Living things and environments

by Russell Tytler, Filocha Haslam and Suzanne Peterson

Introduction

There are many possible ways to study biology, including accessing texts and websites and watching television shows. Numerous newspaper articles assume a knowledge of biology in discussing environmental issues; for example, loss of habitat, endangered species or agricultural and food issues. This chapter takes the view that a powerful way of studying living things is through investigating them in natural or constructed environments. The three sections of the chapter – invertebrates in the schoolground, studying the adaptive behaviour of small animals in the classroom, and plants in the school environment – are therefore bound by this vision. Many schoolgrounds or local parks are functioning ecosystems with a range of animals, plants and animal–plant interactions available for study. Schoolground habitats generally harbour a variety of life forms that students are normally oblivious to. The study of animal behaviour provides the opportunity to look at the adaptive purposes of animal structure and function and to develop knowledge of experimental processes used in biology.

These phenomena provide valuable opportunities for children to investigate three ‘big ideas’ in biological science: the interdependence of organisms in the environment, the adaptive function of structures and behaviour of living things, and the biodiversity, change and continuity that characterise any ecosystem.

This chapter draws on the authors’ experience in using the local environment in research, and in teaching biological concepts to undergraduate teacher education students and to primary school children as part of school-based programs run by Deakin University. The first section on Invertebrates in the schoolground was developed as part of a research project: The Role of Representation in Learning Science (RiLS). The second section on animal behaviour was developed as part of a longitudinal research program and refined in Suzanne’s classroom. The chapter covers a range of aspects of living things, from animals to plants to ecosystems, and research perspectives from the classic 1990s findings about children’s conceptions, as well as more recent work on sociocultural and representational perspectives, and values. The chapter is organised as follows:

- children’s ideas about living things (alive, animals)
- representations and learning about animals – illustrated through a classroom case study
- learning about life cycles, food and energy, and planning and assessing habitat activities
TEACHING PRIMARY SCIENCE CONSTRUCTIVELY

- investigating small animals – illustrated again through a case study and emphasising questioning
- plants in the schoolground, including children’s ideas – there is also a case study of a terrarium and the cycling of matter
- science as a human endeavour – scientists’ ways of working, values and living things, and links to the world of work.

How do children think about living things?

Children’s conception of what it means to be alive

In teaching about life and living in the primary school, the idea of what we mean by a ‘living thing’ is often taken as unproblematic and obvious. However, researchers, in their attempts to investigate what children understand about what it means to be alive, have uncovered a range of interesting conceptions. For instance, Carey (1985) and Stepans (1985) found that movement – action – is the main criterion that children use to determine if an object is alive. Thus, when asked about the various life-cycle stages of a butterfly, they will often indicate that the eggs and immobile pupa are not alive, while agreeing that the caterpillar and butterfly are. In Stepans’ study, for instance, most of the 24 out of 30 Year 5 students who said that lightning is alive gave striking and moving as criteria.

Both researchers found that many children give an affirmative response to the question ‘Is the sun alive?’ This was also the case with Year 5/6 students in the RiLS project (detailed in this chapter). Such animistic conceptions are undoubtedly influenced by everyday, metaphorical use of language that attributes purposeful movement to non-living bodies, such as ‘The sun is hiding behind the clouds’.

Carey further found that children have little trouble in deciding that mobile animals are alive, but experienced greater difficulty deciding that plants, which are markedly less mobile, are also alive. Life is often attributed to plants when they do something that children associate with movement or growth. For instance, they will state that a tree is alive when it is growing fruit. On the other hand, Inagaki and Hatano (1996) found that children as young as five group animals and plants together and differentiate them from non-living things, mainly on the basis of growth and the intake of food or water for maintaining vitality. They claim, therefore, that five-year-old children recognise an integrated category of living things.

We can help children build up a concept of living organisms by asking them to focus on the similarities shared by disparate classes of living things – for example, a gum tree and a yabby – rather than the differences that they can readily identify. This identification of shared similarities is a general strategy for helping develop most inclusive concepts, such as living, animal or plant. Concentration on differences alone, which is often the focus of teaching about the diversity of organisms, tends to produce less-inclusive concepts and leads to more superficial views of the living world.

A class of primary school children’s conceptions of what it means to be alive can be explored using a set of cards representing a range of animals and plants, non-living but moving things such as the sun, fire, lightning and a car, and once-living things such as a plank of wood or a
Activity 7.1 Is it alive?

Build up a set of criteria you would use for deciding whether something is alive in a biological sense. For each criterion, you should decide whether it is a necessary or an optional characteristic. As we have seen, for instance, movement is a criterion that can be misleading, but you might like to consider criteria like ‘breathes’ (or respires) or ‘responds to stimuli’.

When you have developed your criteria, think about how you would respond to a child’s suggestion that fire is alive. How many of your criteria could reasonably be attributed to fire?

Is the question ‘Is it alive?’ the same as ‘Is it a living thing?’ Talk about this with some fellow students and friends. (You might decide there are important distinctions, but the example given below – concerning the freshly picked tomato – shows how fruitful a discussion of what we mean by ‘alive’ can be.)

If you have a chance, talk with some children about their views of what it means to be alive. Give them some instances, such as the sun or fire, to explore the boundaries of their concept.

Activity 7.2 What can flow from a pre-test?

The teachers in the RiLS project targeted their class discussion so that it addressed students’ alternative conceptions, explored via a pre-test. Shown below are the responses of Sean and Naomi, two Year 5 students, to the following question: ‘Which of these do you think is a living thing?’ Write beside each the main reason/s why you think so or not.

<table>
<thead>
<tr>
<th>OBJECT</th>
<th>SEAN’S RESPONSE</th>
<th>NAOMI’S RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth</td>
<td>Living – it moves, grows, lives</td>
<td>Living, because it changes all the time.</td>
</tr>
<tr>
<td>Fire</td>
<td>Non-living – fire moves but doesn’t live</td>
<td>Living – it runs on fuel and it is full of energy</td>
</tr>
<tr>
<td>The sun</td>
<td>Living – like the earth</td>
<td>Living, because it changes all the time</td>
</tr>
<tr>
<td>A virus</td>
<td>Living – a virus eats, moves, grows and dies</td>
<td>Living – it attacks your body</td>
</tr>
<tr>
<td>A daffodil that has just been picked</td>
<td>It still lives but after a while it dies</td>
<td>Living – it drinks</td>
</tr>
</tbody>
</table>

If you had Sean and Naomi in your class, how would you go about helping them to address their views about the concept of living things? Discuss your response with a fellow student or friend.
Discussion arising out of a probe on what it means to be ‘alive’ can expose a range of subtleties concerning the concept ‘alive’. For example, the classroom experience of an intermediate primary grade teacher provides an opportunity to consider your own concept of living. The class investigated the question ‘Is a freshly picked tomato still alive?’ The children could not resolve the question and wrote to experts in universities and agricultural institutions for advice.

**Activity 7.3 Is a freshly picked tomato alive?**

- In terms of your own concept of living, is a freshly picked tomato alive? Discuss this question with some fellow students or friends. You should apply the criteria you developed above to help you decide.
- What are the key questions you asked yourself in deciding this issue? Which criteria are most important?

Using the notion of similarities shared by living things, we might investigate this problem in the following way. Consider the similarities over time between two tomatoes from the same bush, one picked and one left on the bush:

- If both were green at the time of picking, one placed on a sunny shelf would change colour from green to red at a similar pace to the tomato still attached to the bush.
- At different rates, both would eventually show signs of water loss and decay. However, even when mouldy spots appear, the whole tomato tissue would not be rotten.
- Parts of the flesh of the picked and unpicked tomatoes are able to maintain themselves in a condition not dissimilar to that of a young tomato ripening on the bush.

Thus, the observation and recording of the similarities that exist between a picked tomato presumed not alive and the attached tomato presumed to be alive can assist children to explore the different processes that living things undergo.

Such an investigation is unlikely to be totally convincing. Of the 19 experts who responded to the children’s letters, 17 took the view that the picked tomato was not alive. Nevertheless, there is a good case for arguing that the freshly picked tomato is alive because it is able to maintain its biological integrity for a considerable period of time after the picking.

**Activity 7.4 Further thoughts on the tomato and constructivist approaches**

- Consider whether this discussion has altered your view about whether the tomato is alive. Do you agree or disagree with our contention that a freshly picked tomato is alive?
- Refer to the discussions on constructivist views of learning and teaching in Chapter 1. In what ways do you think the exercise above and the discussion of what it means to be alive relate to a constructivist view? What would you hope would be the outcome of such a discussion in a classroom context?
- Think about how this relates to the strategies exemplified in this section. To what extent have these encouraged you to reflect on your own concept of living things? To what extent have your understandings about living organisms been modified?
- Probing children’s prior conceptions is often a matter of finding a productive question or challenge. You might like to review activities in other chapters that perform the same function as the strategy exemplified by the ‘Is it alive?’ exercises.
The children’s responses detailed in Activity 7.2 show that even older children have difficulty with the notion of what it means to be alive. However, children do move considerably towards a biologist’s view of the living world over their primary school years. Carey (1985) suggests that this is due to the accumulation of experience and specific knowledge that all children inevitably gain over these years – knowledge, for instance, that a leopard’s spots help camouflage it, or that all the animals you find on a farm have livers, or that the fish you find in a mountain stream are different to those you find in the sea.

Children’s conception of animals

Young children’s conception of animals tends to be largely restricted to mammals. Bell (1993), in a classic study, investigated which organisms children thought of as animals, and why. She found that, while mammals such as a cow presented little difficulty, whales were more problematic; organisms such as spiders and worms were regarded as animals by between only 20 to 50 per cent of primary school children. In fact, young children aged five to six years are more likely to think of spiders and worms as animals (the biologist’s view) than are children aged nine to 10. This is thought to be because, as they gain knowledge of biological groups such as reptiles and insects and various types of worm, they lose the inclusive animal concept. This is another example of the difficulty associated with focusing on difference rather than similarity. Perhaps it also means that a little knowledge is a dangerous thing. Bell also found that there was an increasing preparedness over the primary school years (from 20 to 57 per cent) to regard humans as a class of animal. Yen, Yao and Mintzes (2007) found that Taiwanese students have similar patterns of difficulty in achieving a scientific conception of ‘animal’, linking the term mainly with vertebrates, and where they make distinctions it is mainly on the basis of external appearance, habitat and movement.

Does having a different conception of animals to that of scientists matter, in practical terms? Bell and Freyberg (1985) show that a class that was explicitly taught the concept of an ‘animal’ before a teaching sequence on consumers and producers did much better than a class without this prior teaching. They argue that the results clearly show that, if we can get the simple underlying words understood, then sound learning can occur. In this instance, the problem seems to be not with the more complex term consumer, but with the simpler, more common ones such as animal and living (ibid., p. 39).

Does having informal experience with living things make a difference to children’s conceptions? Prokop, Prokop and Tunnicliffe (2008) found that children with pets had a better understanding of their internal organs, especially if they kept two or more, but keeping pets made no difference to their misclassification of invertebrates. They therefore advocate a greater focus in science activities on rearing invertebrates and improving children’s attitudes towards and knowledge of them. Prokop and Tunnicliffe (2008) were interested in attitudes to animals as a key outcome of environmental education. They found that pet owners had more positive attitudes towards wild animals but negative attitudes towards less popular animals such as insects, spiders and rats, compared to non-pet-owners. They also found a correlation between attitudes and alternative conceptions, in that more alternative conceptions were associated with more negative attitudes.

Myers, Saunders, and Garrett (2004), in a study of children’s developmental understandings of the needs of animals, found that even four- to five-year-old children recognised animals’
basic physiological needs, but that their ecological and conservation needs showed strong but
different developmental trends. They argue that we should not underestimate even young
children’s ability to understand the ecology surrounding animals (their habitats, interactions
with other living things), and that drawing connections with animals children experience in
their own lives can be a powerful strategy for building a conservation ethic. With a similar
environmental focus, Lindemann-Matthies (2005) reported on a Swiss program, Nature on the
Way to School, which supported teachers in using their local environment, including children’s
walk to school, to identify and study local animals and plants. The highlight of the program was
a ‘Nature Gallery’ where students framed a plant that they especially valued. Lindemann-
Matthies found that the more wild plants and animals children noticed in their local
environment and could name, the more they appreciated them.

The key message that comes from these studies is that children’s familiarity with and
experience of animals and plants in natural settings is critically important for their conceptual
learning and also their growth in positive attitudes. Knowledge and values, it seems, go hand
in hand. In this chapter we will explore ways of studying animals and plants that are
consistent with these messages.

Representations and learning about
animals

The following case study is of a Year 5/6 sequence on animals in the school environment
which included a rich range of teacher- and student-generated representations, investigative
activities and discussion. It exemplifies what an explicit representational approach entails and
the role of representations in:
1 supporting learning and reasoning in science
2 framing and developing science explorations.

Research findings from a study of this sequence are reported in Tytler et al. (2009). As a
comparison sequence, the Primary Connections unit ‘Schoolyard Safari’ (see www.science.org.au/
primaryconnections/curriculum-resources/schoolyard-safari.html) includes studies of individual
animals (snails, worms, ants) as well as exploration of habitats, and also has a literacy focus.

CASE STUDY

Invertebrates in the schoolground: a teaching and
learning sequence that explicitly uses inquiry with a
representational approach

The case study reported here aimed to investigate
the relationship between representation and learning in the
context of an inquiry-based unit on animals in the
schoolground at primary school level. The research
team worked with two primary teachers, experienced in
Years 5/6, to develop a teaching sequence 'Invertebrates
in the schoolground’. The teachers combined their classes and co-taught the unit, which focused explicitly on representations to promote students’ understandings of key concepts related to animals in the school environment.

Schoolgrounds provide an ideal environment where animals can be studied closely over a period of time – life-cycle changes, the interrelationships between animals and details of structure and behaviour are more accessible for observation. When investigating the schoolground, it is important to focus much of our observation on the similarities shared by all animal life. Children need to investigate a wide range of features that various animals exhibit so that these similarities become more obvious. The chance observation of a beetle might lead to a range of questions and observations.

A body of recent Australian research on the use of representations in learning science (Hubber, Tytler and Haslam 2010; Carolan, Prain and Waldrip 2008; Tytler et al. 2009; Tytler, Prain and Peterson 2007; also see Chapter 1) has identified various key principles to guide the effective planning, implementation, and evaluation of student learning. Consistent with an effective focus on conceptual learning in science generally, the teacher needs to be clear at the topic’s planning stage about the key concepts or big ideas it’s intended that students learn. This conceptual focus provides the basis for the teacher to consider which sequence and range of representations, including both teacher- and student-generated ones, will engage learners, develop understanding, and count as evidence of learning at the topic’s end. These principles are based on previous research (Cox 1999; Greeno and Hall 1997) that argues the need to have students generate non-standard representations in reasoning and solving problems.

Teaching sequence: key characteristics of lessons and student activities

The teaching sequence ‘Invertebrates in the schoolground’ was designed according to the following representational principles. The various sessions of the sequence were flexible, and specifically designed to provide a rich range of student-generated representations aimed at introducing students to the ideas and methods of field biology, including sampling and mapping techniques. They were also designed to help develop in students the concepts of ecosystem, habitat, diversity of animal populations, interactions between plants and animals in an ecosystem, animal structure and function, and the adaptive purposes of animal behaviour.

The key characteristics of the sequence were:

- a focus on the methods used in science to study animals
- an inquiry approach – students asking questions, exploring and investigating
- explicit focus on representations
- students generating their own representations and using multimodal representations.

Each session consisted of between 45 and 90 minutes of class time. An overview of the sequence is presented in Table 7.1, with brief notes on the teacher actions, purpose of each session and student activities.

### TABLE 7.1 The invertebrates in the schoolground activity sequence

<table>
<thead>
<tr>
<th>TEACHER ACTIONS</th>
<th>STUDENT ACTIVITIES</th>
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<tbody>
<tr>
<td>1 Administration of a pre-test – teachers identified students’ existing ideas about living things, the way scientists work in exploring environments, and the relationship between the structure and function of small invertebrates. Class discussion to unpack students’ alternative views and explanation of the ways in which scientists collect and represent evidence when studying a terrestrial habitat.</td>
<td>Students completed the pre-test, debated the characteristics of living things, and worked on computers to construct interactive questionnaires about the attributes of ‘living things’. They discussed what it would be like to work as a team of scientists finding out what living things exist in their schoolgrounds, and why.</td>
</tr>
<tr>
<td>TEACHER ACTIONS</td>
<td>STUDENT ACTIVITIES</td>
</tr>
<tr>
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<tr>
<td><strong>2</strong> Introduction to the schoolground – teachers identified different habitats in the schoolgrounds and allocated them to groups of students: G1 – The school pond; G2 – The compost heap; G3 – Under the gum tree ...</td>
<td>Students predicted what they might find in their habitat. They then visited the habitat to document it in their workbooks. They reported their observations back to the class and discussed inferences as to what they think happens in the habitats.</td>
</tr>
</tbody>
</table>
| **3** Methods for habitat studies – discussion about sampling, distributions and the need for developing and representing quantitative data. Emphasis on: the inquiry approach and the use of multimodal representations – what to document and how, and the need to use appropriate representations (e.g., graphs) to represent populations. | Students conducted habitat explorations with a view to complete a poster to present responses to:  
- what is in the habitat  
- what exactly happens in the habitat, or what life is like for the invertebrates living there  
- how the various living things in this particular habitat interact with and depend on each other. |
| **4** Research questions – teachers helped the class generate questions for group investigations, based on questions generated by individual students according to their intrinsic interests. | Students further explored habitats to answer research questions. They recorded environmental conditions, noted the number of each invertebrate found, and drew and annotated drawings to describe body structures and behaviours. |
| **5** Animal diversity, classification and safety issues were discussed – teachers detailed the use of branching keys, Venn diagrams and drawings focusing on similarities between the distinguishing characteristics of invertebrates: jointed bodies, number of legs, presence of wings and so on. | Students captured selected invertebrates, observed them and recorded body structures using annotated drawings and digital photographs. They used digital microscopes and the Internet to identify and classify them. They then released the invertebrates where they had been found. |
| **6** The difference between observation and inference was established – student-generated representations were used to discuss form and function of representations to generate meaning: What does this graph represent? What doesn’t it represent? | Students developed and presented posters giving an account of living things found in their habitat and discussed their preliminary ideas of how the animals and plants might interact. They then exhibited their posters around the classroom. |
| **7** Ways of observing and describing body structures of invertebrates using different modes of representation were discussed (see the Chapter 1 section ’Representational and related strategies’ on p. 31). | Students conducted group-generated activities using mealworms and stick insects to establish ways of describing body structures, movement and feeding, and for testing behaviour, and they used Venn diagrams to note similarities and differences. |
| **8** Discussion about concepts of biological evolution – how biological evolution accounts for the diversity of species, how it is developed over many generations, and how adaptations include changes in structures, behaviours and physiology that enhance survival. | Students collected one invertebrate and observed it with a view to constructing a model that would represent the movement or feeding of that invertebrate. They used digital microscopes, made annotated drawings and time-sequence drawings, and described how the body structures and behaviours of the invertebrate are adaptive to the habitat. |
| **9** 3-D modelling to represent movement of invertebrates – teachers dedicated two sessions to encourage students’ creativity in constructing a model that would specifically represent the movement of invertebrates. | Students used scrap materials, building blocks, modelling clay and plastic straws to build a 3-D model of the invertebrate that they then used to represent as accurately as possible how it moves or feeds. |

Post-test – To explore student knowledge about concepts related to animals in the environment, the nature of science and science investigation.
The following sections discuss a range of ways in which representations are key elements in children’s development of science understandings and investigative approaches and skills. These interactions will be discussed by drawing on the experience from research on the sequence described in the ‘Invertebrates in the schoolground’ case study, as shown in Table 7.1.

**Activity 7.5 Prior knowledge about invertebrates in the schoolground**

Before considering questions concerning invertebrates in the schoolground, it would be a useful exercise to examine your own expectations of what sort of animals one might find in a schoolground or local park environment.

- Think about your own experience of schoolgrounds and construct a list of animals and plants you might expect to find there. Compare your list with that of a fellow student or friend.
- Can you arrive at a list you would agree on? For each animal listed, think about where exactly you might find it. Why do you think that?

**Building science concepts through representational challenges**

Habitat-exploration activities (see Table 7.1 on p. 268) are designed to enable students to understand the concept of habitat: the place where the animal lives and that contains everything it needs to survive: water, food, shelter and suitable conditions for reproduction. Students need to understand the concept of animal adaptation as linked to the imperative of the species’ survival. Hence, teachers need to explicitly ask students to observe and note down the characteristics of animals that are found in the environment under investigation. Scientific observation is an important capability (Haslam 1998; Haslam and Gunstone 1998) and students need support to focus on and record the structures, functions and behaviours that enable animals to interact with:

1. the physical features of the particular habitat, such as shelter, moisture and temperature
2. plants within the habitat, for shelter, feeding and as a source of food for their prey
3. other animals within the environment, such as predator–prey relations and mutualism.

These three issues form the focus for student representations for the sequence in the ‘Invertebrates in the schoolground’ case study (see p. 267).

The representational activities involve students in acting as scientists in observing, reasoning and communicating ideas. Table 7.2 shows how each of a number of research questions involved students in active representational work in pursuing answers.

It is important to teach children how to sample and draw up representations using tables, graphs, diagrams and cross-sections. In session 4 of the sequence outlined in Table 7.1 (see p. 268), the teacher focused strongly on the representations students might use to study the invertebrates living in their assigned habitat.

**Teacher**

What sorts of things you might want to record? Temperature, what was the weather like, humidity. ... Can we find out at what depth these creatures are living? Whether they interact with each other? Are there any predators? What else?
This discussion was aimed at helping students understand that each animal lives in a particular ecological niche, which not only involves interdependence with other living things but also dependence on non-biotic factors.

**Using student-generated questions**

The framing of a teaching sequence based on children’s investigation of their own questions is the essence of the interactive approach (see, for example, chapters 1 and 4). The schoolground offers an ideal basis for such an approach since there are many questions to raise and investigations to carry out in the immediate school environment.

Some of the questions generated by a group of Year 5/6 students, following the pre-test and discussion, and after a preliminary visit to their allocated habitats, included: What is the population of beetles in this area? What [if any] are this beetle’s unique features? Why is it...
living in this environment? What are the sources of nutrition for this beetle? Are there signs of damage to the environment and what impact has it had/will it have on the environment? Is this beetle endangered?

The schoolground can provide immediate access to a rich range of experiences. Investigations of animals and plants will encourage the development of science processes, such as scientific observation, measurement and experimentation, alongside the growth of conceptual understandings about animal and plant structure and function, and their interactions within a schoolground community.

This is also an opportunity for teachers to develop, in students, a conservation ethic with respect to the animals and plants in their surroundings. The understanding of ecological concepts about living things in the immediate environment, in this case the schoolground, can thus contribute to our own survival on this planet.

Within the general framework of study of various habitats in the schoolground, many opportunities will arise for you as a teacher to support children in their observations and investigations by providing suggestions about what they might look for, how they might better focus their questions, or how they might set up an investigation, as well as creating opportunities to challenge and extend their ideas. There is quite a lot of suitable, locally produced reference material, on the Internet and in books and DVDs/videos, that can be used to provide children with background knowledge to orient them to a schoolground study, or to use in exploring their questions and raising more questions.

The role of representations in reasoning and learning

Science, more than most disciplines, is communicated through multimodal means. Researchers in classroom studies where students were guided to construct their own representations of scientific ideas (Carolan, Prain and Waldrip 2008; diSessa 2004; Greeno and Hall 1997; Hackling and Prain 2005; Tytler, Peterson and Prain 2006; also see Chapter 1) claimed that students benefited from multiple opportunities to explore, engage, elaborate and re-represent ongoing understandings in the same and different representations, and noted the importance of teacher and student negotiation of the meanings evident in representations in these multiple modes, which include:

- textual – might be written but also spoken
- visual – diagrams, 3-D models, animations and simulations, photographs
- mathematical – formulae, graphs and tables
- gestural or embodied – gestures, role-plays.

Achieving an understanding in science involves being able to coordinate these representational modes and re-representing information appropriately to construct an explanation.

Activity 7.7 Representing diversity in a chosen quadrat

- Work with a partner to select and explore a habitat of your choice, and complete a PowerPoint presentation using at least five different representations that document your observations about:
  - the invertebrates found: slaters, worms, spiders or whatever you can discover (compost heaps, damp soil covered with rotting leaves and twigs, and oil from...
Greeno and Hall (1997) argued that different forms of representation supported contrasting understanding of topics, and that students needed to explore the advantages and limitations of particular representations. Students need to know the function and form of the representations they use. Note the difference in the representations made by a Year 5 student (see Figure 7.1) in response to the same question in a pre-test and post-test: ‘Use the most appropriate representation to show that ten ants are eaten by an echidna on the 14th of May, seven are eaten on the 15th of May and two are eaten on the 16th of May’.

Cox (1999) noted that representations can be used as tools for many different forms of reasoning, such as for initial, speculative thinking, as in constructing a diagram or model to imagine how a process might work, or to find a possible explanation, or see if a verbal explanation makes sense when re-represented in 2-D or 3-D. Students need to learn how to select appropriate representations to address particular needs, and be able to judge their effectiveness in achieving particular purposes.

**Activity 7.8 Advantages and limitations of representations**

Refer to your PowerPoint presentation (see Activity 7.7 on p. 273). For each of the representations in the presentation, such as a graph, a diagram and so on, ask yourself the question: What does this representation show? What doesn’t it show? Then complete a table to document the effectiveness and limitations of each of the representations you presented.
Representation tasks supporting purposeful observation

In the RiLS study, teachers built on one student-generated question, ‘Why do they move the way they do?’, to challenge the entire cohort to conduct scientific observations; that is, to observe with a specific purpose in order to understand the movement of a chosen invertebrate. At this stage, the teachers’ intention was to give students practice in observing and representing just one aspect of animal behaviour – that of the movement of the invertebrate.

**Teacher** Now, spend a couple of more minutes observing it move. Make it move. Observe its legs. Is there a pattern in the way it moves? See if you can show it to us in a diagram. [pauses, repeats] Is there a pattern to the way it moves?

In the RiLS study, students worked in pairs to select an invertebrate of their choice and recorded their scientific observation using representations such as drawings, annotations, scales and keys, with the sole purpose of completing a 3-D model to explain the invertebrate’s movement. The class had access to magnifiers and digital microscopes. Most students included details of the invertebrate’s body parts related to movement, as shown in Figure 7.2 and 7.3.

**FIGURE 7.2** Student notebook sketches
The representations of Melanie (Year 5) show clear evidence of observation of the spider made with the intention to record movement. In Figure 7.2, the sketch on the left has numbered lines accompanied by small arrows pointing forward. The intention here is to show the direction of movement only, whereas the place of the attachment of the spider’s legs is shown in the sketch on the right. Following is an excerpt from the class presentation Melanie did with Karen, who worked with her:

Karen: We did a brown spider and it has four legs on each side.
Melanie: And we noticed that the legs were actually, were attached to the first part.
Karen: More attached to the smaller part of the body.
Melanie: The head part [raises her arms upwards, touches them to her ears, close to her torso] like this [points to her own abdomen] not down here [quickly moves her hand to the larger piece of wood that represents the spider’s abdomen].
Karen: [picking up the pipe cleaners that represent the second set of legs as represented in Figure 7.2] These two move first, then that one [picks up the first set] then that one [moves the third set] and then that [moves fourth set].

Representations in science classrooms can serve many different purposes. In the sequence above, Melanie and Karen were engaged in close observation of their spider, and focused on making sense of its leg movements and the nature of the leg attachments. In other examples, children used elastic bands to reason about the sequential stretching and contracting, thinning and thickening of a worm as it moved, while another group modelled and demonstrated with gestures the undulating movement of the segmented body and legs of a centipede.

**Activity 7.9 Representing and re-representing for a better understanding**

- Select an invertebrate of your choice from the habitat that you explored in Activity 7.7 (see p. 273). Capture the invertebrate in a container. Conduct purposeful observations and write a paragraph to represent either how it moves or how it feeds.
- Draw it in as much detail as possible. If you have access to a magnifier, use that for fine detail. Draw with the intention to use the drawing/s or a sequence of drawings to help you to build a model that will...
Data from the RiLS study showed that in an active classroom environment where students have agency in exploring and interpreting phenomena, the representations of science (graphs, tables, drawings, reports, photographs and models) serve as reasoning tools, central to the process of coordinating ideas and evidence in scientific explorations, and to knowledge generation and learning.

**Activity 7.10 Learning from a representational task**

- How did Activity 7.9 help you to focus your observation of the invertebrate?
- In what ways did the model serve as a tool to provide you with a better understanding of how the invertebrate moves/feeds? What specific concepts do you think you have better understood?
- Think about what you knew about the structure and lifestyle of this invertebrate before you started the drawing and subsequently built the 3-D model. Compare that knowledge with what you know now after building and presenting the model to a fellow student or friend. How has your knowledge of the invertebrate changed?
- You may find that your increased knowledge is not confined to factual information about the invertebrate's structure. Did you find yourself asking questions and drawing inferences about the use and purpose of some of the features of the invertebrate? To be able to do this is a valuable investigative skill.

Representing animal diversity

In the case study discussed above, the use of tables and graphs were central to the task of conceptualising the distribution of animals in an environment; the coordination of annotations and sketches was essential for building a picture of the variation in environments, and their different elements, Internet images and classification keys were essential for building a picture of the diversity of animals and their commonalities and differences; and the various tasks of sketching posters and modelling focused attention on and supported the development of the exploration of animal behaviour. At each stage in the generation of ideas there was the active production and refinement of representations and the coordination of these into a coherent communication.

Tytler et al. (2009) noted that the understanding of the Year 5/6 students of the diversity of invertebrates, through quadrat sampling, involved the generation of tallies of invertebrates, annotated drawings, bar graphs, formal naming systems identified on the Internet, Internet search protocols and Venn diagrams. They argue that each of these
FIGURE 7.4 Representations of invertebrate diversity in a habitat

representations was part of their experience of the entire concept, and that this concept cannot be thought of as separate from these representations. This view of understanding of a concept, as the capacity to coordinate a range of representations to respond to a question or problem, is very different from the traditional view of a concept as something that can be verbally defined.
Simon is in Year 5 and worked in a group of four to observe the habitat ‘Next to frog pond’ as part of the RiLS case study sequence. Figure 7.4 shows four consecutive pages of Simon’s notebook, in which he represents a variety of aspects of his exploration of the invertebrates in that habitat: their distribution, number, different characteristics, and details of their structures and size.

**Activity 7.11 Multiple representations of diversity**

This activity addresses two aspects of the role of representation in learning. Firstly, each representation of a phenomenon will be selective in drawing out a specific aspect, and will ignore other aspects. Secondly, a concept is built from a range of representations, each selective in its focus.

- Look at Simon’s drawings in Figure 7.4.
- In what ways do the representations on each page demonstrate Simon’s growing conception of animal diversity?
- For each representation, identify:
  - the specific aspect(s) of diversity it shows
  - the aspects of diversity it does not show.
  (For example, referring to the spider drawings of Figure 7.2 (see p. 257), these show the number of legs of the spider and the sequence of movement, some detail of the structure of the legs, and, broadly, their attachment arrangements. They do not show body structures such as jointing and cover in any detail. They are selective in their focus on legs and movement.)
- Referring to Simon’s drawings, discuss the claim of Tytler et al. (2010) above, that understanding a concept should be thought of as the capacity to coordinate a range of representations.
  - What is the evidence for Simon understanding ‘diversity’?
  - Are there other important aspects of diversity not covered in his notes?

**Helping children to classify: pictorial identification keys**

Schoolground studies provide children with opportunities to closely observe a variety of animals, grouping them according to shared, observed similarities. Children could group together all those animals that have in common the presence of jointed appendages. They could then subdivide these into smaller groups using the number of appendages as the criterion. Such groupings provide accurate information for the construction of new names for the various animals. This information also assists children in approaching the Internet and books for identification purposes.

Classification maintains a prominent position in school science curricula, yet students find it difficult. The formal classification scheme in biology is based around similarities and differences. In classroom investigations, children are more often directed to emphasise specific concepts based on differences (e.g., colour, size, speed of movement) rather than the more inclusive concepts based on similarities (e.g., presence of a backbone, feathers, life-cycle stages). Schoolground invertebrate studies allow children to modify such personalised classification systems by grouping animals according to shared similarities, before consulting resources for confirmation of their reasoning.
Pictorial keys of invertebrates may be found in a number of books and on websites, and can be very useful in helping children identify animals. However, they do have a number of problems, described below. An activity that circumvents these problems and provides a common purpose for studying the range of animals in the schoolground is the production of a pictorial identification key.

Designers of pictorial keys tend to make many assumptions about the skills and understanding users have when using their keys. For example, animals depicted in pond keys are very often not drawn to scale and the enlargement or reduction is indicated by the use of a cryptic symbol, such as ‘(3)’, indicating that the representation is three times the size of the real animal, or by a bar labelled ‘1 mm’, showing the size of the animal relative to a millimetre. Yet scale is a sophisticated concept that many primary school children will have difficulty with, and will need to be explicitly supported. At the other extreme, in many pictorial keys published for primary school children, the details of the scale are omitted entirely, which creates a number of difficulties. Children cannot use the drawn animal as a means of identification unless its actual size is understood. The production of classroom keys gives a real purpose to accurate observation and recording. It leads to a shared resource that can be used and refined over the whole term of a schoolground habitat investigation.

**Activity 7.12 Pictorial keys for assessment**

- Think about a strategy for using a combination of published and class-produced keys. For instance, you might consider ways in which children could take a published key and modify it for their purposes or successively refine the classroom key. How could that be encouraged and managed? You might think of ways in which a class-produced key could be developed for display, but with published material being available to support more detailed investigations.
- Discuss how you could use the class-produced key for assessment purposes.
- Thinking about formative assessment in particular, how could you use such a key to ascertain the level of children’s understandings or their observation skills? How could you use the key as a trigger for discussions about behaviour of the animals?

**The nature and purpose of biological drawings**

Scientific drawings represent a discrete genre of science discourse that has a long and important history, within biological science in particular. Children’s drawings can be a powerful means of expressing their understandings. Biological drawings can also be used to develop children’s observation skills as well as their conceptual understandings by requiring the paying of close attention to the characteristics of organisms (Hayes, Symington and Martin 1994). Children’s drawings of live animals display a degree of accuracy and detail that often surprises adults.

Biological drawings are intended to represent a selective and accurate description of details of organisms and their behaviour. In the RiLS animal study, we found that when large activity books with blank pages are provided to students, they tend to use the entire page,
which advantages their drawing of detail and the inclusion of multiple perspectives. Examples of strategies that could assist students in developing their drawing skills are:

- the measurement of the animal or plant so as to preserve in the drawing the length–width relationship
- the control of scale – the application of a common multiple (e.g., 3) to their measurements
- the use of vertical and horizontal axes to assist plotting of such measurements
- the use of geometric shapes to help them draw body structures
- the need to count, as with the number of appendages, body parts and so on
- the use of a black fine-pointed pencil rather than crayons or softer coloured pencils
- the use of multiple drawings to represent an animal (e.g., front view, side view, detail)
- the use of a sequence of drawings to represent motion or feeding
- the use of annotations to convey information difficult to present in a drawing.

The drawings made by children in the RiLS study exhibit some of these features. An examination of Melanie’s and Karen’s (see Figure 7.2 on p. 257) and Simon’s (see Figure 7.4 on p. 261) drawings shows the use of scale, geometric shapes, the counting of appendages, concise pencil use, multiple perspectives, and annotations.

Representations and assessment

Children’s sketches and other representations (annotations, sequence diagrams, graphs, scales) can be used as an assessment tool. The detail in the representations – what the children notice, how they choose to represent different features of the animal – can all be used as indicators of children’s conceptual understandings as well as their ability to observe and represent. Annotations in particular, if they refer to the function of body parts in contributing to the animal’s lifestyle and survival, can provide valuable insights into children’s thinking and understanding. Such assessment can be used in a formative sense at the beginning of or during a unit to help plan strategies for challenging and developing every student’s understandings.

Teachers could use a variety of art activities to support and assess science understandings in the primary school. McGrath and Ingham (1992) explored this notion using various activities involving painting, drawing, modelling and collage. They describe, for instance, the use of 2-D moveable models of different birds using lever systems to explore variations between species. This idea could be readily adapted to explorations of animals in the schoolground. Danish and Enyedy (2007) explored the way kindergarten and Year 1 students’ creation of models of pollination supported their learning, and the importance of teacher scaffolding and the negotiation of meaning associated with their models.

Activity 7.13 The use of representations for assessment

- Discuss with a classmate how you could use the representations from Figure 7.4 (see p. 278) for assessment purposes. Thinking about formative assessment in particular, how could you use it to ascertain Simon’s level of understanding or his observation skills?
- How could you use the images of animals for discussions about the behaviour of invertebrates in their quadrat?
Learning about life cycles, adaptation and ecology

Life cycles commonly observed in classrooms include those of silkworms, mealworms, snails, butterflies, crickets and stick insects, all of which can be purchased over the Internet. The discussion here applies to all these animals. In studying any of their life cycles, it is important to look beyond a simple description of the life cycle to its adaptive functions.

Activity 7.14 Life cycles and adaptation

- Consider these questions:
  - Why do cicadas emerge all at the one time?
  - When do they emerge in your area?
  - What factors influence the number of eggs a cicada produces?

- Why can you find exoskeletons of cicadas in grassy areas?

- Construct a set of possible answers and discuss them with some colleagues.

There are many questions that teachers might ask to probe the concept of life cycles. As biologists, we answer questions about life cycles in terms of their adaptive advantages for the organism in its environment. This would include the reproductive advantage of cicadas/grasshoppers/crickets/dragonflies that reach sexual maturity together to maximise mating opportunities, and when there is an abundance of food and mating occurring at an advantageous time for egg deposition.

The easily observed cricket is a well-known noisy insect, well adapted to the schoolground environment, and adept at feeding, seeking a mate and laying eggs to ensure the arrival of the next generation. Crickets are an excellent example with which to teach incomplete metamorphosis. The nymph is similar to adults, without fully developed wings. Crickets grow in length each time they moult. The female cricket can be identified by the presence of a long tube-like structure called the ‘ovipositor’. However, the adaptive features of life cycles are poorly understood and inadequately represented in classical life-cycle drawings such as that which appears in Figure 7.5. The representations in Figure 7.5 do not address the concepts of competition, predation, death, sexual reproduction and natural selection.

For these concepts to be well understood, life-cycle studies and models need to focus on a number of crickets rather than the traditional single animal. Life-cycle understandings central to their adaptive purpose would include the need for two adults to produce eggs, the different life histories of males and females, the proportion of eggs that result in a mature adult (not succumbing to disease, accident or predation) and the need for all stages of a life cycle to be well adapted. Part of the understanding of the adaptive purpose of metamorphosis is to broaden the ecological habitat and niche by reducing competition for space and food between the adult and offspring, thus enhancing the survival rate of the offspring.
Children’s ideas and learning about insect life cycles and adaptation

Children over the primary school years develop a sharper conception of insects (Shepardson 2002). Young children will classify spiders, worms and slaters as insects, but through to age 11 they increasingly learn to differentiate, although there is a lingering tendency to classify arthropods, particularly spiders, as insects. Part of young children’s conception of insects is related to size and shape. They tend to emphasise the negative features of insects, such as biting or stinging, and do not recognise insect roles in, for instance, pollination, scavenging litter, providing a food source for other animals (birds, reptiles) and making products for human consumption (honey, wax, silk). After conducting a study of children’s developing conceptions,
Shepardson recommended that children should be provided with the opportunity to observe a variety of insects and non-insects, explore insects in their natural settings as well as a variety of different insect life cycles, study a variety of insect survival mechanisms (adaptation) such as colouration, odour, mimicry and behaviour, and study the social nature of insects.

In a prior study on insect life cycles, Shepardson (1997) studied a class of Year 1 children during a teaching unit in which they kept a journal as they studied a variety of insects. Initially, the children tended to have one-, two- and mostly three-stage models of insect life cycles (ignoring the egg stage), but over the course of the unit they developed more scientific views of some insect cycles. However, their everyday experience of and ways of thinking about insects and the way the language associated with the new knowledge (pupa, chrysalis, nymph) interacted with this experience acted as a constraint to adopting a more general model of metamorphosis. Shepardson recommends the study of a number of insect life cycles, including some with fewer stages (for example, crickets and silverfish), the studying of some insects in their natural habitats, and an emphasis on the adaptive purposes of life cycles.

Children’s ideas about adaptation of organisms

Young children have difficulty in seeing the features of organisms in terms of their adaptive advantages. Carey (1985) argues that young children interpret animal structures and behaviour in terms of wishes or wants in the same way as they think of humans as deciding what to do. This is related to the common finding that children commonly hold anthropomorphic views of animals (or of inanimate objects such as trains or the sun), a circumstance no doubt encouraged by children’s storybooks. Through the primary school years, they gradually learn to interpret structures or behaviour in terms of the functional needs of organisms. Thus, the change in young Annaliese’s thinking over four weeks, from ‘that one has three things jutting out of its bottom … and the other one, he has only two’ to understanding the role of the ovipositor of the female cricket – ‘the one in the middle is to lay its eggs’ – represents a major shift in her view of animal structure and behaviour.

Naive views about adaptive purposes, however, can be very persistent, as Symington and White (1983) found in studying children’s responses to the question ‘Why do trees have bark?’ Few children thought of the reason in terms of the trees’ needs. The equivalent question, ‘Why do plants have flowers?’, was explored with students in two age groups. Their responses are reported in the plant section of this chapter (see Table 7.4 on p. 307).

Clough and Wood-Robinson (1985) refer to a confusion that exists, even for university students, between several different meanings of the word ‘adaptation’. It can refer to immediate physiological changes in an individual (e.g., sun-tanning) to the characteristics of an organism that fit it for particular environments (e.g., a yabby’s powerful tail), and also the process by which a population is modified towards greater fitness for its environment. This last meaning refers to the evolutionary process or natural selection, but primary school students tend to describe adaptation in the second sense, as a feature that develops in response to environmental conditions. Focusing on this sense of the meaning of adaptation makes sense in a study of animals in the schoolgrounds. This would include studying the function of the various features of the different animals in terms of the way they confer a selective advantage on individual species. It would also include focusing on the adaptive features of the life cycle of animals.
One of the difficulties in discussing adaptation with primary school children concerns their restricted sense of time. The study of animals in the schoolground over a period of weeks can give some sense of the flux in populations as they interact, or in changes of form as animals go through their life cycles. Studying the continuity of the schoolground ecosystem over the school year can give a sense of adaptations related to the seasonal cycle. Knowledge of these seasonal cycles is important for Aboriginal hunter–gatherer communities, enabling them to utilise resources, on an annual basis, over the span of a human lifetime.

**Food and energy relationships within the schoolground**

Children almost invariably come to schoolground study with simplistic views about the networks of food and energy relationships between organisms. Leach et al. (1996b) found that children aged between five and 11 tended to talk about predator or prey relationships as existing between one predator and one prey organism. They also found that children experience difficulty in interpreting food chains in which the energy exchange relationship is depicted by arrows (see Figure 7.6). Arrows are used to indicate many everyday concepts, and thus confusion may arise when they are used to indicate a specific relationship, such as that between predator and prey.

When teaching about food chains, we need to explain that there is a flow of energy from the sun through one organism to another and that some energy is always lost at each trophic level – ‘trophic level’ is the ecological term used to describe the position of organisms along a food chain. In a food chain, the pathway of energy begins with the sun and is one-way, whereas matter is recycled.

Children in the middle primary school years, in talking about the effect of introduced species such as cane toads, which usually feed on insects, think of their impact in terms of direct effects on local species (such as the cane toad eating crickets), rather than indirect effects such as competition for food or depletion of the environment. The notion of a food web, describing multiple energy pathways within an ecosystem (see Figure 7.7), is a much more difficult concept than a food chain, in which only one energy pathway is depicted.

Sometimes not all possible connections are shown in food webs drawn in books or those you find on the Internet, so as to not make the diagrams too complex. This creates an opportunity for you to ask students about all the possible connections.

The schoolground provides the opportunity for children to gauge the answers to a range of questions concerning nutrient relationships, particularly through the use of an interactive teaching approach. Access to animals and plants in schoolgrounds means that children are able to establish and selectively observe ecosystems to answer questions such as ‘What will happen to a population of herbivores if we put them in with plants but without any carnivores?’ or ‘What happens in a system if the very small animals become depleted?’.

**FIGURE 7.6** The flow of energy along a food chain
**TEACHING PRIMARY SCIENCE CONSTRUCTIVELY**

![A forest food web](image)

**FIGURE 7.7 A forest food web**

**Activity 7.16 Constructing a food web**

- Locate a food web diagram in a textbook or on the Internet. Use this as an example to construct a food web for the schoolground or park habitat you studied. This exercise is best done by pooling the knowledge of all your colleagues.
- Having constructed the food web, use it to generate a number of hypotheses about the effect of selected interruptions on the ecosystem. Use the form of question ‘What would happen if …?’ (all the tea trees were burnt, all the leaf hoppers were removed, the population of caterpillars was quadrupled and so on).
- Do you have any evidence to support your hypotheses?
The energy relationships within the schoolground between the different levels of producers and lower- and higher-order consumers is sometimes represented by a pyramid in which the numbers of the higher carnivores (for example, the kookaburras in the food chain example in Figure 7.6; see p. 286) are less than those of the lower carnivores, with the producers (grass, in this case) being present in the greatest amount. Figure 7.8 illustrates such a pyramid. The pyramid emphasises the relatively small numbers of higher-order carnivores in any ecosystem compared to the comparatively large numbers of herbivores. It takes many grasshoppers, for instance, to feed one kookaburra, and a number of kookaburras to feed one powerful owl (What would happen if the number of owls became equal to the number of kookaburras?). The reason has not only to do with the relative size of the animals, but also with the fact that a continual source of energy is needed by, for instance, the kookaburra to respire, keep its organs functioning and to move. At every stage up through the trophic levels, energy is lost to the system as heat, associated with animals’ energy use in keeping alive. This implies that a large number of organisms is needed at each level to maintain a much smaller number of organisms at the level above. The pyramid is a natural consequence of the way energy flows through an ecosystem.

FIGURE 7.8 Food pyramid for a schoolground
The concept of energy has been discussed at length in Chapter 5. In the case of animals in an ecosystem, the main energy transformation involves chemical energy (stored in organisms as chemicals such as starches, fats and protein) being transformed, through the chemical reactions between food and oxygen that constitute the process of respiration to heat energy (involved in maintaining body temperature) and movement. Some of the energy is stored as chemical energy, with a corresponding increase in body mass, but most is lost to the atmosphere as heat through radiation or convection. It is important to remember, in this context, that food itself is not energy, but is the source of energy associated with changes in the ecosystem. The energy in an ecosystem derives ultimately from the sun’s radiant energy, which is transformed by plants into chemical energy by photosynthesis.

Abell and Roth (1995) found that Year 5 students who were taught this pyramid diagram tended to misunderstand it, thinking, for instance, that it represented the amount of space available for each type of organism. This very literal interpretation of scientific diagrams is not uncommon, so teachers must be careful when using scientific models such as this that students are not misinterpreting the representation. Abell and Roth recommended that children be encouraged to build up their own models representing the relationship between these population numbers, as only then will they be ready to accept the purpose of this more abstract model.

### An environmental modelling game

The study of organisms found in the schoolgrounds related to the cyclic seasonal patterns in various habitats, and the interrelationships between them, can provide a platform for a range of discussions concerning the changing urban or rural environment and pressures on organisms’ survival. Discussions of the availability of food could centre on the effects on the ecosystem arising from changes to one element within it.

An interesting activity that focuses attention on the consequences of change in an environment can be played with primary school children. This ‘survival consequences game’ is an example of a modelling activity that can be effective in allowing children to explore the interactions between the different elements in a system, in this case an ecosystem involving layered feeding arrangements.

The purpose of the ‘game’ is to help children understand the relationship between parts of a food chain and interference to some item in that chain. As preparation, the children should draw the following set of items on small pieces of card: 20 grass cards, eight insect cards, three small birds’ cards and one card that depicts a raptor. The teacher can make several other cards of these items. The relationship 20:8:3:1 is only a suggestion but is effective at

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### Activity 7.17 The food pyramid as a representation

- Examine the food pyramid shown in Figure 7.8. What does this representation of the food pyramid show? What doesn’t it show? Refer back to the discussion in Activity 7.11 (see p. 279) as an example of the specificity of representations.
- Whenever a representation is shown to the students, it is important to ask the above questions. Discuss why this might be so.
- Consider the same question in relation to:
  - the food chain of Figure 7.6 (see p. 267)
  - the food web of Figure 7.7 (see p. 268)
the conceptual level. Make a simple spinner with an equal chance for each food chain item. To begin: each child has one card as a label. The group arranges itself with grass sitting in a line on the floor, insects kneeling behind them, and small birds standing behind the insects. The raptor stands on a chair at the back and apex of the group. The children will see that the opening configuration could be described as a triangle or pyramid. Discuss the predominance of the grass and the single raptor. Play the game. The spinner is turned and the designated card must be handed in and the holder asked to return to their classroom seat. Ask the children what two consequences might arise from the removal of the card. For example, if a grass card is removed, then one insect card and one bird card would be removed as they are dependent on one another. As another example, if the spinner indicated a small bird was destroyed, then this would mean that more insects would survive. Hand out another insect card, but then another grass card would have to be discarded as the greater insect population would consume more of the grass inhabitants that they rely on. Turn the spinner 10 times and make the appropriate moves. Ask some children to record each move. Discuss the possible reasons for change – wilful destruction (killing birds), intentional destruction (inappropriate use of pesticides) and destruction caused by natural events (bushfires).

The game is based on the concept of an ecological web but it is representative only and the teacher would need to emphasise that it represents a closed field in that nothing except the organisms on the cards can influence the result, and there is no new grass growing to replenish the pasture. The implications of these two qualifications are important.

Teachers may wish to discuss or even model the effect of an ‘open’ field. A further possibility is to enlarge the universe of the game by including, for instance, logs with the grass cards, fungi cards, some rabbits with the small birds, and two snakes between the raptor and the bird line. Alter the spinner and play 20 spins again.

**Planning and assessing habitat activities**

Exploration of schoolgrounds and investigations of its inhabitants can lead to knowledge and understanding of concepts about the living world, and to the development of skills and concepts of evidence and the synthesis of these in carrying out investigations (see Chapter 2 for a detailed discussion of these aspects of thinking and working scientifically). Schoolground investigations can also lead to attitudinal development in regard to animals and their habitat, such as a greater valuing and sense of responsibility towards animals and their environment, as well as a development of interest in the detail of animal structure and behaviour and interactions between animals and plants. The activities described above can be as much concerned with these aspects of science as with conceptual knowledge.

Table 7.3 sequences some of these schoolground activities in order of increasing conceptual sophistication and describes a range of conceptual and attitudinal outcomes that could be associated with these activities. The activities are closely related to the sequence described in Table 7.1 (see p. 268) and to the discussion above. The columns in the table represent an attempt to define a progression in children’s science conceptual understandings, science inquiry skills and values, and attitudes (the last mentioned having a strong association with ‘science as a human endeavour’) that children can be expected to move through in association with these activities. This text, by its nature, focuses mainly on the conceptual elements of learning science, including
the design and interpretation of science investigations. Learning science also has a strong affective/aesthetic component that must be recognised and taken into account in teaching and learning (see the “Hot” conceptual considerations: student engagement’ section of Chapter 1, on p. 26), and Table 7.3 reinforces this aspect.

The table has a number of purposes; namely, to:

• provide guidance as to the appropriate habitat exploration activity for moving each student forward in terms of their concepts, processes and attitudes
• help conceptualise children’s progression in each of these three aspects of science as they interact with the habitats
• show that the development of processes and value positions go hand in hand with the development of conceptual knowledge
• provide descriptors that could be used to assess children’s positions along these stages of progression.

Activity 7.18 Planning and assessment

From Table 7.3 choose a number of the position descriptors related to conceptual understandings, inquiry skills and values and attitudes to formulate learning outcomes (describing more specific understandings or attitudes in a form that specifies how the outcome would be demonstrated). For each of these:

• relate the outcome to the activity described in the left-hand column. Decide what teaching strategies you would use to encourage the development of the outcome, using the appropriate activity from the left-hand column.
• Think about what evidence you might collect to judge whether the outcome applies. If possible, you should tackle this task as a group, with overlapping responsibilities so you can compare different interpretations.

It should be understood, of course, that the descriptors are not such that a child is uniquely identified by that position. Children are capable of infinite variation in their understandings, processes or attitudes, depending on the context.

• Compare the science conceptual understandings and science inquiry skills descriptors with outcomes in the corresponding strands of your science syllabus/standards/outcomes document. Can you find a matching outcome for each of the descriptors? Discuss whether you think the sequencing in Table 7.3 is appropriate.
• Discuss with colleagues the year level at which each of the activities would be most appropriate.
TABLE 7.3 Development of conceptual understandings, inquiry skills and dispositions using investigations of schoolgrounds

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>SCIENCE CONCEPTUAL UNDERSTANDINGS</th>
<th>SCIENCE INQUIRY SKILLS</th>
<th>VALUES AND ATTITUDES (SCIENCE AS A HUMAN ENDEAVOUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random hunting</td>
<td>Recognises that many plants and animals coexist in the schoolground (but does not think they interact in any significant way).</td>
<td>Carries out simple observation sequences to answer simple questions. Sorts animals according to simple criteria. Reports on activities using simple statements.</td>
<td>Sees animals as interesting play objects (but sees plants as inhibiting hunting activity and shows minimal regard for animals).</td>
</tr>
<tr>
<td>Directed hunting/collection of particular animals or types of animal.</td>
<td>Explains that the invertebrate supports a diversity of animals with different characteristics.</td>
<td>Recognises patterns in animal type and behaviour. Groups data concerning diversity of animals in simple block-and-column format. Makes a record of observations using simple drawings.</td>
<td>Shows interest in the variety of invertebrates. Shows concern for the welfare of larger animals. Asks the names of invertebrates rather than how or why questions.</td>
</tr>
</tbody>
</table>
| Directed hunting/collection in particular habitats. Collecting plants. | Can explain that:  
  - plants and animals interact within the habitat  
  - animals use different areas of habitat  
  - plants have a variety of features. | Develops drawings appropriate for use in a key. Poses questions and suggests observations that might lead to an answer to a question. | Plants seen as interesting and important entities in their own right. Adopts a responsible attitude to the maintenance of the schoolground environment. Asks questions about the diversity of features of animals and plants. |
| Selection of animals and plants for close observation of structures and behaviour. Detailed representations such as annotated drawings of animals and plants. Modelling aspects of animal behaviour and structure and report on outcomes of observations. Design of an organism to live in a particular habitat. | Understands that plants and animals exhibit a variety of structures and behaviours that are adaptive and help them survive. | Uses conceptual knowledge to make relevant observations of structure and behaviour. Participates in planning simple investigations about animal behaviour or the purpose of plant structures. Makes detailed drawings with annotations and identifies key features when reporting on observations. | Habitats are seen as interesting discovery places. Looks for detail in features of organisms, and asks questions about purpose. Enjoys comparing and classifying animals. |
Children investigating small animal behaviour

In this section, Suzanne describes, as a case study, a unit she developed and ran for her Year 3/4 children who were learning to focus on scientific investigations through working with different small animals. The unit is based on the work of Kathleen Metz, whose research (1995, 1997) indicated that young children are able to think and work at more sophisticated levels than is normally accepted. Metz's work refers to the ‘scaffolding of independent inquiry’, which she proposes to support her argument that Swiss psychologist Jean Piaget's work has been wrongly interpreted to justify an ‘age appropriate’ curriculum that restricts science education for younger children to observation, classification and manipulation of concrete materials. Metz’s work in classrooms shows that children can carry out experiments that involve hypotheses, the control of variables and inferential thinking. As you read the case study, consider what elements are consistent with constructivist precepts and whether there are features of the sequence that move outside these boundaries.

CASE STUDY

Thinking about and working scientifically with small animals

Convinced that primary age children can apply their thinking and activity to rigorous and independent inquiry in a much more energetic and productive way than generally allowed, I have followed Metz’s approach to investigation in
units of work, one of which is described below. The approach explicitly casts children in the role of neophyte scientists, encouraging and supporting investigation and introducing learners to a range of scientific techniques and procedures. This enhances the children’s view of themselves as scientists and enriches their view of the NOS (see Chapters 1 and 2).

The unit of work aims to allow the practice of science in a purposeful context that engages children’s imagination (and hands) in observation, questioning, investigation, design and the management of data. It accepts that young children try to succeed and to understand what is occurring and that their inability to reason about abstract ideas is ‘simply because children tend to be novices in most domains, and knowledge of the novice is limited to surface features’ (Metz 1995, p. 105).

This approach requires scientific thinking more than description and classification and focuses the inquiry on goals that can be evaluated in terms of the quality of investigations and the collection and analysis of authentic data. It also provides topics that are highly motivating and that allow for diversity of interest and a broad range of metacognitive ability.

The first stage introduces an animal that is interesting to observe. I have used crickets, fish, birds and mice for this activity. The central skill is to observe behaviour and to discriminate between what is seen and the anthropomorphic conclusions that children tend to make. When observations are shared and noted on the board, the children can be asked to consider whether a fish that is looking around at everybody through the glass is an observation or an assumption. Changing animals during the observation stage helps children practise the skill and refine their notes. ‘Keeping close to the glass’ or ‘opening and shutting mouth’ become more usual observations as it is the behaviour that predominates rather than sentiment about an animal’s supposed wishes.

The next stage is more demanding and children often revert to the fish-trying-to-talk and the mice-trying-to-escape level. The process practised at this stage of the unit is the drawing of inference. From a set of personally observed behaviours, the child makes suggestions about the behaviour. You can see in Maddy’s work (see Figure 7.9) that she has some knowledge about fish behaviour, but the inferences she draws still pertain to a childish identification with a fish as an equal.

When certain behaviours are established, then tallying of frequency, as non-prescribed observation and then as a time sampling, can proceed as the third stage.

Jenny’s tallying of Panda the mouse is produced in Figure 7.10. She had drawn up a list of possible behaviours from a previous observation and was satisfied with the characteristics she noted as ‘hiding’ and ‘sniffing’. She was then required to present her data in some form of visual representation and chose the bar graph (see Figure 7.11).

The time sampling was undertaken a number of times. We put the two mice, Pumpkin and Panda, in a large shallow box around which all the children could sit, at various heights, in order to map the behaviour. As well as the template of the enclosure with food, crushed paper, paper roll and water dish indicated, each child had adhesive spots numbered one to 10. Each child had to watch only one mouse and observe what the mouse was doing when I called ‘Now’, which I did at 15-second intervals. David’s map is shown in Figure 7.12. David also had spots marked A–J, which he added to his mapping after we had removed the food tray. Each child then wrote about this event.

Here is Marianna’s record of her work:

We watched Panda, the black and white mouse, and every time Suzanne said ‘Now’ we put a spot on the map where Panda was. We did this ten times and Suzanne said ‘Now’ every fifteen seconds. Panda went to the food on time one, time three and time six. At time seven and nine and time ten she was going around the edge of the box. She was looking around the whole box just about the whole time. Then we took the food bowl away. Dots with ABCD show this and Panda stayed in the corner the whole time. We counted the same as before and we didn’t have more dots but Panda stayed in the corner still.

It is important for children to consider the data and to discuss what the time sampling and observations do not tell. This was more difficult for the children and was discussed as a whole class. Some of the suggestions the children offered were:

- How far would the mouse run out from the corner to get food?
- Does being in the corner mean fear?
When would a mouse hide in the cardboard roll?
Does a mouse know it’s hidden?
Over a day, would a mouse go to dry food as much as to water?
Would a mouse go into the wheel more than the corner if we put the play wheel in the enclosure?

We then decided which of these could be investigated in the classroom and which could not. This led to planning for different investigations, determining a research question around one of the suggestions, preparing materials and deciding whether conclusions could be realised.
An extension of this stage used snails as the small animal under investigation and we observed snail behaviour employing similar stages to those outlined above.

Figure 7.13 is an early attempt by Michael to frame a question and to devise an investigation. The notion of there being an answer had never been raised, but children often feel compelled to know what the conclusive position is. After some reflection, other children decided that they should investigate the same question and devised different ways of going about it. The differing methods were analysed by other class members. An atmosphere of friendly critiquing was established as they set up a community of practice that questioned the nature of investigation in a surprisingly mature way.

The issues that were raised included:
- You would need pairs of colours with different surfaces.
- Where the snail started off would be important.
Smoothness and roughness as characteristics had to be the same in all cases: ‘There are different sorts of roughness’.

Just counting over a short time wasn’t enough watching. The closeness of each pair was important and when one child put them next to each other, this was judged to be sensible.

You had to think where snails would go because colour might not have anything to do with where they would move. They might always move onto green.

These reflections gave rise to increased curiosity and subsequent research designs, which resulted in additional plans for watching snails in the natural habitat.

Roddy wrote a report of his experiment with the mice and discussed what his experiment did not reveal:

We had two mice in the big bread crate with the sides covered with newspaper. Their names were Panda and Pumpkin. We wanted to see if they could cross a row of thousand blocks to get to the other mouse. We made it so that they could see a little bit through a gap in the blocks. When I put them in Panda was on one side and Pumpkin was on the other side. Panda stayed still and Pumpkin tried to get out of the crate. I pushed her back in about five times. Panda stayed mostly still. Then Panda walked up near the blocks and found the little gap and went through. Then we put Panda back by herself and put the gap in another place. Pumpkin did not look at the gap. Then Panda saw the gap and went through it. We did the same again and put the gap in other places and Panda went nearly right to it. I think Panda wanted to explore...
and wanted to be with Pumpkin but Pumpkin just wanted to get out of the crate. When we made no gaps Panda started to walk around the crate. I thought she would try to jump over but she just walked around. Then we took all the blocks away and I thought Panda would run over to Pumpkin but she did stay still [sic].

The question was to see if the mouse can cross a barrier to get to the other mouse. I don’t think I know if Panda will always look for a gap and I don’t know why Pumpkin didn’t look for a gap. Food might be better. If they were hungry can they look for a gap? They can jump over if they are starving maybe.

Over the term, the class followed the same set of exploratory stages but different animals were used, posters were made and presented to other classes, and boxes of new pets adopted. Without direction or prompting, one child carried out multiple 60-second trackings of a goldfish movement in a tank (see Figure 7.14 for two examples) and wrote about patterns she could observe; for example, the fish only stopped once in a minute and this is shown by the star shape. There was no pattern to where it started and ended and it did not seem to return regularly to any place in the tank. Her next project was to research the effect on the goldfish of a new fish being introduced.

Another child made drawings of budgies, noting body parts and differences, including the characteristics of one type crossing its wings at the back (see Figure 7.15). Interviewing an expert revealed that this was specific to the breed known as the English budgie, which was perplexing because the child thought all budgies had to be Australian. This set her on a discussion of animal exporting and breeding practices.

It is evident that the children’s ability to collect and analyse data, to plan and present investigations and to evaluate their own and others’ work enriched their specific knowledge and, more importantly, engaged their interest and sense of purpose in pursuing science questions in practical ways. Not only did the unit provide a
constructivist sequence in the conceptual change mould, but it also established a community of inquiry with the children learning to participate in a science discourse, communicating, affirming and challenging different ideas.
Questioning and assessment

Working with animals stimulates curiosity in children and learning to ask questions stimulates metacognitive thinking. A 'Questions' sheet pinned up for class use encourages contributions and comments, and a community of inquiry environment, such as that represented in the above case study, with its focus on the investigation of children's questions, encourages discussion on philosophical questions that arise. Such questions can provide insight into children's level of understanding and sophistication in inquiry, which can feed into assessment of their science capabilities.

An informal 'hierarchy' based on Elstgeest's (2001) categories can be useful in determining the sophistication of questions. Watching birds may give rise to a 'level one' style of thinking which is only attention focusing – such as 'What is its beak like?' or 'What colour is it?' At 'level two' are the quantitative questions which refer to counting and comparisons – for example, 'How far did the fish swim in one minute?' or 'Which mouse has the longest tail?' In science inquiry, the 'level three' qualitative questions are powerful, looking at similarities and differences. For example, in the animal studies, children looked for the things that snails and fish had in common as well as the differences between them. At the next level of thinking are the action questions, which require some implementation and refer to 'What would happen if ...?' proposals, such as 'What would happen if a Slater's pathway was blocked by water?' A 'level five' question style usually poses a problem. These are generally context-bound and dependent on prior knowledge; for example, 'How can we find out whether a mealworm goes underneath the bran to avoid light or to eat?' Cognitive and affective linking questions also give rise to more complex thinking as they require memories for instances and feelings, and serve to link the learner with earlier experiences and provide language for expression. This 'level six' style may include questions such as 'Have you ever seen a rabbit digging a burrow?' or 'What sort of action do they use?' 'Level seven' involves reasoning questions which may be metaphysical or philosophical, having no agreed definitive answer. They give rise to spirited discussion and reflection, handling assumption and examples as part of the thinking process. Children have discussed such questions as 'Are snails good mothers?' and 'How do silkworms know how and when to spin cocoons?'

The nature of science arouses curiosity and wonder which benefits all learners and appeals particularly to the talented child. One question that arose with a group of eight- and nine-year-olds was about silkworm behaviour: 'How does a silkworm know to eat a certain amount and then make a cocoon when no other silkworms are there?' Children with a special bent for philosophical speculation seek clarification and make connections that can stimulate and assist the whole group.

Science is an area of the curriculum that, at its most interesting and investigative, arouses curiosity and determination in children with particular talents who might otherwise not have been conspicuous in academic work. It can provide challenges and tasks that can satisfy children who find the classroom a problematic work space. For children with a particular talent for language, for instance, science promotes enriched writing and research skills that extend these abilities as far as the individual wishes to exercise them. It is open-ended. Science fosters critical thinking, questioning and reflection.

For the child with a physical, intellectual or emotional disability, science offers enjoyable and purposeful activity. The consistent interaction with environment, the emphasis on tactile
experience and the less regimented classroom allows endeavour and some success regardless of the aspect of disability or its severity. Watching crickets in their enclosure was very stimulating for one special-needs child, for instance, and led to the development of enriched vocabulary about movement. For the NESB student, science gives a consistent opportunity and need to describe and question specific occurrences and outcomes.

**Activity 7.19 Planning for thinking**

- It could be argued that the case study ‘Thinking about and working scientifically with small animals’ focuses on quality of thinking. Discuss with colleagues just what view is represented of quality thinking in science. What are its characteristics?
- Select a science investigative activity you have previously discussed or had experience of. Generate, with colleagues, a list of questions that could arise in the activity to illustrate the question categories described above.
- Discuss how children’s questions could be used to assess their level of thinking. Generate some questions relating to the case you would regard as representing a high level of thinking.

**Interpreting the case study: sociocultural perspectives**

In this case study, the children have been active participants in a process of inquiry, collaborating in deciding on their questions and discussing and critiquing their investigative designs. An important part of Suzanne’s task as a teacher was to establish an environment in which the language of exploration and the collecting and evaluating of evidence were central elements. This case can, therefore, be viewed through a sociocultural or situated cognition lens in which the children do not so much learn to master concepts and processes as individuals (although this happens), but rather move from a position of relatively peripheral to more expert participants in the sociocultural activity that is science, represented within Suzanne’s classroom. Suzanne’s use of the term ‘community of practice’ can be related to this. These ideas are broadly based on the work of Vygotsky (1986), a Russian psychologist who emphasised the way language and culture are fundamental to how we come to learn about the world, gradually taking on established discourses as the basis for our own thinking. Note how Suzanne, following Metz, spent some energy in teaching the children the thinking tools and processes of the ‘discursive’ or language elements of science – the language of evidence, inference and observation, as well as particular measurement and analysis tools. The conceptual end point of the study was not strictly determined, but the quality of thinking and discussion was a prime focus. Sociocultural theorists view learning as essentially constituted within participation, and understanding as fluid and contextual rather than as stable conceptual frameworks located in people’s heads. Rogoff (1998, p. 691) argued that, ‘What is key is transformation in the process of participation in community activities, not acquisition of competences defined independently of the sociocultural activities in which people participate’. These ideas are discussed in some detail in Chapter 1.

This focus on ‘discursive elements’ (the languages and processes we use, including mathematical language and diagrams) represents a growing recognition of the importance of
language practices in framing thinking and understanding. There is growing recognition that science is a mix of languages involving multimodal forms of representation, and that learning science involves students being able to interpret and integrate science texts such as tables, graphs, diagrams and science reports (Lemke 2004). The representational resources that children need to develop are the literacies of science, and teaching should focus attention on introducing and negotiating productive representational resources through which students can explore and interpret phenomena (Tytler, Peterson and Prain 2006). This explicit focus on literacy underpins Primary Connections (AAS 2005). Pedagogies appropriate to a representational perspective have been described in some detail in the schoolground invertebrate sequence.

It is interesting to view Suzanne’s practice in the case study above, through this representation lens, as she introduces students to different ways of representing animal location, movement and features, and asks them to coordinate these ideas in explanatory text. The case study represents a very rich literacy environment, which arguably is the key to its strength as a learning environment.

**Activity 7.20 Developing a view of the case study**

Discuss with colleagues the case study ‘Thinking about and working scientifically with small animals’ in order to come to a view about how best to consider its features.

- Write down the main elements of the sequence and identify Suzanne’s role as teacher in each of these.
- Identify those characteristics of the case that provide a good illustration of constructivist principles.
- Discuss the different representational modes (e.g., written, diagrammatic, graphical) that children are asked to use in the case study to explore animals. Identify examples in the sequence where Suzanne asks students to re-represent ideas in different modes.
- Do other case studies in this text illustrate the notion that a supportive learning environment involves students in negotiating representations, and representing ideas in different modes?
- Develop a position on the extent to which you feel the teacher needs to have in mind a specific conceptual outcome or inquiry skill for a sequence such as this, against taking a more flexible view of what individual learning might take place.
- Review some other case studies from the different chapters in this text. Do they differ in the specificity of the end conceptual position? Can sociocultural perspectives help us make sense of these other cases?

**Plants in the schoolground environment**

Most schools have grounds containing a variety of plant species, including a variety of native trees and shrubs as well as introduced species planted for their colourful flowers. As a result, the schoolground can be a rich source of material for studying plant structure and function. In this section, we will discuss children’s and scientists’ ideas about plants and introduce activities designed to clarify ideas about plant growth, plant reproduction and adaptation.
Children’s ideas about plants

Children’s conception of plants is much less developed than their conception of animals. Several researchers report that children think plants are only alive when they have flowers or are producing fruit. Plant movement is much more subtle than that of animals and as such it makes little impact on children’s thinking.

Biddulph (1984), in a study of seven- to 11-year-old children, found that their understanding of plant reproduction was such that, when asked why they thought various plants had fruit, not one child out of 80 understood the concept that fruit functions as a seed-dispersal mechanism. Again, ambiguity between the everyday and the scientific meaning of fruit could account for some of the confusion. When asked the supplementary question ‘Would the fruit be of any use to the things they grew on?’, 56 per cent of nine-year-olds answered that the plant grew fruit for us to eat.

A number of studies (e.g., Leach et al. 1995, 1996a) have found that, for students even up to the age of 16, the scientific notion that the body matter of all organisms is derived from chemically transformed food poses significant problems. In the case of plant nutrition, pupils find it difficult to conceptualise plant body mass coming from invisible atmospheric gases and water (in photosynthesis plants use the sun’s energy to transform atmospheric carbon dioxide and water, drawn in usually through roots, to simple sugars and starches), rather than the more solid substances of soil and water, which are usually identified as the source of food. Children’s understanding of trees’ need for light, rather than being framed in terms of specific energy needs, is more often explained in the non-functional statement that plants need light to grow.

Biologists define plants as organisms that produce their own food through the process of photosynthesis. There are a number of broad phyla in the realm of plants, the main one of which is angiosperms or flowering plants, but also others which include plants such as conifers, ferns and mosses and so on. You can find details of these in biology texts or most secondary school science texts. You can also find details of the life cycle of flowering plants.

Ideas about plant structure and function

In everyday language, the word ‘plant’ has a rather narrower meaning when compared to its use in science. Young children may mainly associate plants with things in pots in gardens and do not necessarily view a tree, a bush or grass as a plant. When asked to draw a plant, they tend to revert to stereotypical plants with flowers and single stems. A productive elicitation and exploration activity would be to focus attention on the details of a variety of plants and plant parts and identify their commonality of purpose. Tunnicliffe and Reiss (2000) found that children tend to recognise and identify plants mainly in terms of their large-scale anatomy and where they live (for example, mosses live in damp places). They recommend that children be encouraged to observe the finer details of plant structure and to link plant features with their environmental adaptive functions. They argue (p. 177) that ‘we don’t want pupils to have a model of the environment simply as a background against which individual organisms stand. Rather, we want pupils to understand the ways in which plants and other species affect and are affected by their environments’.
In a similar activity with children in their first year of school, drawing plant parts from real life during a plant unit (Figure 7.16) seemed to jolt children out of their stereotypical representations of plants (Figure 7.17), encouraging them to make some detailed and focused observations of plant parts. Note how the use of pencils in Figure 7.16 allowed much more detailed representations.

Activity 7.21 Plant parts

- Collect or work with a variety of parts from native plants from the local environment, including leaves, gumnuts or banksia fruit, tea tree seed and a variety of seed pods, cones, flowers, bark and buds.
- Identify each plant part’s function. What is its role in the plant’s survival?
- Draw carefully the details of selected plant parts.
- Generate a set of questions that arise from the activity.

FIGURE 7.16 Children’s drawings of plant parts from real life
Ideas about plant reproduction

The important aspect of flowering plants is that the details of the reproductive cycle (seed–germination–seedling–plant–bud–flower–pollination/fertilisation–fruit–seed) represent an adaptation by which the plant is fitted for survival. Flowers are the mechanism for sexual reproduction in angiosperms and each flower has male and/or female parts. Pollen, the equivalent to sperm, is distributed by various means, such as insects or birds, to pollinate the female part of the flower. Pollination (transfer of pollen) occurs before fertilisation (fusion of male and female gametes), which takes place in the ovules in the ovary within the receptacle of the flower.

Table 7.4 shows the responses – from Symington and White’s (1983) study – of children from two age groups to the question ‘Why do plants have flowers?’ As can be seen from the table, young children see the purpose of flowers mainly in terms of the needs or desires of humans, or of other animals, such as bees, rather than in terms of the adaptive needs of the plant itself.

Large, brightly coloured, perfumed petals and sweet-smelling nectar are adaptations that attract birds and insects, which assist pollen transfer from one flower to another. Flowering plants that rely on wind for pollen transfer are less conspicuous. The position of the stigma varies in different plant species. Most commonly, the stigma is found above the stamens (e.g., hibiscus) so that it is less likely for pollen from the same flower to adhere to the stigma. Advantages of this arrangement for the plant include facilitating cross-pollination rather than self-pollination. In turn, cross-pollination assures variation in the seeds (produced after
fertilisation), which enhances the species’ survival in a changing environment. Following fertilisation, the ovary of the flower becomes the fruit that contains, protects and nurtures the seeds. Different flowering plants have different means of seed dispersal (Why would plants be advantaged by dispersing their seeds?), such as by wind (in the case of a dandelion, for instance, which produces many seeds, each of which would have only a small chance of germinating successfully), water or by animal transport (for example, animals might eat the fruit and scatter the seeds in their faeces).

The diagrams of flowers in texts tend to show an idealised structure of a flower, with the male and female structures arranged in an ordered way within the petals. Flowers can vary a lot within this basic structure and children should experience, preferably firsthand, a variety of these so they can begin to see the broad patterns within the variety. Some flowers have a pistil with multiple heads and, in some flowers, such as the grevillea, the stamens are wrapped inside the petal and are difficult to find if you are not aware of this possibility. Some plants, such as dandelions or echium, have many tiny flowers, each with its own reproductive structure, clustered together in what most people would think of as a single flowering head.

### Activity 7.22 Flower dissection

- Cut up a variety of flowers, including some Australian natives such as grevillea and eucalyptus, and some complex flowers like a daisy or dandelion. You should use a scalpel (note the need to consider safety issues) and/or scissors, and tweezers. A magnifier can be useful for identifying parts in a small flower. Identify the ovules in the ovary. Where is the stigma found and where are the stamens? Decide which flowers have a structure to assist cross-pollination.
- Identify and sketch the main parts. If running this task in a classroom, discuss the following principles with colleagues.

### Table 7.4 Seven- to 12-year-olds’ views about the function of flowers

<table>
<thead>
<tr>
<th>THE MAIN REASON A PLANT HAS FLOWERS IS</th>
<th>PERCENTAGE OF PUPILS CHOOSING EACH REASON</th>
<th>7–8 YR OLD N = 83</th>
<th>11–12 YR OLD N = 115</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Because it just grows that way</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2 To grow seeds</td>
<td></td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>3 To make it look nice</td>
<td></td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>4 To grow fruit</td>
<td></td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>5 Because bees need the pollen and nectar</td>
<td></td>
<td>45</td>
<td>28</td>
</tr>
<tr>
<td>6 To show where the fruit will be formed</td>
<td></td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7 Because it is spring time</td>
<td></td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>8 I don’t really know why it has flowers</td>
<td></td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>9 I’ve never thought about it</td>
<td></td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>
One of the difficulties for children in studying the nature of flowering plants is that they have a rather narrow view of which plants have flowers. Many people think of a flowering gum as one of only a few eucalypts that have flowers, yet all eucalypts are flowering plants. Another difficulty involves the identification of fruit as a category of food, which does not correspond exactly to the biological view. For instance, a gumnut is a fruit, as is the cluster of hard woody balls on a tea tree, since they contain the seeds. A peapod is a fruit and the pea is a seed. Biologically speaking, then, any part of a plant that contains seeds is a fruit and this includes avocados, tomatoes, olives and pumpkin. The broccoli we eat is the flower of the broccoli plant.

Using plant trails

Given the abundance of plants in most local school environments, it seems a pity to focus classroom sequences on plants around textual representations only. Plant trails have been described in numerous publications (e.g., see the Gould League website at www.gould.org.au/index.asp) and come in a variety of forms. The essential nature of the trail is that it takes students through a structured observation experience: it asks them to notice significant features of plants and to become more sensitive to plants in the environment. Trails can be quite structured (e.g., asking children to collect or draw particular parts of particular species) or quite loose (e.g., asking children to search for examples of particular features of plants in general). In planning trails, it is a good idea to prepare children in advance concerning what they will be looking for by providing examples of different plant parts beforehand, for instance, or workshopping questions they might have about plants that could be explored on the trail. Botanic gardens often have sections offering insights into Indigenous people’s use of plants, and information can be found, for instance, on the Australian National Botanic Gardens website (see www.anbg.gov.au/gardens/education/resources/index.html).

Activity 7.23 Plant trail

- Construct a means of collecting specimens of plants in an orderly array. This might consist of a manila folder with small plastic bags stapled into it. Each manila folder could be dedicated to a particular plant.
- Walk around the local environment with the aim of setting a trail for children. Identify plants with interesting features and select one feature to place in the folder. The features might include new and old leaves, bark, fruit, seed and flowers in different stages.
- Swap your folders with a colleague. The task for each of you now is to collect a specimen from each plant, of other designated features.
Plant growth and the cycling of matter

There are many experiments one can do concerning the growth of plants, including growing bean or lentil seeds in soil and cotton wool and charting the way shoots and roots develop, or monitoring their growth in conditions of light, or low light or differing amounts of water, soil and/or cotton wool. There are significant understandings associated with plant growth and the case study and associated discussion below is meant to show how plant growth relates to a variety of cycles of material in natural systems.

**CASE STUDY**

**The terrarium**

The first part of the story is drawn from an episode relating to a longitudinal study of children’s ideas (Peterson and Tytler 2001). We had been involved in running a unit on plant growth. This included experiments with seed trays grown under different conditions, studying plants in pots and growing beans in jars. In that unit, and in interviews with selected children afterwards, Suzanne had explored their ideas about life (What does it mean to be ‘living’?), the conditions for plant growth, and reproduction (Where do seeds come from, and what are they for?). Following that unit, the children had little trouble in telling us that plants need sun, soil and water to grow. Most of them knew that water came in through the plant’s roots, but understandably had no real idea of how or what happened next.

**The terrarium activity**

There were two things we wanted to focus on in using the terrarium. Firstly, because it represents a closed system, it provides a challenge to children to think in terms of the cycling of material to nurture the plant. Our focus was on the cycling of water. The idea came from a Swedish colleague who has been using terraria to explore some very interesting ideas that older students have about the recycling of matter in plants (Hellden 1997). Secondly, we set it up as an investigation to support and explore the children’s ideas about the design of experimental investigations, since we had previously worked with them on this.

We provided the following equipment:

- small fish tanks, each lined with very slightly damp potting mix
- clear plastic sheets and tape (cling film will suffice)
- water mist spray
- a variety of small seedlings.

We set the tanks up to explore the effect of the closed system and the amount of water. The children planted three small commercial seedlings in the fish tanks. These were arranged to compare what happened with and without sealing the tank and the effect of varying the amount of water.

We had an initial discussion about what the children thought would happen over the week to the plants. In general, they were convinced that the plants in the closed tanks would die, either because they would get no air to breathe or because they would grow and bump into the plastic ceiling. Interestingly, while we were discussing their expectations, condensation appeared on the sides of the closed tanks, which excited their interest. One child noticed there was more fog on the tank in the sun and speculated that this was related. We had a very animated discussion, with children explaining the fog using associations that related it to breathing or to heat. These children were thinking of the fog as an effect, not necessarily as a material on the inside of the tank.

The tanks were all left in the same place – positioned on a high sunny shelf. One week later we took them down and discussed the conditions of the plants in the various tanks. The children were absolutely amazed that the plants in the closed tanks were doing better – no-one had predicted that – and we had a very animated discussion. There were lots of ideas about the presence of water droplets on the sides and lid of the closed tank. Most of the initial ideas had to do with the lack of air or associations...
with closed spaces and sweating. Over the next few weeks we monitored the plants regularly, as it became clear that those in the closed tanks were thriving and the open-tank plants were wilting. At this stage we interviewed a number of the children about what they thought and found a range of levels of understanding of the cycling of water in the tank. Here are some examples:

- It got so hot water went into the plastic.
- I think it gets all hot and melts.
- Like we get all sweaty.
- [The water comes from] the hotness … ’cause it’s so hot in there … It starts to, like, turn into water.
- … because the moist (sic) it comes down the bottom of the soil and it gets really hot and it starts to get wet and so it grows up and up and then it goes into here and finally gets up here and spreads around. The plant got too heavy and a bit dropped off it and might flick the water up there.

One child, Hugh, made a startling leap, likening the tank to a mini globe:

It’s just like the world. Just pretend the world is a container and the clouds are fog and when the clouds get really big some of the clouds turn into water or they come down and some stay up there and when it gets really big it breaks.

Hugh thought the difference was that there is air in the world, but none in the tank.

Hellden (1997) has used terraria to explore the development of children’s ideas about the cycling of matter over a number of years. He asks questions such as:

- Where does the green matter in the growing plants come from?
- If the leaf matter in the terrarium is in the forest and is replenished each year, what happens to those leaves over time?
- Why do trees lose their leaves?

### Activity 7.24 Cycles in the terrarium

- Discuss with colleagues what happens with water in the terrarium. Trace its pathway and discuss its role in the plants’ survival.
- Tie a plastic bag around the leaves of a bush or a tree and leave it in the sun for an hour or so. Predict, observe and discuss what happens.
- Discuss as a group Hellden’s questions. Construct a list of ideas and your own questions that arise from this. Trace, if you can, the recycling of matter within the terrarium as the plant grows.
- What would happen to the weight of the terrarium as the plants grow?

### Children’s and scientists’ understandings of plant growth and the cycling of matter

Over a 10-year study of the ideas of 25 students, Hellden found that their ideas and the way they approached thinking about plants and matter developed considerably (Hellden 2005; Hellden and Tytler 2008). He found that, gradually, their ideas became more sophisticated and their concepts more differentiated. For many students, their views seemed to be strongly linked with episodes in their early childhood and, over time, their ways of looking at phenomena retained some coherence. For some students, naïve ideas persisted for many years. Examples of Hellden’s findings are:

- Students do not easily understand that plant material comes from carbon dioxide and water vapour in the air, driven by light in the photosynthetic process. The idea that plants produce their own food (in ecological terms they are producers and animals are consumers) is fundamental in biology, but students tend to assume they ingest food through their roots.
• Students refer to leaves as being broken down or eaten by animals over time. They do not understand that the material in the leaves eventually is transformed into gases, including carbon dioxide and nitrogen, which are recycled through the atmosphere. Some students were convinced that the leaf litter would build up over time and the world would gradually expand.

• Many students held anthropomorphic views, maintaining that flowers were for human benefit and that leaves fell because their muscles atrophied in autumn. This leaf-centred view eventually gave way to a tree-centred view (the tree drops them), and then to a more adaptation-oriented view involving seasonal triggers within the tree shutting off the flow of nutrients.

Science as a human endeavour

There are many activities presented and discussed in this chapter that demonstrate human interactions with living things in the environment, and many more activities that could flow from these that would further support learning in this strand.

Scientists studying living things

The case study ‘Invertebrates in the schoolground’ involved children quite explicitly discussing how scientists might approach studying animals in the environment. The approaches to data collection and analysis, and the generation of representations such as graphs, tables, drawings and models, were couched as representing good scientific practice. The forming of children into groups around investigation of animals generated a high level of engagement in exploration, which we have described elsewhere (Tytler, Haslam, Prain and Hubber 2009) as a community of inquiry modelling the knowledge-building practices of scientists. The model-based reasoning encouraged by the animal-movement modelling task, and the challenge for students to generate representations to explore questions and construct explanations, we have argued is a more authentic representation of scientific knowledge-building practices than following a predetermined sequence of steps people might imagine represent a ‘scientific method’.

In that study, a pre- and post-test question was posed, asking of two scientists researching a small beetle living in leaf litter:

1. what questions they might ask
2. what methods they would use to answer these questions
3. what their journals would look like.

In the pre-test, children had little idea of how to respond, suggesting questions like ‘What are they called’ and ‘What do they eat’, and writing very little about methods beyond ‘Looking carefully’. Figure 7.18 shows a typical good-quality response in the post-test to the same question, with the student asking sensible questions and providing a range of representations that scientists might use to study the beetle and its habitat.

Similarly, Suzanne’s classroom animal studies (see the case study ‘Thinking about and working scientifically with small animals’ on p. 293) focused explicitly on the way scientists go about framing questions and then generating data to answer them. We are thus arguing that students generating and negotiating non-standard representations leads to powerful
conceptual learning and also to better understandings of the NOS – how scientists work to build knowledge.

In terms of understandings of how other cultures have built knowledge, there are rich opportunities in a study of living things to explore how Indigenous peoples manage their environment in a sustainable fashion. Aboriginal perspectives on animals and their use of plants in healing and for sustenance in different seasons provide a different but powerful way of understanding the environment and how we need to care for it. Information on Indigenous Australians’ use of plants for a variety of technology purposes, and for food or medicine, can be found on a number of websites (e.g., see http://sydney.edu.au/science/uniserve_science/school/curric/stage4_5/nativeplants/gallery).

**Generating a personal ethos**

Sustainability is an important theme in the science strand, and care for the environment flows naturally out of and is enriched by studies of the natural environment. Whether it concerns habitat preservation or duty of care towards classroom animals, putting children in direct contact with animals and plants directly raises these ethical questions about our human role as custodians of that which we explore and explain. While this chapter has mainly focused on conceptual knowledge, there are many points in the case studies in which issues of value and aesthetics emerge.
Carolina Castano (2010) has explored with some success the potential of studies of animals and their needs to ameliorate antisocial behaviours in schools of low socioeconomic levels in Colombia. Her results suggest that science education can have a positive impact on the attitudes of these children, promoting compassion towards animals and reducing their aggressiveness towards each other and generally. There is growing interest in the role of values in science education and the way pedagogy links with values in supporting quality learning and also positive identity responses to science (Schreiner and Sjøberg 2007; Tytler, Barraza and Paige 2010). Interest in exploring socioscientific issues, of which there are many related to animals and genetically modified foods, has recently expanded to include consideration of value positions (Zeidler and Sadler 2008; see also Chapter 1).

Bloom (1992), in a study of children exploring worm structures and behaviour, found children’s thinking to be extremely fluid, progressing through a rich mix of conceptual and emotional, ethical and aesthetic commitments. In a similar vein, Per-Olof Wickman (2006) draws on the work of Dewey to argue that the traditional dichotomy between aesthetic and value positions and conceptual knowledge building is false. He argues that, for scientists, ‘Aesthetic experience is everywhere evident in their daily life as scientists, in the creative moments, in finding new connections and results, and in communicating science with others, but also in the intimate relationship scientists often have with nature’ (pp. 17–19).

Exploring links between aesthetics (matters of taste and judgement) and science learning in primary schools, Jakobson and Wickman (2008) pointed to very clear instances of how primary teachers of science blended aesthetic and conceptual talk in challenging and motivating students in a science class. In a study of buds on a plant, for instance, a teacher reinforced the surprise that students experienced in examining buds under a magnifying glass, and one student, Bosse, discovered a new relation:

EVA: I can see!
TEACHER: You may borrow this so you can also look at the buds.
EVA: Wow!
TEACHER: There you go! [inaudible] Also look at the buds ... Yes, just super! Did you see?
BOSSE: Wow!
TEACHER: It’s super. Can you take it?
BOSSE: Mine have red in it too.

Jakobson and Wickman 2008, p. 56

Jakobson and Wickman (2008) also quote passages where students have varying responses (delight or disgust) to worms, in which case the task of the teacher is to work with students to convince them of the intrinsic interest, if not ‘cuteness’, of the worms, in order for them to learn productively.

Thus, there is a close and complex relation between, and an entwining of, values and aesthetics, and conceptual learning. Thus, learning about and investigating invertebrates, and appreciating them, must proceed together. This is as true for scientists as it is for students. The developmental progressions in Table 7.3 (see p. 291) illustrate the way these strands interact. In the traditional view of science education, which denied the importance of dispositions and values, aesthetic and attitudinal dispositions were seen only in relation to their ‘motivational’ value in supporting knowledge building. With dispositions now an important part of the ‘science as a human endeavour’ dimension of science education, we can
see them in a clearer perspective as an outcome in their own right and an essential aspect of deep learning.

On the social plane, the study of living things in the environment and the learning of an appreciation of the living world feed directly into the possibilities of environmental studies, and having students explore habitat change and threat, including endangered species.

**Activity 7.25 Dispositions, aesthetics and learning about living things**

The previous section illustrated some strategies teachers use naturally to enlist interest in living things as part of children’s learning.

- Choose one of the case studies in this chapter. Discuss the strategies you might use to support children to develop a positive disposition as part of their learning in the sequence described. Are there any overt strategies used that you feel are successful in promoting aesthetic responses?
- Look at the interaction between the columns of Table 7.3 (see p. 291). Choose one level and generate a list of examples of ways in which the outcomes in each of the relevant columns could influence each other.
- For the case study you chose for the first question, generate a further sequence of activities that would support children’s learning of the way science knowledge is used in the workplace.

**Living things and environments and the world of work**

There are many occupations that deal directly with living things and the environment. Studying aspects of horticulture, for instance, including maintaining school gardens, is a natural extension of, or context for, plant studies. Interacting with gardeners, garden suppliers or florists can put children in contact with practical knowledge about plant care and reproduction. A trip to the greengrocers can sharpen their understanding of plant structures and the difference between the scientific naming of plant parts and culturally based distinctions between ‘vegetables’ and ‘fruit’. In rural areas, there are opportunities to interact with the agriculture or livestock industries and draw on children’s experiences of this.

There are also opportunities to extend a unit on living things to include excursions to science resource centres such as a museum, aquarium or zoo. Principles for planning for such visits are discussed in Chapter 3 (see the section ‘Excursion to a science resource centre’ on p. 144). Local parks, rangers and environmental resource centres are also sources of insights into personal and social interactions with the living environment. The role of rangers in the preservation of environments and the management of public interactions with parks could be a fruitful extension topic. There are many occupations, and many informal interactions, that people have with living things that could form the basis of a productive context for studying living things in the environment.
Summary

In this chapter we have explored scientists’ and children’s ideas about a variety of life forms, and strategies for teaching and learning that focus on the study of organisms in constructed environments. Teaching and learning about animals has been discussed in the context of schoolground invertebrates, which provides the opportunity for a rich mix of activities focusing on animal structure and function, adaptation, reproduction and life cycles, and ecological concepts such as food webs and energy flow. A case study of animal behaviour introduced investigative principles and an example of a powerful way to engage children in learning about science and scientific practice. The link between the ideas and the discursive representational elements of science was discussed. In the last part of the chapter, the biology of plants was explored in the context of studies of plants in the schoolground, with an emphasis on plant structure and function, reproduction and the cycling of matter. Finally, a range of approaches to establishing understandings of science as a human endeavour were discussed in the context of studies of schoolground environments.

Concepts and understandings for primary teachers

Below are some key conceptual ideas and understandings related to biology with which a primary teacher should be familiar. You should read and interpret this list with an appreciation of its limitations as described in the Chapter 1 section ‘Concepts and understandings for primary teachers’ (see p. 49).

The following list of biological understandings attempts to lay out the major principles, not as things to be learnt, but as organising ideas that make sense of myriad observations and the detailed knowledge about organisms that is the basis for appreciating and making sense of the living world.

Broad concepts of living things

- There is no absolute definition of what we count as living organisms; this has changed over time. Living organisms mostly have a cellular structure but, currently, viruses are counted among living things and they do not. Living things have a variety of characteristics that are displayed to different degrees: they respire, move, respond to stimuli, reproduce and grow, and are adapted within a complex of living things within an environment.
- When a plant is picked or cut or when an animal dies, some basic life processes will occur. There is no universally agreed-upon answer to the question ‘Is it alive?’
- The way in which living things are classified has also changed over time. Animals and plants are the main realms but fungi, mosses and viruses have their own separate realms.
- Animals are consumers in that they ingest food to survive. Food provides the energy for growth, movement and other life processes.
- Plants are producers and grow through the photosynthetic process by which carbon dioxide and water are used to produce starches of which the plant material is made. Sunlight drives this process.
- Animals and plants are further divided. A major category of plants is flowering plants or angiosperms. These differ from conifers or ferns, for instance, in the way they reproduce. Animals include a multitude of organisms, from microscopic creatures through insects, reptiles, mammals and so on. These different organisms are all interconnected through an evolutionary history.

Structure, function, adaptation

- Living things have various structures that enable them to survive: transport structures in plants by
which water and trace elements move, digestive structures and respiratory structures in animals, reproductive structures. Each organism has particular forms of these that are essentially solutions to the business of survival.

- Biologists look at organism structures and behaviours in terms of their survival purposes. Children should be supported to do likewise.
- Each organism is adapted to a particular ecological niche, which involves interdependence with other living organisms as well as dependence on non-biotic factors.

**Ecosystems**
- In an ecosystem, animals and plants are interrelated through a multitude of interdependent survival needs.
- These are interconnected by the flow of energy through the ecosystem, which is the reason an ecosystem can be analysed through the notion of trophic levels, with producers at the bottom through to carnivores who prey on other carnivores at the top.
- As well as the flow of energy, there is also a cycling of nutrients and elements, such as nitrogen and water. Thus, decaying plants are consumed by scavengers and broken down, with the products becoming an organic part of soil, and then gases, such as nitrogen, carbon dioxide and water vapour. Chemical change is an integral part of life processes.

**Flowering plants**
- The majority of plants on Earth are flowering plants and this includes trees, grasses, cacti and other small plants, as well as the more obvious examples. All eucalypts are flowering plants, as are most deciduous and rainforest trees.
- The reproductive cycle is an important adaptation and the formation and dispersal mechanisms for seeds (contained in fruit, pods and nuts, which are the outcomes of fertilised flowers) are multifarious. Conifers do not have flowers but seeds produced in cones.
- All flowering plants have a similar reproductive cycle.

**Life cycles**
- Life cycles should really be called ‘reproductive cycles’. In animals and plants they have unique details that are adaptive to the particular environment, including the number of offspring (or seeds) and the cycle timing and frequency, as well as mechanisms.
- In animals, the reproductive cycle can coincide with the life cycle of an organism if the adult dies after fertilisation (as with butterflies, and also effectively within some mammals, such as the male Antechinus). However, most animals will go through many reproductive cycles in a lifetime.

**Animal behaviour**
- Animal behaviour must be understood in terms of its adaptive function. Animals behave in ways that maximise their survival chances.
- Each species has unique behavioural characteristics, which can be studied using a range of techniques.
- For schools, it is most fruitful to study the behaviour of simpler life forms since their behaviour is not so complex and there is less tendency for children to anthropomorphise.
CHAPTER 7 Living things and environments

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References


TEACHING PRIMARY SCIENCE CONSTRUCTIVELY


