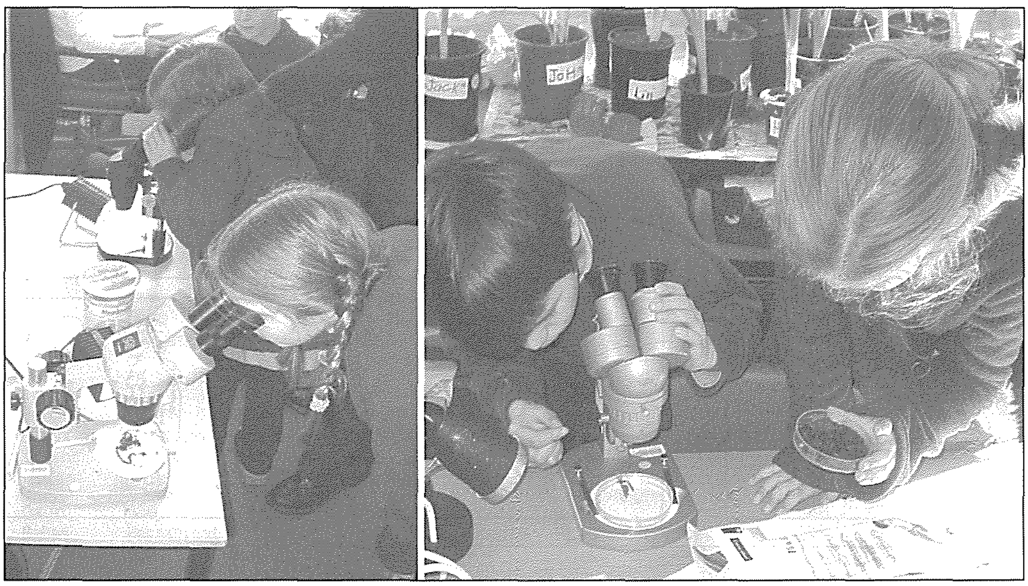


**Figure 2.5(a) & (b)** Taking a close look at animals is important for developing understandings

## Animal or non-animal?

The following 'animal and non-animal' task should also generate a number of interesting responses from children.

## >> Research orientation 2.2: Animal and non-animal

Individually interview three girls and three boys of approximately the same age about their understandings of the concepts of 'animal' and 'non-animal' things.

Figure 2.6 shows small pictures that you can use for the interview. You can photocopy these and make them into cards. Do not alter these cards in any way, for example by colouring them, as alterations might distract the child and change his or her response.

Before interviewing the children, record what you understand by 'animal' and 'non-animal' and go through the cards and categorise them into 'animal' or 'non-animal' things. Then make some predictions about what the children will understand and how you expect them to categorise the cards. Note these predictions. This helps to tune you into the children's thinking.

During the interview, ask each child to:

**1.** name the object on the card;
**2.** think about whether the object on the card is animal or non-animal;
**3.** put the card into one of three piles: animal thing, non-animal thing, not sure;
**4.** tell you why they've put that object into that pile.

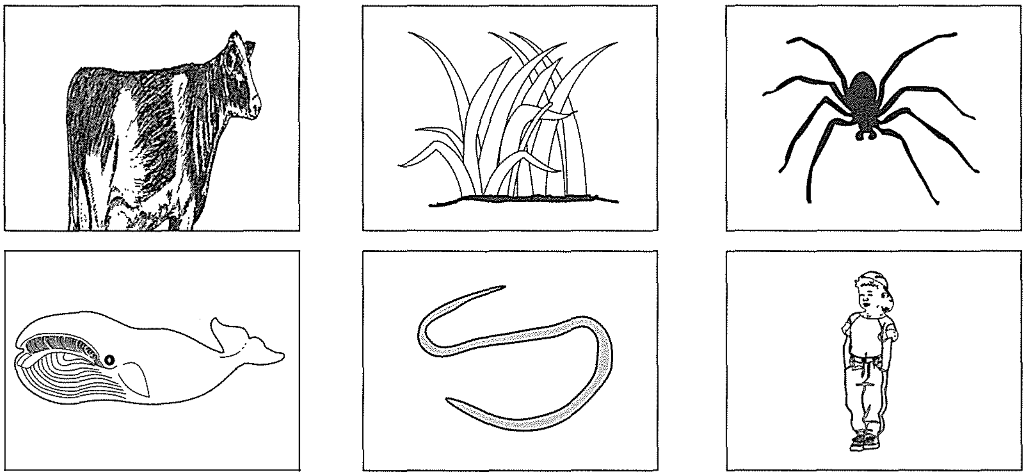


**Figure 2.6** Pictures to investigate meanings for the word 'animal'
*Source:* Adapted from Osborne & Freyberg 1985.

Record:

1. the child's name, age and year level; and
2. the reason(s) for each placement given by the child (recording his or her exact words—if you cannot capture all of them, then record the key words and phrases; a tape recorder can be useful).

## >> Research orientation 2.3: Reflecting on the data collected

Reflect on and record:

1. what happened during the interviews;
2. comments on interesting aspects of the data gathered (e.g. were your predictions confirmed?); and
3. what you have learnt from the experience.

Now compare what you have recorded with the following results (Table 2.1) obtained by a student teacher. Her cards differed from Figure 2.6, but you are likely to find some similarities in the criteria used by the children in their thinking.

| INTERVIEWED CHILD | TREE | BOY | BICYCLE | CAR | SPIDER | SEAGULL | FIRE | FISH |
|---|---|---|---|---|---|---|---|---|
| Jenna 5 years | Alive. Grows. | Alive. Walks. | Not alive. Doesn't walk or swim. | Not alive. Doesn't walk. | Alive. Crawls. | Alive. Flies. | Not alive. Doesn't walk or swim. | Alive. Swims. |
| Natasha 6 years | Not alive. Dead–leaves have come off. | Alive. Nothing is hurting him. | Alive. Nothing can make it break. | Alive. Nothing can make it die. | Not alive. It's dead. Something stepped on the spider. | Not alive. It's dead, been shot. | Not alive. It's gone out. | Not alive Someone has cut the fish. |
| Hannah 6 years | Not alive. Leaves fallen off. But some are alive if they grow they're alive. | Alive. Moves like us. | Not alive. Hasn't got eyes, mouth like we have. | Not alive but can move around same as bicycle. | Alive. Catches food and eats food. | Alive. They tweet. | Not alive. | Alive. Lives in water. Can breathe in water. Feed them. |
| Sarah 4 years | Not allive. Got no legs. Can't move | Alive. Move. | Not alive. You can make it move. | Not alive. Doesn't have mouth, eyes, nose. | Alive. Got legs for its walking. | Alive. Has wings and feet. Its eyes are open. | Not alive. | Alive. Eyes are open. |
| Ryan 6 years | Alive. Grows higher water it gets bigger | Alive. Walks. | Not alive. A person rides it. | Alive. Moves. Makes a noise. | Alive. Wriggles around. | Alive. Flies and eats. Eats food to get energy so it can fly. | Alive. Steams up. Doesn't eat. | Alive. Swims and eats to get energy. |
| Patrick 6 years | Alive. Drinks water and grows. | Alive. Eats, drinks and grows. | Not alive. Has a handle, wheels and flag. | Not alive. Has an engine. Not in a shape. | Not alive. Dead. Can't move. | Alive. Have air and fly, eats flowers and worms. | Not alive. Doesn't move. | Alive. Swims, drinks water. If they don't they die. |
| Darren 6 years | Alive. Has roots and grows. | Alive. Drinks and eats | Not alive. Because it drives. | Not alive. Because it drives. | Alive. Crawls. Stings. Eats. | Alive. Flies. Eats. | Alive. Makes a noise. | Alive. |

**Table 2.1** Results of an interview by a student teacher

Some interesting realisations about children's thinking can occur when they are interviewed. Did that happen for you? You may have noted from your data that:

- children might confuse deciduous trees with 'dead' trees;
- movement is an important variable in classifying something as living (e.g. 'a car is alive because it moves');
- static pictures of living things are deemed to be 'dead' (e.g. the spider is not alive because 'something stepped on the spider'); and
- human characteristics, such as eyes, are important in classification (e.g. 'it is alive because its eyes are open' or 'it's not alive because it does not have eyes, ears and a mouth').

Now consider some of the responses made by children who were interviewed by second-year Bachelor of Education student teachers who have done the 'living and non-living' task with young children, using similar cards to yours.

**MICHELLE**

I had six Year 2 children, four of them were seven and two boys were eight. I found that almost half of the responses they made were based on the criterion of movement, which is pretty much in common with everybody else.

They said kangaroo, waves, child and the sun were alive, because the sun comes up in the morning and it goes down at night, and also the waves come onto the sand.

The fire they were not sure about. One of them said that it was not alive because you cook stuff in it. Most of them said it is not alive, but also they said they were not sure, because it is sort of alive because it grows and moves, but they ended up putting it in the not alive category anyway.

The bike and the computer were not alive. One girl said, 'The computer is not alive because it has a memory, but it's not like a human memory, it stores lots of things, but it can't remember all by itself.' She had a pretty good idea of what was going on there. And then she went on to explain how the computer stores things, but she was blundering around for words, and then she said, 'Because it's got lots of wires and that's why.'

There was one girl who had really good responses. She said, 'The kangaroo was alive because it had babies and it was a mammal', and this is a seven year old. Then she said, 'The tree was alive because it drinks water into its roots and it breathes in carbon dioxide and breathes out oxygen.' I thought that was really incredible for a seven-year-old girl.

The sun really confused her. She said, 'The sun is a star and it has fire, and a fire is not alive.' I then asked her to explain that a bit more and she got all flustered and said, 'It's just not alive, okay.'

**TANIA**

I asked one girl (age five years) if she was alive and she said, 'No, I am too little'. She also thought that a computer was alive when it was on and not alive if it was switched off.

I was talking about the sun, and I said, 'Oh the sun moves around the earth' and this five-year-old girl told me, 'No it doesn't', she said. 'The earth moves around the sun.' She knew all about planets and things like that.

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What is interesting to note about the responses reported by the student teachers is that, first, there is a wide range in understanding; second, the age of the child does not always correlate with better understanding; third, some children apply one criterion for sorting things (e.g. the relationship of the object to themselves); finally, many children already hold quite sophisticated views of living and non-living things. You may like to add a brief summary of the main ideas to Table 2.1 for easy reference and for later planning.

Have you been challenged in your own views about what is living and non-living as a result of this exercise? Quite often, student teachers have that experience, and sometimes they feel less certain about the distinction being black and white. For instance, is a branch that has just been cut from a tree a living thing or a non-living thing? What about a packet of seeds? And what about viruses in a crystalline form: are they living or non-living? Reflection on such questions might suggest that scientific ideas are not always clear-cut. As a further challenge, try out the interview exercise with some adults—you might be surprised by their responses.

Finally, you might like to think about how these ideas may be different for children from different cultures. How we classify the world into animals and plants is socially constructed within our western culture and may be quite different from the way some traditionally oriented indigenous groups in Central Australia would classify them. For example, some indigenous groups use the seasons as a way of classifying living things (Fleer 1999; Ninnes 2000).

## Teaching about animal and non-animal

In each of the scenarios described above, quite a different starting point is needed for a teaching sequence on 'animal and non-animal'.

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## >> Research orientation 2.4: Teaching children the concept of 'animal' and 'non-animal'

*How would you teach the children you interviewed about the concept of animal and non-animal things?* Record your thoughts. We return to those ideas in later chapters (see Chapter 7, Research orientation 7.10).

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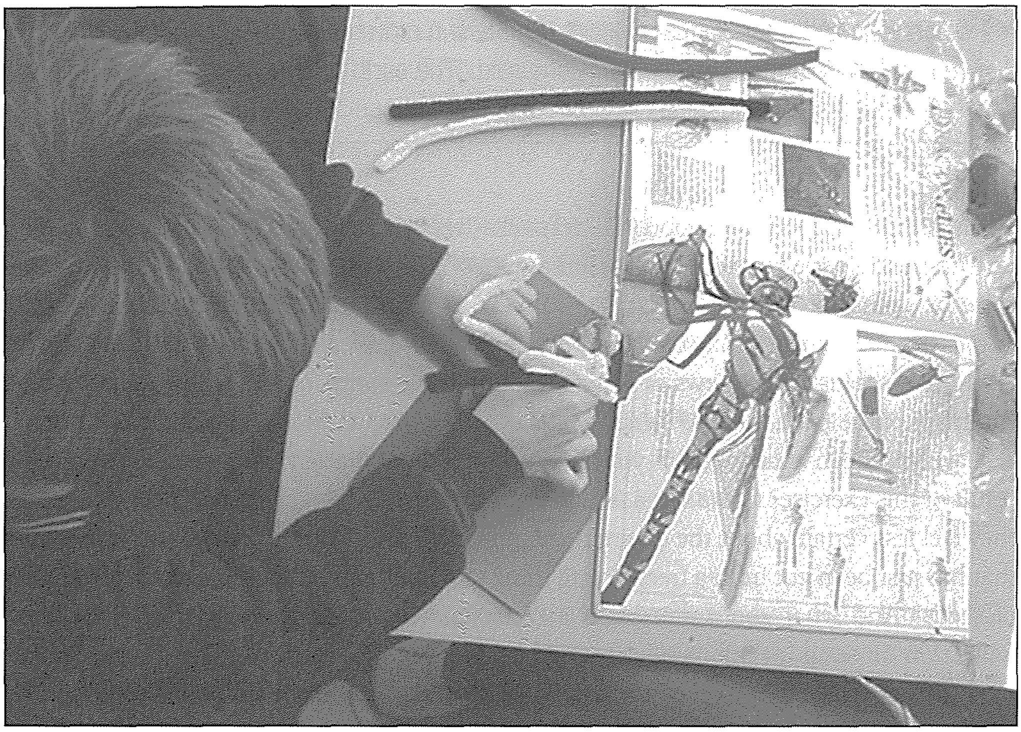

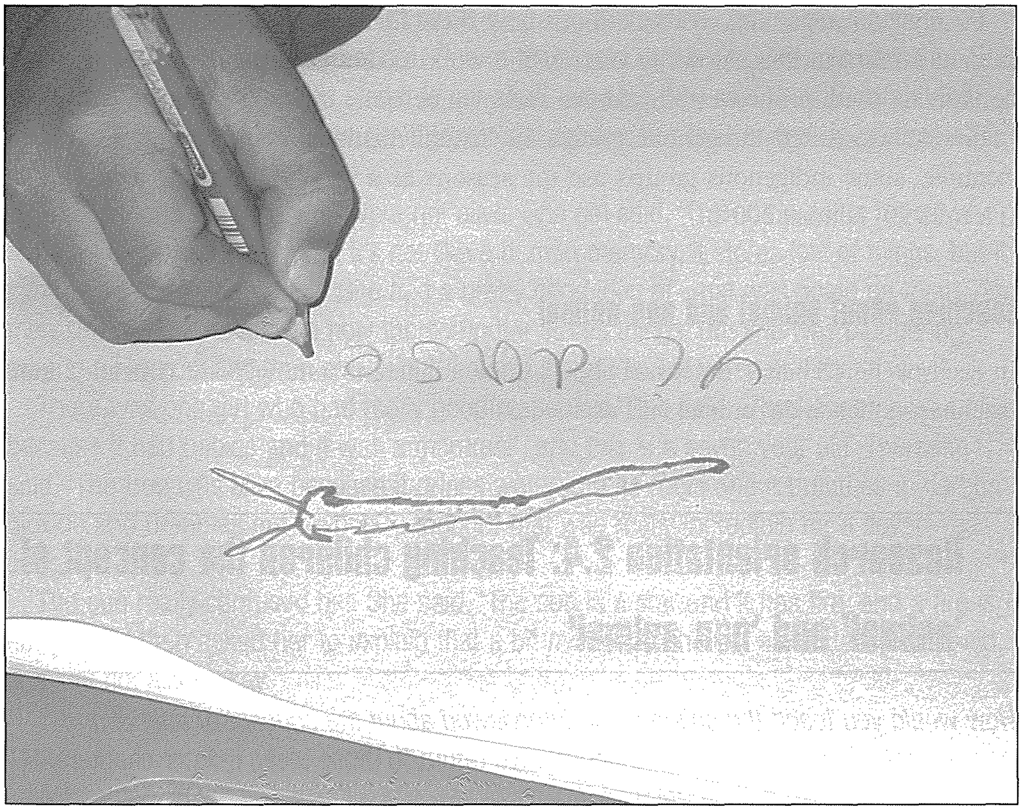

**Figures 2.7 and 2.8** Representing your observations can be done in many different ways

# A cultural–historical approach to science education

## How do concepts develop?

According to Vygotsky (1987), concept formation should be thought about at two levels. At the everyday level, concepts are learned as a result of interacting directly with the world—developing intuitive understandings of how to do things, such as closing the doors when it is cold, or opening the windows when it is hot. Children put on jumpers when they feel cold, and will tell you that the jumper will keep them warm. These are important everyday concepts. But children may not know the science behind these actions. They may not be aware of the scientific concept of insulation. Vygotsky argued that these everyday concepts lay the foundations for learning scientific concepts. Developing everyday concepts in the context of children's everyday world is important for living. However, everyday concepts cannot easily be transferred to other contexts. For example, knowing that a jumper keeps you warm may not be useful if you are learning to surf. How do you keep warm in the water? But knowing about insulation will help you ask for and understand how a wetsuit works. Being locked into everyday understandings is disempowering for children. Learning science is important for increasing children's thinking capacity and ability to navigate around the world in which they live.

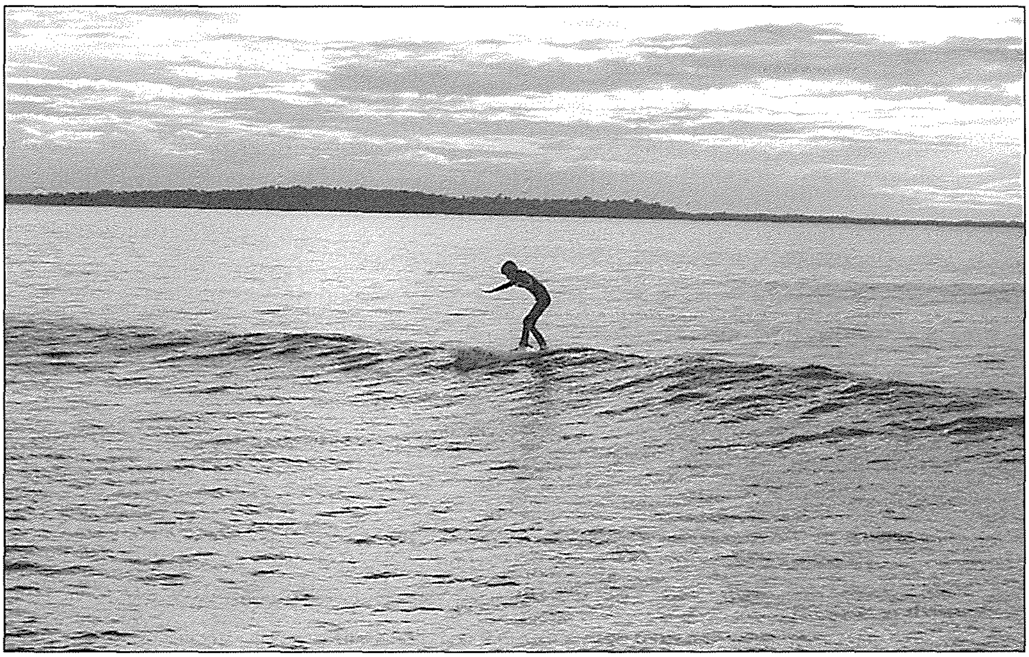

**Figure 2.9** How do you keep warm in the water?

Vygotsky (1987) also argued that simply learning science concepts at school, away from the context in which such concepts are used, locked scientific ideas up as well. For instance, learning about insulation by putting different materials/fabrics around jars with hot liquid in them, in order to determine which stays warm the longest, will only be useful if it relates to children's real-world experiences. Trying to keep icy poles from melting when going on an excursion is an authentic experience related to children's needs and interests.

Vygotsky argued that when children develop everyday or basic concepts, these experiences lay the foundation for higher order thinking. For example, having lots of experience with different types of blankets or jumpers, and talking about how they insulate or keep your body heat in, lays the foundation for talking about insulation. In this context, it makes perfect sense to a child to learn about insulation (scientific concept). Learning about insulation can transform the child's everyday experience. It is transformative, as the child can transfer this knowledge to other contexts. It is a higher order concept that provides important understandings across a range of everyday contexts—such as insulation in housing, insulation of lunch boxes, insulation of fridges and insulated drink containers.

Both everyday concept formation and scientific concept formation are strongly connected to each other. That is, everyday concepts that are grounded in the day-to-day life experiences of children and adults create the potential for the development of scientific concepts in the context of more formal experiences. Similarly, scientific concepts prepare the structural formations necessary for the strengthening of everyday concepts (Vygotsky 1987). As children bring together their working everyday knowledge of 'keeping warm' and their scientific knowledge of 'insulation', they transform their everyday practice.

Hedegaard and Chaiklin (2005) suggest that the most powerful learning contexts are those where the professional keeps in mind the 'everyday concepts' and the 'scientific concepts' when planning for learning. Hedegaard and Chaiklin (2005) have called this the 'double move' in teaching. As early childhood professionals, we create many different types of learning contexts for children—some of these are opportunities for building everyday concepts, and some are contexts that suit the introduction of scientific concepts. What is important here is the double move on the professional's part—where everyday concepts and scientific concepts are interlaced so that a child's thinking and practice will be transformed.

## Knowledge construction through curriculum sanctioning

Over the past five years some researchers have begun to question the curriculum framing of school science, as a result of examining children's everyday thinking. A number of

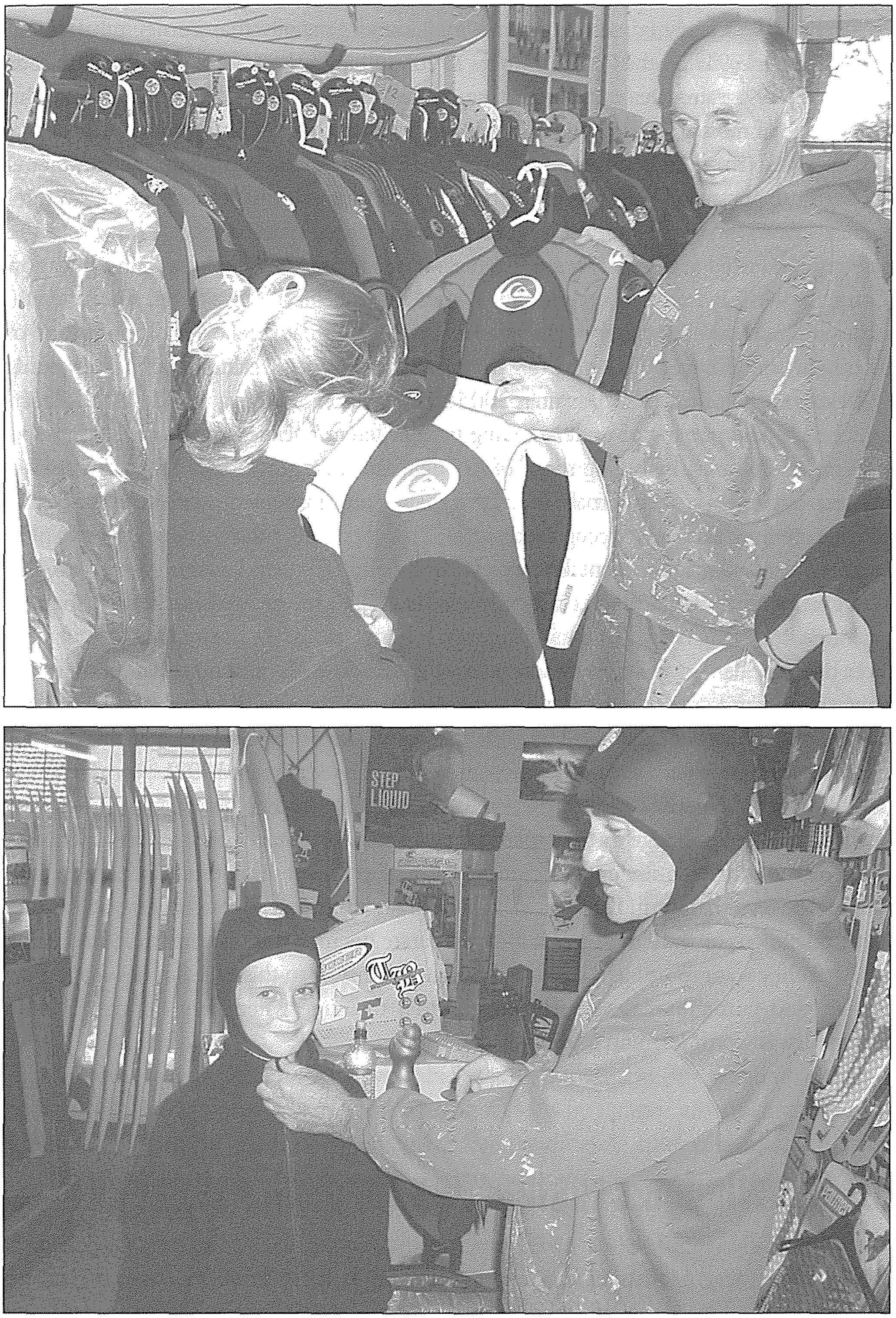


**Figure 2.10** Knowing about insulation helps you ask better questions when buying surfing gear to keep warm in the water

researchers have analysed school science and found generally that curriculum framing (e.g. Christie 1991; Fleer 2000; McKinley 1998) and implementation (e.g. Aikenhead & Huntley 1999; Lee, Deaktor, Hart, Cuevas & Enders 2005) demonstrate that the knowledge of most worth in schools is western science.

This western world view is clearly evident in many curriculum documents throughout Australia. Most curriculum documents have some statement on cultural inclusiveness, and recognition of indigenous scientific knowledge; however, the scientific knowledge generally features only a western perspective (Australian Education Council 1994: 3).

Scientific knowledge has been expanded by the cumulative efforts of generations of scientists from all over the world (e.g. Cuevas, Lee, Hart & Deaktor 2005; Jimoyiannis & Komis 2003; Russell & Atwater 2005; Verjovsky & Waldegg 2005). It has been enriched by the pooling of understanding from different cultures—western, eastern and indigenous cultures, including those of Aboriginal peoples and Torres Strait Islanders—and has become a truly international activity. The contributions of women to Australian science are now also being recognised.

The organisation of content knowledge sends out a powerful message: that we give thought to other world views, but only as they relate to the western construction of scientific knowledge.

In New Zealand we find a Maori science curriculum document situated alongside a western science curriculum. However, even within such a culturally aware and inclusive community as New Zealand, we find that the structure of the Maori science document had to feature a western view of science (as reported by McKinley 1998).

Although the New Zealand experience has produced two documents and, as such, has sent out a strong message to the community of the importance of indigenous science in New Zealand, the Maori science document has had to fit within a western science mould. Do you believe that an indigenous view should sit alongside a western view within the same document or should we put it into a separate document for communities to decide whether they want to use it? Thinking through the answer to this question is what policy makers and curriculum developers must do all the time when they decide on what knowledge is worth learning in schools and centres.

## Knowledge construction through research

Consider the range of alternative views expressed in the first part of this chapter. They are also framed within a western orientation. When we think about children's alternative views, we must ask, 'alternative to what?'. Clearly, it is alternative to a western world view. Our research paradigm has embraced a western orientation to framing what knowledge we look for. For example, in investigating children's ideas about night and day, we may well look only for western views and not indigenous views. With only western lenses on, we may not have allowed certain forms of knowledge or understandings to emerge. As teachers, we must be thinking about children's views—not simply from a western framework but also from a local indigenous framework, or other cultural orientation that may be likely, given the multicultural nature of Australia today. For example, if we ask about and look for understandings about the night sky based only on the Hercules constellations, how will we allow the emu and kangaroo constellations and storytelling that are a feature of some indigenous cultures within Australia to emerge?

A further example is cited by Jegede and Aikenhead (1999), who detail how, in 'some African cultures, a *rainbow* signifies a python crossing a river or the death of an important chief' (1999: 276, my emphasis). In western science terms, we would talk about the light refracting as it hits the water molecules. These are two different views of the world. The findings not only add to the growing body of research of children's thinking in science but demonstrate the complexities associated with children's thinking and the need to think beyond a western orientation.

Investigating cultural constructions of knowledge in science are important for building shared understandings and respect across and within cultures. Ensuring that non-indigenous students have access to, for example, eastern, western and indigenous worldviews is as important as indigenous students accessing western, eastern and non-indigenous world views. Through providing insights into other ways of thinking about the world we build respect and provide a range of ways of thinking (rather than one view) about our world. However, we also begin to be able to give thought to how students may have large or small differences in their belief systems between indigenous cultural and everyday thinking about the world, and western scientific understandings.

## Border-crossing

Jegede and Aikenhead (1999) have labelled the movement in thinking from an indigenous world view to a western science school view by indigenous students a 'border crossing'. They argue that how children negotiate the differing cultural borders—borders of school science and lived everyday experiences—will significantly influence their success in science. When the everyday lived science experiences or their world view is similar to school science, the transition is harmonious and without difficulty. School science supports the child's view of the world. Jegede and Aikenhead (1999) have termed this border-crossing experience in science learning for the child 'enculturation'.

When the border-crossing experience leads to the child abandoning his or her world view, assimilation has taken place (1999: 2).

Assimilation can alienate pupils from their indigenous culture, thereby causing various social disruptions; or, alternatively, attempts at assimilation can alienate pupils from science, thereby causing them to develop clever ways (school games) to pass their science courses without learning the content in a meaningful way, as expected by the school and community.

Border-crossing from a cultural world view to school science can be categorised as (Jegede & Aikenhead 1999: 5, original emphasis):

1. *Potent scientist,* whose transitions are *smooth* because the cultures of family and science are congruent;
2. *Other smart kids,* whose transitions are *manageable* because the two cultures are somewhat different;
3. *'I don't know' students,* whose transitions tend to be *hazardous* when the two cultures are diverse; and
4. *Outsiders*, whose transitions are virtually *impossible* because the cultures are highly discordant.

As children's border-crossing experiences will influence their success or failure in science, it is important to understand how children navigate border-crossing.

Jegede and Aikenhead (1999) have argued that the cognitive process of border-crossing can be termed *collateral learning*. They give four examples of collateral learning (seen as points along a continuum):

- parallel,
- simultaneous,
- dependent, and
- secured.

*Parallel collateral* learning occurs when children have a scientific and a commonsense understanding, but will apply the scientific understanding only to the school context, and the commonsense understanding to their home or everyday context. For example, children will talk about the rainbow at home in relation to its cultural significance—that is, the python crossing the river or an elder passing away. In the school context they will discuss the refraction of light producing the rainbow.

*Simultaneous collateral* learning describes the way children can hold in their minds two different ways of explaining a science concept; for example, knowing that electricity is conserved in the battery, but believing that when a battery 'goes flat' the energy is squeezed out—a toothpaste theory of electricity. They hold these views simultaneously within and external to the school context.

At the other end of the continuum—*dependent* and *secured collateral* learning—children do not necessarily have the same levels of cognitive conflict. They have developed ways or justifications for holding onto differing views or, in fact, do not hold opposing views—rather, their thinking is more closely aligned to the accepted scientific perspective.

Cobern (1996), as cited in Jegede and Aikenhead (1999), has termed the segregation of school science content within the child's mind *cognitive apartheid*. (To gain an appreciation for the complexity of switching between world views, see Aikenhead 2000; Jegede & Aikenhead 1999.)

Clearly, then, border-crossing is a treacherous path, as the mindset that must be negotiated to engage in western science is exceedingly different from how many people think, feel and connect with their real world. For many indigenous students, the border-crossing between home-lived experience and school science can be seen as more marked than it is for non-indigenous students. For some students it can be viewed as *cultural violence*. Cultural violence is said to occur when school science is totally at odds with a child's view of the world (family belief system). For example, creationists could experience cultural violence when studying the evolution of humans.

A useful metaphor for thinking about how to help children with border-crossing has been put forward by Jegede and Aikenhead (1999). The teacher as 'culture broker' is viewed as the person who will guide children between their 'life world culture' and the 'culture of science'. The culture of science is the principal site of investigation, and the teacher 'coaches pupils on what to look for and how to use it in their everyday lives outside of school' (1999: 9). Jegede and Aikenhead use the metaphor of *the student as traveller*. In this scenario, the teacher acts as a tour guide. For students who require less assistance with negotiating their travels through to another culture, the teacher will act as a *travel agent*: 'A travel-agent teacher provides incentives for pupils, such as topics, issues, activities, or events that create the need to know the culture of science' (1999: 9).

Whether we act as a tour guide or travel agent, we need to be mindful of the world view that many children have. We also need to appreciate the discontinuities that may exist between children's everyday view of the world and school science (Novak 2005; Fleer & Robbins 2003). When science learning is presented as connected to children's experience, children more easily make the transition between their world view and school science. This results in more harmony and greater dignity. Valuing and respecting the diversity of world views that may arise within a single classroom or centre in a culturally and linguistically diverse Australian community is an important first step in planning for children's learning in science.

## Ways of learning

We have now explored how children think about the things around them. In posing challenging questions to children, we begin to understand that they can have quite sophisticated ideas, as well as many other views that do not easily fit within a western science curriculum. The criteria used by children in making judgments about their world may or may not be particularly helpful when the context is different (e.g. school, family or community). As teachers, we must listen to children so that we understand what they think about the concepts we are considering teaching. However, it is not enough just to find out children's views; we must also think about how we can move children towards scientific understandings so that border-crossing is a sensitive and not a violent experience.

## Summary

This chapter challenges you to explore the ways in which children make sense of their world and how such knowledge might influence your approach to teaching. We now turn our attention to different methods we might use to assist children to develop their scientific ideas. Chapter 3 focuses on planning and assessing for children's learning.

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