Changing students' ideas about matter and change

As described in earlier sections of this chapter primary students hold vastly different ideas from the accepted scientific view about how matter changes. As a consequence of these studies some general teaching principles are emerging. A major focus on physical changes would seem more appropriate from the early years of primary school as young students do appear to appreciate that materials can be modified while still retaining their identity, that is, they are the same materials. Chemical change should not necessarily be omitted in the early years, but an emphasis on chemical change would be better left to at least the middle and later primary years, when explicit and carefully considered scaffolding could be used in discussions about the observed changes (Rahayu & Tytler 1999).

How have primary teachers planned lesson sequences about changes in matter that take students' ideas seriously? In the following sections teaching suggestions, based on constructivist principles, are provided. Initially, the focus is on physical change; examples related to chemical change then are described. Physical (reversible) change examples include phase changes (for example, from gas to liquid – condensation, from liquid to gas – evaporation, liquid to solid – freezing and from solid to gas – sublimation) and dissolution. Chemical change examples refer to cooking, rusting and properties of acids. Depending upon classroom discussions some of these examples could lead into discussion about the particulate nature of matter.

Learning about physical change

The contexts for students studying physical change can be many. Examples include the backyard, the household, the kitchen, the supermarket and the farm. Suitable activities for use in lesson sequences can revolve around the properties of water and ice, various solutions (for example, salt, coffee), milk (including making icecream), clay, and slime and oozes (Aubussen & Elliott 1997; Aubussen 1998; New Zealand Ministry of Education 1998). Case studies of upper primary investigations related to freezing (Skamp 1991) and sublimation (Skamp 1992b) have been reported. Both refer to the students' own ideas and investigations of their own questions. The following case study describes how a lesson sequence commenced with the intention of students investigating the properties of hot and cold water and how it became a sequence focusing on condensation.

Case study: a condensation sequence

The teacher of a Year 2/3 class with thirty students commenced a lesson sequence with the intention of her students investigating the properties of hot and cold water. She initially showed her class two pictures, one of children playing at a picnic on a sunny day, the other a snow scene with children skating. The students were asked to give their ideas about the differences, especially relating to the water in the pictures. The students seemed clear about the concepts of hot and cold water. Some questions were raised, which the teacher noted on a wall chart. The teacher listened to the students' concepts and asked them questions to help them clarify their ideas. There was not much interaction between the students about their ideas and they did not challenge each others' ideas because they seemed quite clear about the terms.

The second lesson involved exploration of materials and the raising of students' questions about hot and cold water. The students were divided into groups of four and were provided with different containers, hot and cold water, ice, stirrers of different materials, rulers, measuring containers and magnifying glasses. In this lesson the students handled the materials, observed and experimented before coming together to report. Each group had been asked to have an observation to relate or a question to ask. Much discussion and organisation occurred within the groups and the teacher encouraged the students to challenge each others' ideas. Some activities observed were

- mixing hot and cold water
- pouring hot water onto ice
- putting ice into hot water
- holding rods of different materials in hot and cold water
- looking at hot and cold water (and many other things) under a magnifying glass
- putting hot water in different containers and feeling the outside
- pouring hot and cold water along the desk.

When the group gathered together there were dozens of observations, for example, 'When we put the silver spoon in the water it went grey', but only a few questions to report. To conclude this second lesson the groups were asked to go to their work areas and try to decide on a group question that they could investigate. However, as they sat down there was a similar exclamation from all parts of the room. Many students had observed that 'water bubbles' had appeared on their containers. It was immediately discovered that only the cold water containers had water droplets on the outside and that the best examples were on styrofoam cups. The class regrouped. Six of the eight groups wanted to investigate this phenomenon. The other two groups wanted to know, 'Why does the water look grey when we put a silver spoon in it?' and, 'Can you boil ice?' With the teacher's help the students rephrased the most popular question as: 'Where do the drops of water on the cold cup come from?'

During this second lesson the teacher circulated among the groups, listening to the discussions and taking quick notes about their ideas. One example noted of how students' ideas can be changed through interaction with other students and the teacher is the following:

NEIL	The water bubbles aren't really bubbles because they'd have air in them.
TEACHER	What do you think is in them?
NEIL	Just water
TEACHER	How could we find out?
NEIL	I'll show you. (He found a pin and popped some of the droplets.)

The other group members were satisfied that the 'bubbles' were indeed full of water.

The students were really interested and showed remarkable perseverance in a long lesson that required a lot of concentration. The teacher was a little disappointed that no one asked why droplets appeared on the cold containers but not the hot.

ACTIVITY 9.6

What has happened here?

- This teacher was guided by the interactive teaching approach (see chapter 4) in her planning. What do you think she was trying to achieve in these first two lessons?
- What role(s) did she take to try to reach these goals?
- Did this teacher experience any difficulties? If so, can you suggest any reasons why this may have been the case?
- What happened in the second lesson? What decision(s) did the teacher make here? Can you suggest what might have been guiding her actions?
- What would you have done?

In the third lesson the students' ideas were elicited about what they thought was the source of the water droplets on the cold cup. They did this initially in groups, knowing that they had to report to the whole class. The teacher moved around the groups, helping the students clarify their ideas with open-ended questioning and playing a naive role. She was surprised by the assurance with which most students held their beliefs. When the whole class met, the explanations were listed on a wall chart and numbered. After some discussion and merging of ideas nine acceptable explanations were listed. Several were discarded as being too far-fetched or unrelated to the topic. The nine ideas were:

1 People bumped the desk and spilled the water.
2 **a** The water came through the air holes in the cold cup and mixed with air to form bubbles on the cup.
  b The water seeped through the cup.
3 Wind spilled the water.
4 The water is so cold that it freezes the cup and makes water come from inside to outside.
5 People stamped on the floor and bumped the cup and spilled the water.
6 Water could have spilled onto the outside of the cup when we poured it in.
7 When we put the spoon in the cup it could have overflowed.
8 Little drops, like on cobwebs in the cold mornings, could have come onto the cup.
9 It could have been dew on the cup because it was cold. The dew could have come out of the air.

The ninth explanation came from Jayde when she announced, 'I know the answer because my Poppy [father] told me. It comes from tiny bits of water in the air'. (Jayde's father is a secondary science teacher and had told her this. She admitted though that she really didn't understand what he meant.) This explanation was amalgamated with one from several other students, that the drops came from 'dew' or 'fog' in the air. Most of the students held their explanations quite strongly. Please think about Activity 9.7 on page 363 before reading further.

The fourth lesson revolved around planning the investigations. The students were asked to form groups supporting one of the nine explanations, which resulted in interest groups of a workable size. The groups were given some time to discuss how they would test their hypothesis; a spokesperson had to explain the plan to the class. A lot of

ACTIVITY 9.7

What would you do now?

- What has the teacher done in the third lesson?
- What, in essence, are the nine ideas the students have proposed?
- How do they relate to what you have read about students' ideas on condensation?
- What would you do now? Why?

interaction with other students occurred through questioning and criticism of plans, which resulted in flaws being pointed out and improvements being made. Eventually, the teacher wrote a refined plan to test each proposed explanation. It was numbered to correspond with the explanation and the students who suggested the plan had their names written next to their refined plan.

ACTIVITY 9.8

How would you test the students' hypotheses?

For each hypothesis, decide at least one way you could test the idea. A critical feature of being able to test hypotheses is to identify the variable to be changed so that tests can be planned. For each of the hypotheses the students proposed can you identify the independent and dependent variables (see Harlen 1985a, pp. 58–74; Hackling 1998; and chapter 2) and hence plan a test of the hypothesis? If you are unable to do this, try using if–then reasoning; namely, if the hypothesis is true, then it could be predicted that … (and the effect of a variable change is suggested which could then be tested). Compare your responses to those the students proposed in the fourth lesson; these are in appendix 9.4.

In this fourth lesson the teacher once again helped students clarify terms and questions as well as acting as a recorder. The students worked very cooperatively to plan their tests and were eager to carry them out immediately. The teacher felt that the tests were, in general, very thoughtful, although no group suggested putting a lid on the cup and observing whether the droplets still appeared (which would have not supported the spilling, overflowing and wind theories).

In the fifth lesson, which was quite short, the students in their groups carried out their tests and observed the outcomes. Prior to testing the students had a brief whole-class discussion to remind them about fair testing (a concept with which they were now quite familiar). On moving to their groups there were some accusations of unfair procedures; for example, excessive desk bumping and not observing results carefully. The teacher felt it necessary to call a class meeting to make it very clear that finding that an explanation is not supported is all part of being a scientist.

After the testing two groups had inconclusive results. For example, the group that used a container that they knew water couldn't come through, still observed droplets and couldn't agree whether this supported their explanation that the water had seeped through the foam of the original cup. The whole class gathered to hear each other's results. It was agreed that six explanations had not been supported, two were inconclusive and one – that the droplets had somehow formed from dew or fog in the air – was most probably right. The students wanted to tick or cross their explanations on the chart during this session.

During this lesson the teacher was very busy trying to ensure that the students were keeping on task, ironing out practical difficulties, providing equipment and wiping up water. There were some practical difficulties in the lesson, but the teacher felt that for students of this age the tests were carried out with a fair degree of rigour. (She wondered whether next time she would do the testing one group at a time while the other groups worked at activities not requiring close supervision. This, she felt, would give her more opportunities to interact with the students and to monitor progress.) The teacher also tried to observe and record interactions, which were abundant and interesting. On several occasions the teacher was able to challenge the students' ideas; for example, a group of students was observing to see if water was blown out of a cup with an electric fan:

DEAN	It did blow out – there's water on the floor.
TEACHER	Did you actually see it blow out?
DEAN	No, but it must of [*sic*].
TEACHER	How do you know?
DEAN	There's nowhere else it could have come from.
RACHEL	Yes, we could have spilled a bit when we poured the water in the cup.
DEAN	Oh! Yes!

ACTIVITY 9.9

Generating and testing hypotheses

Harlen (1985b) has suggested four types of investigation lesson sequences. These can be integrated into the interactive teaching approach (see Appendix 4.4) depending upon the questions that arise. The questions could lead to a comparing investigation (see the absorbency case study in chapter 8), or a pattern-finding investigation (see the dissolution example later in this chapter). In this lesson sequence the key question led to a testing hypotheses investigation. (Harlen's fourth investigation type is question raising, exemplified in the dry ice case study also found later in this chapter.)

If possible read Harlen (1985b, pp. 169–71) and identify the similarities and differences between her 'Generating and testing hypotheses' investigation type and what the teacher did in the third, fourth and fifth lessons of this sequence. How could the teacher have varied her decisions?

This activity stresses that teachers aware of different models for sequencing lessons can vary and integrate such approaches to suit their purposes.

The sixth lesson sought the opinion of an 'expert' (Jayde's father). The students knew he was the high school science master and so he was readily thought of as an expert. He was invited to hear the class's findings. Each group explained their idea and how they had tested it. This turned out to be an unexpected bonus as it further helped in clarifying ideas. To promote discussion Jayde's father asked the students open-ended questions. The class teacher again played the role of a naive fellow investigator; she observed, listened and asked questions. She felt that this made the students feel secure in not having to know all the answers because even adults have a lot to learn. Jayde's father brought along a kettle and made steam and showed the students how the droplets did come from the water floating in the air. This provoked a new series of questions, including (at last), 'Why do the drops form on cold things and not on hot?'

The final lesson in this sequence had the students critically reflect and report on their findings in written and pictorial form. It was also to assess the extent to which the students' ideas had changed to more scientifically correct concepts. Working as individuals, the students filled in a pro forma relating to their group's test of their explanation: 'Our aim – to see if …', 'What we did', 'What happened' and 'I think it happened because …'. (The teacher felt later that the pro forma needed changing, especially in relation to the last unfinished sentence, which didn't apply in all cases.) They were also asked to write their own explanation of where the water droplets on the cold cup came from. Two examples are shown in figure 9.1 (see page 366).

Using the students' work and formative observation notes written during the sequence the teacher determined that, at the end of the sequence, ten students held the same idea with which they commenced; six changed to another incorrect idea and eleven changed in the direction of more scientifically correct ideas. Although the teacher was somewhat disappointed with this outcome, she did comment that many other learning outcomes were achieved, for example, students asked genuine questions, carried out their investigations and quite a number were critical of their conclusions and considered alternative ideas.

9.10 ACTIVITY

Overviewing this interactive teaching approach sequence

- Try to identify the various steps and the role(s) the teacher played in the above lesson sequence and then compare and contrast them with a description of the steps and the teacher and student roles in the interactive teaching approach (see, for example, Biddulph & Osborne 1984; Fleer & Hardy 2001; see also chapter 4).
- What do you think are the advantages and disadvantages of the sixth lesson?
- During this lesson sequence what assessment procedures did the teacher use? Compare and contrast them with different ways of using observing as an assessment procedure, for example, questioning, dialogue, listening, assessing processes and products (Harlen, Darwin & Murphy 1977).
- Suggest possible interpretations of the results that the teacher found in the final lesson. In particular, refer to the earlier research findings about students' conceptions of condensation.
- Choose a key concept associated with the physical change of materials and develop an outline of a scheme for a sequence of lessons based on the interactive teaching approach.

Michael

I think water droplets came on the cold cup because it came from the cold air. And onto the cup.

Name} Holly

I think water droplets Came on the Cold cup because. they apeard from the cup and they came therow the cup.

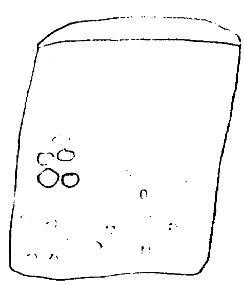

FIGURE 9.1 Two examples of student reports related to the final lesson in the phase change sequence

- because chemical change involves the redistribution of atoms (or the making and breaking of bonds), molecules of the reactants are not conserved
- the molar amounts of new substances that have been formed at any time are related, usually by simple ratios, to the molar amounts of reactants that have been consumed.

(The last mentioned does require specific chemical knowledge, namely, what molar amounts are.)

Burning, Driver 1985; *Chemical Change*, Bucat & Fensham 1995

Appendix 9.4 Children's tests for their hypotheses about why the water was on the outside of the styrofoam cups

1 One person bumps the desk while the other people watch to see if the water spills.

2 **a** Test a foam cup and a container that we know water can't come through (a tin) to see if water comes through.

b Measure the height of the water with a ruler before and after the bubbles come.

3 Put the cup near a fan to see if the water spills.

4 Put cold, though not freezing, water in the cup. Do the drops still appear?

5 Ben stamps on the floor near the cup. Does the water still form drops?

6 Pour water into the cup and watch carefully to see if it spills onto the outside of the cup.

7 Put spoons in the cup again and watch carefully to see if the water overflows.

8 Put two cups out and fill with cold water. Put one in a plastic bag. Suck all the air out and tie a knot. After five minutes, look to see if it has drops on it.

Appendix 9.5 Slime recipe

There are many recipes for various types of slime (see references within the chapter). One common one is as follows.

Ingredients

60 mL of PVA glue
1 disposable cup
1–2 drops of glycerine
food colouring
1 tsp of hand lotion
1/2 cup of borax
180 mL of warm water

Method

Put 60 mL of glue into disposable cup. Add 1–2 drops of glycerine. Add hand lotion. Add borax to 180 mL of warm water to make a solution. Add 60 mL of the borax solution to the glue mixture. Stir slowly until mixture begins to look stringy. When mixture looks stringy add the other 120 mL of borax solution. Mix and stir.

Appendix 9.6 Student ideas and questions about the behaviour and properties of dry ice

Typical descriptions by the students *after the messing around* period were:

> Dry ice is very cold … slides off the table easily … lets of [*sic*] fumes when it slides … makes a noise when you squeeze it.
>
> Nathan