Session 5: Blank Slates or Clever Minds

There are different ways to consider learners: as blank slates open to learning information as it is transmitted to them; or as having clever minds already full of preconceived ideas and personal constructs that affect how the learner understands new information.

Research shows that the ideas and frameworks students bring into the classroom—even in the earliest grades—are already quite well developed. On their own, children make generalizations from their direct experience and through social interaction with other young people and adults. They enter school with boundless curiosity and a great thirst to learn more—but they also have devised quite elaborate mental frameworks to try to explain and make sense of what they have already experienced of the world around them.

These frameworks need to be taken into account as new learning takes place. The *construction* of new understanding results from integration of prior experience and learning, new experience and information, and readiness to learn. There is a large body of research on science concepts that students of different ages bring with them into the classroom. These often mistaken or incomplete ideas are sometimes called "misconceptions" when they are not accurate. They have also been called "preconceptions" to reduce the negative connotations and indicate that they precede more fully-developed concepts.

This view of learning and learners comes from a constructivist approach. Constructivism groups together a number of related learning theories and educational ideas based on the research and practice of educational psychologists, cognitive scientists, and a wide range of educators. It is by no means monolithic, and is no stranger to controversy and debate! With roots in the work of John Dewey, Maria Montessori, Jean Piaget, Lev Vygotsky, Jerome Bruner, and many others, it has branched out in a multitude of directions. Constructivism is a widely used term in science education circles. One of the goals of this session is to provide you with a chance to think about the tenets of constructivism.

Importantly, research has shown conclusively that such personal constructs can be held on to quite stubbornly and creatively! People do not part easily with their established frameworks and previous understandings. When confronted with new experiences and/or data that do not make sense to them, people sometimes still force a new interpretation to conform to their existing framework. To fully achieve new understanding, successive experiences over time are often required, of greater complexity from grade to grade. It is especially helpful to work with substances, phenomena, or models that behave in unexpected (or discrepant) ways that cause students to directly confront their previous interpretations. Reflection upon these discrepant experiences and discussions in which alternate points of view are raised can be instrumental in student development of more accurate conceptions.

Studies show the "tenacious nature" of student preconceptions, but rather than leading to pessimism about learning, the results of these studies have led to strong advocacy by educators for more effective teaching strategies that take into account major misconceptions identified by researchers and provide students with experiences to help them revise their earlier ideas. These methods include active, experiential, "hands-on, minds-on" learning in which students engage in meaningful, relevant activities that allow them to discover, infer, reflect upon, and apply the concepts involved. The role of the teacher is as facilitator of learning, rather than simply transmitting information. It is these kinds of experiences that have been shown to be most effective, over time, in helping students acquire new ideas, deeper understandings, and construct more complete mental frameworks. Again, research has shown that it is when students (of all ages!) grapple with alternate ideas raised by their own experiences that concepts are retained and meaningful learning takes place.

Unfortunately, teachers and other educators are often unaware of or give little attention to these pre-existing ideas. As a result, they do not probe for underlying reasoning or provide sufficient opportunities for active learning. Students may then hold onto their misconceptions, even repeating back information given by the teacher in order to pass a test, but not really believing, understanding, or retaining it.

The body of constructivism/misconception literature is quite rich and our selected reading is by no means the definitive analysis. Rather, the essay by Wynne Harlen on *Children's Own Concepts* offers an introduction to children's ideas about their world–offering examples of student preconceptions from life science and physical science. The reading contrasts how these ideas are or are not influenced by science teaching and suggests possible actions to change student misconceptions.

An excellent further reading for those interested in science misconception theory is Making Sense of Secondary Science by Rosalind Driver, et. al. The book provides a concise, accessible summary of the research that has been done internationally in this area.

Driver, R., et. al., (1994). *Making Sense of Secondary Science: Research Into Children's Ideas.* Routledge Falmer, New York.

2 Look carefully and critically at any worksheets or cards that children use. If these do all the planning for the children, don't use them too often; they prevent children from developing planning skills.
3 Start encouraging children to plan with a fairly simple problem (some suggestions follow), chosen so that you know that they will be able to think through what might be done from their experience.
4 Provide a structure to help them think about the 'things' (variables) to be kept the same, or to be changed, and those to be observed or measured.
5 Organize children to prepare plans in groups so that they combine their thinking.
6 Sometimes discuss plans before the children try them in practice and pool ideas for improving the plans.
7 Always review what was planned after the activity so that experience can be used to improve subsequent planning.
8 Some ideas for starting points for taking children through the steps of planning:

(a) Does hot water freeze more quickly than cold water?
(b) Do road signs show up better if the letters are white on black or black on white?
(c) Do tea cosies really keep teapots warm?
(d) Which kind of surface is best for a kitchen worktop?
(e) Is a plastic carrier bag stronger than a paper one?
(f) Does a crushed ice cube melt more quickly or more slowly than a whole one?
(g) Does a soaked bean seed germinate more quickly than one planted without soaking?

7 Children's own concepts

Roger Osborne

Introduction

I recently spent the day with a class of nine-year-old children and their teacher. During the course of the day the children had a lesson on foods and taste. The teacher was well prepared in that she had undertaken some background reading on the subject and had prepared an activity which would involve children tasting various foods. To begin the lesson the teacher asked the class, 'Why do we eat food?' Thirty eager hands leapt skywards. Answers seriously offered included, 'to help us come alive in the morning (breakfast)', 'to stop us feeling hungry', 'so that we don't get tired'. It soon became apparent that while these ideas were listened to by the teacher, they were not the one or ones that she wanted. Each answer in turn received a cursory nod of acceptance from the teacher but was passed over apparently in search of an answer which the teacher considered to be more scientifically acceptable.

We often pay lip service at least to the idea that before we teach a topic it is desirable to first find out what children already know about that topic. Many lessons begin with a question such as 'Why do we eat food?'. Sometimes we may even pre-test children to find out what they already know. And yet, even if we do this, it normally is simply to find out the 'correct' ideas the children have already acquired. How often in a science lesson are we really interested in the non-acceptable (that is, unscientific) ideas that children hold? We so often ignore, in the politest possible way, all the ideas children have which impinge on the topic being taught, or the questions being asked, but which we deem to be not scientifically acceptable.

What are these non-scientific ideas? Are they important in terms of children's classroom learning? Can we afford to ignore them when we plan what we are going to teach and when we interact with children in the teaching–learning process?

Children's own ideas

Particularly over the last few years, considerable in-depth interview work has been undertaken in various countries to explore children's meanings for words used in science and to determine children's views of the natural and technological world. This work has set out not to establish whether or not children hold acceptable scientific ideas, but to find out the ideas that children hold whatever these meanings and views might be. The work has yielded a wealth of information and has been followed up in certain cases with surveys to ascertain the prevalence of particular viewpoints across representative samples of children at various age levels. All this information, along with interactive observational work in the classroom, has led to the following conclusions:

1 Children have views about a variety of topics in science from a young age, and prior to learning science at school.
2 Children's views are often different from scientists' views, but to children they are sensible, useful views.
3 Children's views can remain uninfluenced, or be influenced in unanticipated ways, by science teaching.

We shall now look at two specific examples to illustrate these points.

Animal

An investigation of children's meanings for the word 'animal' has been carried out by Beverley Bell (Bell, 1981). She showed children pictures of various living things including a cow, a person, a whale, a spider and a worm. For each picture the child was asked, 'In your meaning of the word animal, do you consider this to be an animal?' Irrespective of whether or not the child said yes or no, he or she was asked to give the reasoning which had led to the response. 'Why do you think that?' 'Can you tell me your reasons?' were typical questions asked by the interviewer. Interviews of some of the children surveyed established that many children consider animals to be only the larger land mammals, such as those found on a farm, in a zoo or jungle, or in the home as pets. The reasons used by many children to

categorize something as an animal included number of legs (animals have four), size (they are big), habitat (they live on land) and skin covering (animals have fur). Surveys were designed to establish what percentage of children at various age levels consider a cow, a person, a whale, a spider and a worm to be an animal. Typical results are provided in Fig. 7.1. The 16- and 17-year-old pupils were studying biology, all other pupils were studying science.

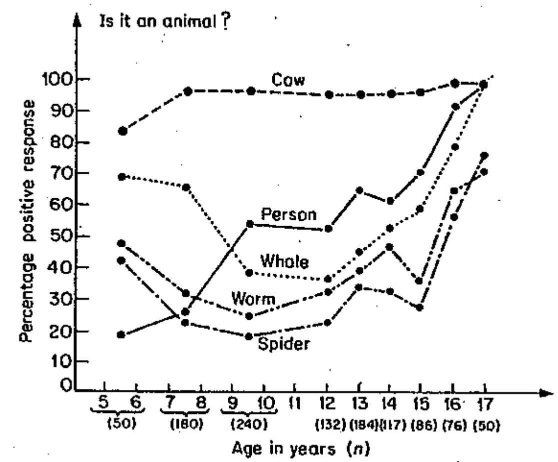


Fig. 7.1 *Survey responses to 'Is it an animal?' (after Bell, 1981)*

The results show that children have ideas about what 'animal' means when they enter school. In some ways the ideas of these young pupils appear more scientifically acceptable than the views held by 12-year-old pupils! The common use of the word animal in statements like 'No animals allowed', 'Animals go to vets while humans go to doctors', 'Animals put humans to shame' (newspaper heading) all reinforce a narrow meaning of the word animal. Teaching which emphasizes sub-categories such as mammals, insects and arachnids may also tend to encourage a restricted use of the word animal. For whatever reason, it would appear that pupils enter secondary school with a limited concept of animal from a biological point of view.

More recent work by Bell and Barker (1982), has shown what happens when secondary teachers attempt to build further learning on a mistaken assumption that 13 year olds have a biologically correct meaning for the word animal. For example it is not helpful if the teacher defines 'consumers' using the statement 'animals are called consumers'!

Electric Current

Children's ideas about electric current in a simple battery–bulb circuit have been investigated in a number of countries (for example, Osborne, 1983). Work which involved interviewing children in the UK, US and New Zealand has suggested that even primary* school children have ideas about how electric current flows in a simple circuit. Four different views about electric current in a simple circuit have been found to be held by children. These four views are described in Fig. 7.2. The majority of primary children given a battery, bulb and wires attempt to light the bulb by connecting the top terminal of the battery to the base of the bulb. Even when these children are shown that a second wire is necessary, some of them still retain, what we call a Model A view of current flow: 'The current goes from the battery

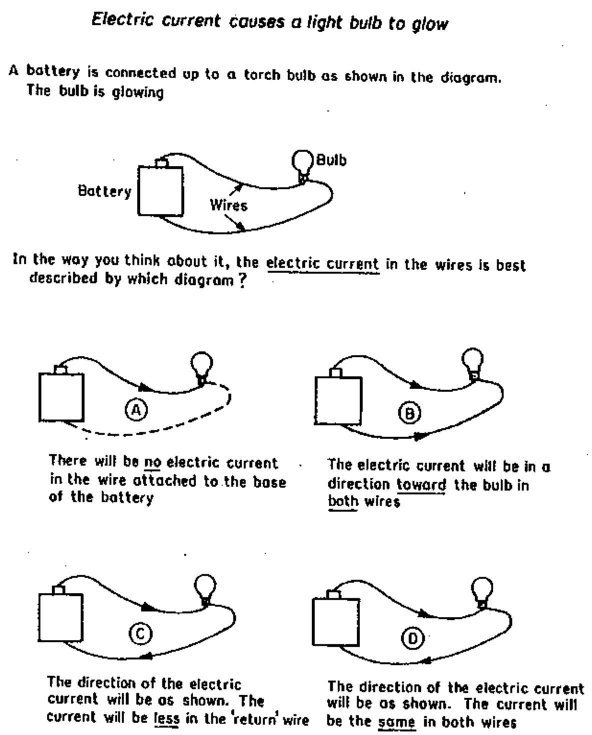


Fig. 7.2 *The four common ideas described by children for current flow in a simple battery–bulb circuit (A–D)*

* In the context of this chapter, 'primary' includes children up to the age of 13.

to the bulb where it is all used up.' The non-current carrying wire is sometimes considered by these children to be 'a sort of switch' (initiates current flow) or a kind of safety wire. Model B is a very popular model among primary children: 'The currents clash in the bulb causing it to light up.' Model C is a view held more frequently by older children. These children seem to appreciate the circulatory nature of current but they consider that 'some current must be used up to make the bulb glow'. Finally Model D is the accepted scientific view. While even some nine year olds hold this view, it is not the most popular view. Young children when asked what they think of Model D tend to reject it. 'How could the bulb light or the battery go flat?' they ask.

Using the question in Figure 7.2, some indication of the prevalence of these views at various age levels has been obtained. The results in Fig. 7.3 were obtained in New Zealand. All pupils of 15 years of age or less were studying science; the 16 and 17 year olds were studying physics.

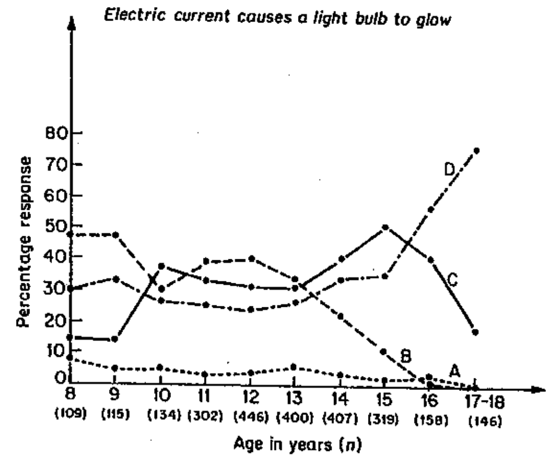


Fig. 7.3 *Survey response to the question shown in Figure 7.2.*

Despite the teaching of simple ideas about electric circuits prior to age 16, the results indicate that a non-scientific viewpoint (Model C) becomes increasingly popular as children get older, and that there is very little change in the percentage of pupils who consider Model D to be the best viewpoint up to age 16. An analysis of the teacher's guide material available to New Zealand teachers on the teaching of simple circuits, suggests that children are assumed to somehow acquire a Model D view of electric current almost immediately they discover that a complete circuit is required for the bulb to light. On the basis of the interviews we have done, we would be surprised if the situation is very different in other countries.

Why are these things happening?

While we have provided only two specific examples of children's ideas and how these ideas differ at different age levels, many other similar examples could be cited. Children's views about *boiling* (what are the large bubbles in boiling water made of?); about *burning* (what are the products of a candle burning?); about *force* (why does a golf ball move through the air in the way that it does?); about *gravity* (is gravity greater or less the higher up you go?); about *friction* (does a person sitting on a slide have any frictional forces acting on him or her?); about *plants* (is a carrot a plant?); about *living* (is a fire living?) and many other topics all yield interesting information about children's ideas and how the prevalence of these views is not always influenced by teaching in the way we might hope (Osborne, Freyberg, 1984). Why are these things happening? Possible reasons include:

1 Children's ideas can be strongly held. Many ideas would appear to develop, as young children attempt to make sense of their physical environment and of the language used by the people about them. The ideas they develop are sensible, plausible and useful to them, within their experience. If experiences are encountered which are in conflict with these ideas, then either the children may appreciate some limitation on the applicability of an idea or they may simply consider that their senses have been tricked. In either case, one or two such experiences, particularly if they occur in the artificial world of the science laboratory or classroom, do not bring about a major rethink of ideas. It is not enough to show children examples which conflict with their ideas; the children must reconstruct their ideas for themselves.

2 Teachers are often unaware of children's non-scientific ideas. This is not surprising. As indicated earlier we are not encouraged to do more than find out the acceptable scientific ideas children already hold. Teacher's guide material rarely, if ever, provides information on those non-scientific children's ideas which nevertheless could influence children's thinking about a particular situation or topic. In the complex world associated with classroom teaching, it is so difficult for a teacher to listen to, analyse, and record children's ideas at the same time as teaching thirty or more children. (See the Appendix to this chapter on page 87, where there is an account of a formal science lesson which illustrates this only too well and from which points equally applicable to other teaching contexts are drawn.)

3 Teachers often make unfounded assumptions about the teaching and learning process. While it might be appropriate when teaching some topics to assume that children have empty heads waiting to be filled up with knowledge, such an assumption about teaching and learning is clearly inadequate in many science lessons. Even to assume that if children have ideas prior to teaching these will be rapidly lost and replaced by taught ideas, seems to be false in many situations. Children *do have* prior ideas, which *do* have considerable influence on their learning.

4 There is often a severe problem of lack of communication between teacher and pupils. When two people communicate, what passes between them are the words and gestures they use to attempt to convey meaning, not the meaning itself. So a teacher has some ideas which he or she hopes to convey by putting them into words, diagrams or symbols. The child may take note of the words, and so on, but from these has to build up a meaning for them. There is clearly a strong possibility that this meaning created by the child is not the meaning intended by the teacher. This possibility is very high if the type of language used by the teacher, or workcard, or textbook writer, is not familiar to the child. Then various things may happen, as Barnes (1976) has so clearly pointed out:

(a) The child may ignore what the teacher is saying.
(b) The teacher may ignore what the pupil is saying (the teacher 'controls' knowledge by using unfamiliar language, consequently the children's ideas are devalued and are only heard when they talk among themselves).
(c) The teacher may insist that the pupils use the 'correct' words and so sound scientific. (We, like Barnes, have seen children praised for 'thinking like a scientist' when it is clear that the children are simply 'making noises which sound scientific'.)

Why do we want to change children's ideas?

If children have strongly held views about how and why things behave as they do, and the views children hold are intelligible, plausible and useful views to them, then one must ask why do we want to change children's ideas? This brings us to the point of asking what are, or should be, the aims of science teaching?

While there can be many possible answers to this question, it is our view that one of the main aims of science teaching, at any level, is to help people make better sense of their world. Better, in that in acquiring a new perspective on a topic or situation the learner considers it to be more satisfactory, that is, more intelligible, plausible and useful, than his or her earlier ideas.

In addition to this aim, it is our view that as teachers of science we want pupils, particularly as they get older, to recognize many scientific ideas as ones that are useful to society. Further we would like our future technologists and scientists to adopt these accepted scientific ideas as their own. Moreover, we would like them to adopt them because *they*, personally, find them to be intelligible, plausible and useful ideas.

Undoubtedly there will be some readers who will agree with the above but who will state that we should leave pupils to develop their own ideas or that one of our problems is that we force scientific ideas on children at too young an age. While accepting this to some extent, our work suggests to us that if pupils are left to develop their own ideas they will not invariably arrive at good scientific explanations. This may well endanger the value of later learning opportunities for it seems quite possible that patterns of thought can ossify as a pupil gets older.

But there is no reason why children should be left to their own ideas. The role of the teacher in the class is to do more than provide equipment and an organization for children to use it. The teacher can use various strategies to intervene constructively in children's experience and thinking.

What can teachers do?

There are no simple answers to the problem of children's ideas limiting the effectiveness of our teaching. However certain things can be suggested.

We need to accept that children's ideas can have an inordinate influence on the teaching–learning process and to appreciate and be sensitive to, the range of possible outcomes of any teaching–learning interaction. Children do not have blank minds that will easily discard old ways of thinking: ways of thinking which have been used relatively successfully to make sense of the world from a young age. We need to appreciate that direct teaching can have surprisingly little affect on these ideas. Taught ideas can be ignored, misinterpreted or stored in a separate

corner of memory, so that a child's way of thinking about how and why things behave as they do is at best unchanged or at worst reinforced by misinterpreted taught knowledge. Alternatively children can become confused or even bemused by the impact of teaching on their earlier ideas. We have interviewed pupils who appear no longer to have any ideas about particular topics that could really be useful to them or anyone else. There are, of course, the success stories, where children develop scientific ideas which are integrated into their way of thinking and which are useful to them; undoubtedly this state of affairs is the one that teachers would like to aim for. However, to be unduly optimistic that this state has been reached in earlier lessons, and to design advanced learning on the possibly false assumption that elementary scientific ideas will necessarily be clearly understood by our pupils, is to build learning on faulty foundations.

If it is accepted that the ideas that children bring to a lesson are of critical importance then we need to be aware of what is already known about children's ideas and about how these ideas can be influenced. There are several groups of researchers working to reveal the nature of children's own ideas relating to scientific concepts. Some examples of their findings are given in Table 7.1.

Unfortunately, less information is available about how to influence children's firmly held ideas. On the basis of what we know already the following suggestions are made:

1 We need to be aware of children's ideas as well as the ideas of scientists about a particular topic.
2 Pupils need to have experience of and be familiar with, the phenomena in which the ideas to be discussed are embedded. Wherever possible this should involve the children in first-hand experience. For example, children need to be very familiar with wiring batteries and bulbs *before* we start discussing ideas about electric current. It is in such practical situations that we need to raise questions in children's minds, to get them to think out answers and encourage them to clarify ideas.
3 If we are to attempt to change children's ideas, we need to encourage children to express their ideas, to present them to others and to appreciate the views of others, including the teacher's view.
4 The value of the modified ideas should be made evident by using them to solve new problems and applying them to make sense of new experience.

The importance of communication, stressed in point 3 but latent in all four points above, cannot be over-emphasized. This is to be valued for the process of a child organizing his or her thoughts as much as for the product in which these thoughts are made available to others. As Barnes (1976) puts it, 'The desire to communicate with others plays a dynamic part in the organization of knowledge . . . What is in question is whether schools do in fact challenge pupils to communicate *their* viewpoints so that they are available to other people with different assumptions.'

Thus, through reasoning, experimentation (or the consider-

Table 7.1 *Some of children's own ideas*

Force and motion	Many children consider force to be something which is *in* a body, acting in the direction of motion. A physicist considers a force acts *on* a body causing changes in motion; force can be acting in a direction opposite to that of the motion.
Friction and motion	Many children associate friction only with motion and do not consider frictional forces exist if two surfaces are not moving relative to each other. To a physicist frictional forces can exist in these stationary situations.
Force of gravity	The physicists' view of the earth's force of gravity is that it gradually decreases as the distance above the earth's surface increases and that it is independent of the presence of air. However, to many children gravity is strongly associated with the presence of air, it increases as the distance above the earth's surface increases, but is zero beyond the earth's atmosphere.
Light	To many children, and to scientists, light travels away from a source. However, to children, how far it travels is considered to depend on how far from the source the visible effects of the light can be observed, e.g. does it appear to illuminate a wall? Hence many children consider light from a candle travels only about a foot in daylight but travels further in the dark! To a physicist the light continues in a straight line until it is absorbed or reflected by some object.
Plants	Children tend to restrict their view of plants to things planted in the vegetable or flower garden. They tend to exclude a number of things that biologists would consider to be plants, e.g. mature trees.

These ideas were found by interviewing children as part of the *Learning in Science Project* in New Zealand (Freyberg, Osborne and Tasker, 1983).

ation of observations and experiences) and communication, the child may realize that there are different ideas from his own and come to perceive the scientific viewpoint as more intelligible, plausible and useful than the originally held ideas. In the Appendix on page 87 is a description of a lesson in which many of the features of learning and teaching just mentioned were sadly lacking. Although it concerns a formal science lesson it nonetheless illustrates the challenge faced by all teachers in the knowledge that children's own ideas are important. It has been suggested (Nussbaum and Novick, 1981) that new roles could well be incorporated into a teacher's activity and into his or her self-image. These roles include:

1 *The teacher as physician*. Here we might think of the teacher as diagnosing that children have particular ideas, where such ideas are known to exist, and discovering children's ideas for topics where children's ideas are not known.
2 *The teacher as listener*. To diagnose and discover children's ideas we need to provide opportunities for children to express these in small groups and in the whole class setting. If children are to express their ideas openly we need to provide a classroom climate where such ideas are valued and listened to.
3 *The teacher as inventor*. Possibly the most difficult task of all, once children's ideas are known, is to be innovative and to invent new ways to help children perceive scientific ideas as more intelligible, plausible and useful than the ones they hold at present.
4 *The teacher as experimenter*. It is important that we evaluate, as objectively as possible, new insights into children's ideas and new ways of modifying children's ideas.
5 *The teacher as researcher*. Good experimentation involves sharing findings about children's ideas and sharing successes and failures about children's ideas with other teachers.

The findings about children's ideas also raise questions about the aims of science teaching, including how and at what age a child should be introduced to an acceptable scientific viewpoint; where this is different from the child's own view of a particular situation or topic. While there has been much discussion in recent years about the inadvisability of introducing scientific ideas at too young an age, it is possible that older children can develop such a complex and inflexible framework of ideas that further learning becomes increasingly difficult. While there are no simple solutions to these problems, we need to base our teaching on realistic assumptions about the teaching–learning process and build on our limited knowledge of children's ideas.

Summary of main points

Children come to science activities with their own ideas about the things that are studied, rather than with empty spaces in their minds ready to be filled with new ideas. Their existing ideas are likely to be rather different from the accepted 'scientific' ones and will strongly influence the sense children make of the activities they undertake. Unless teachers take particular care to find out about children's existing ideas and take deliberate steps to help children rethink their ideas and try out new ones as well as their own, these non-scientific ideas tend to persist and keep out the accepted scientific ones.

The above are some of the findings from research carried out by interviewing children about their ideas on a variety of scientific concepts. The examples described in this chapter are about children's ideas of 'animal' and 'electric current'; findings about other concepts have been mentioned in brief. The possible reasons for the state of affairs revealed by this and other similar research have been discussed. They include the cumulative effect of teachers ignoring children's own ideas, and the problem of communication, when teachers use words in their scientific meaning and pupils take them as having a different, often 'everyday' meaning. Some reasons for wanting to change children's ideas have been proposed and the suggestions made for ways of bringing about change can be summarized as follows.

Guidelines for changing children's ideas

1 Find out what ideas children already have about a phenomenon or situation; what do they think is happening, for what reasons, what words do they use to explain or describe it?
2 Take children's ideas seriously; give them the opportunity to try out their ideas by investigating the objects or situations for themselves.
3 Challenge children in discussion to find evidence for their own ideas.
4 Organize whole-class discussions so that different ideas about the same things can be brought together.
5 Enable children to become aware of ideas different from their own and to try them out.
6 Offer them a scientific view as one worth trying as well as others; don't insist that it is 'right' but let children explore its value for themselves.
7 Provide challenges for them to use new or modified ideas in trying to solve other problems or to make sense of new experience.

Appendix to Chapter 7

To illustrate the kind of evidence which has uncovered the issues discussed in Chapter 7 we give an example of a lesson involving 12 year olds (Tasker, 1982). It is teacher-directed, but activity-based. The class is taught as a whole, but the problems the teacher encounters might be equally prevalent in dealing with groups on the same or different activities.

In this lesson pupils had the experience of heating water in a flask and observing the water turn to steam, recondense in a tube connected to the flask and drip into a beaker. The teacher hoped that through this experience children would develop ideas about the change of state of water in terms of the particle model. In the class discussion at the end of the activity, pupils commented that when the water was heated gas went up the tube. The teacher then stated

'Right, correct . . . OK. That tube is fairly cold on the outside, once the water vapour hits the side of the tube . . . it recondenses into water which comes out the end.'

At this point in the lesson the teacher used volunteer pupils to model evaporation. Five pupils were asked to stand in a line at the front of the class with their adjacent feet touching and with the middle pupil holding the nearest hand of the pupils on each side. The pupils were instructed to wriggle vigorously while the teacher talked.

Teacher: Right, stand in a line and jostle . . . as the water heats more and more they start wriggling and moving a lot faster . . . so people in the middle . . . middle three start wriggling as fast as you can . . . what's going to happen to the people at the ends? (no one answers and nothing happens). Come on you people start really moving.

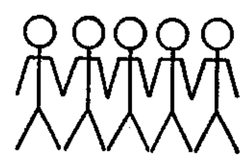


Fig. App. 7.1

Paul: They smack off.
Teacher: (ignores comment) You are not meant to be moving . . . just stand still at the ends . . . come on good shoves from the middle as you are getting hotter and hotter.

(one end pupil stumbles away)

Right . . . OK. One end's fallen off . . . and that's what happens to the particles in the liquid . . . sit down you didn't really do that very well . . . Right, as heat is applied the particles start wriggling and jiggling around . . . and they jiggle the top particles of the liquid up in the form of a gas and it goes up the tube . . . it recondenses and then it comes out the end.

(The class were then given the following instructions)

Write your observations and explain them by talking about particles . . . I want you to explain what happened inside the water in terms of particles as heat was applied . . . I expect to see diagrams explaining and showing particles and what happens.

That the experience had significance relating to particle behaviour was clear in the mind of the teacher – what were the pupils saying and doing?

George: What do we do?
Judy: How do you spell 'gauze' . . . here it is (finds word in a diagram of an earlier investigation) G . . . A . . . U . . . Z . . . E.
Jenny: Equipment is on the board.
Judy: I know.
George: I missed out gauze, burner and tripod . . . how do you spell gauze?
Judy: G . . . A . . . U . . . Z . . . E
Jenny: Look at the board.
Paul: That there is called tripod, that there is gauze, that's the . . .
Judy: Burner.
George: No, that's the burner . . . that's the glass (burner cover).
Teacher: (interrupting) I've written a few words on the board that might help you with your write-up . . . evaporates, recondenses and vigorous . . . particles move in a vigorous fashion so that they were able to lift off the top of the solution.

Paul: That glass thing that you put on . . .
Jenny: It's a rubber stopper.
Paul: (writes label) Rubber stopper.

At this point Jenny, who was ahead of the others, wrote the subheading 'Conclusion' in her book and after it, 'We found that when we put the water on the burner it made air bubbles'. When Jenny was not looking George and Judy copied Jenny's statement into their own books which they then closed quickly before Jenny noticed.

How had the experiences of observation and class discussion influenced children's ideas about the basic phenomena and events involved in the lesson? The extract below is part of a conversation similar to a number held with individual pupils after the lesson.

Paul: When water is boiled it evaporates – turns into gases and goes off from there and turns into air.
Judy: The heat is sort of like . . . pushing out all these little . . . mmm gas . . .
Observer: The gas is in the water?
Paul: I think they are in the water – when it gets heated . . . they come out.
Observer: The gas . . . has that anything to do with water or what?
Paul: It's in the water.
Observer: It's not water?
Paul: No.

At the end of the lesson the observer talked to the teacher, who revealed some dissatisfaction with aspects of the lesson and the unit of work. However these stated dissatisfactions related to equipment and managerial aspects of handling groups of children. Only one comment was made about the scientific ideas that the children might have developed during the lesson.

Teacher: I think the concepts are getting a bit thrashed . . . but actually it's all right – I think they are understanding it, but I think the interest isn't there as much as it was.

To the observer, this comment confirmed that the teacher had no real appreciation of children's ideas. There was no appreciation of the lack of impact, of much of what had been presented, on the children's ideas about changes of state of water.

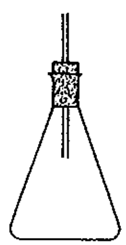
While the number of problems and difficulties with this particular lesson may be atypically large, they reflect in nature the sorts of problems found in many classrooms and discussed in general terms on pages 80–82.

Communication

As far as we were able to detect, ideas of 'particles', 'moving in a vigorous manner', 'evaporates' and 'recondenses', had no impact whatever on the children we observed in the lesson. In fact teacher and pupils appeared to be in two different worlds: the teacher in the world of theory, the pupils in the world of reality. This is something we have observed in a number of classrooms. The children's ideas were only heard in their talk with each other about the burner, the gauze and the rubber stopper. These details seemed to assume more importance than the phenomenon they were observing. Perhaps the lack of encouragement to express in their own words ideas about 'the steam' or 'the water disappearing and reappearing' provided little opportunity to focus their thinking on, or have their thinking challenged with respect to, those things which the teacher considered central to the lesson.

The purpose of the lesson

The original purpose of the lesson intended by the teacher was for children to investigate the expansion of a liquid. This was made explicit on the blackboard (see Fig. App. 7.2)



Expansion of a liquid

Method: Fill a flask with coloured water.
Mark the level of the water in the tube.
Heat the flask using a burner.

Observe what happens to the water level.

Explain why this happens by talking about particles.

Fig. App. 7.2

The apparatus supplied to the children had stoppers with a short length of tubing attached to a length of clear plastic tubing. The children found it extremely difficult to fit the stoppers into full flasks of water. However, they overcame this problem by emptying out some of the water. The purpose to the children then became heating the water, observing the boiling, watching the recondensed water dripping from the plastic tube. As we have seen the teacher changed the 'purpose' of the activity to follow the direction taken by the pupils. This of course does not necessarily happen. In many classrooms only some pupils construct a purpose which is obviously different from that intended. Sometimes, even frequently, pupils construct a purpose subtly different to that intended by the teacher.

One consequence of pupils not appreciating the teacher's intended purpose for a teacher directed activity, or pupils constructing even a subtly different purpose to the one constructed by the teacher, is that the critical design features of the activity may not be appreciated. In the above example, the critical necessity to have the tube immersed in the liquid was not appreciated by pupils, nor pointed out or explained to them.

The significant results

The pupils did not appear to share the teacher's view about what were the significant results of the activity. The pupils focused on the concrete aspects of the activity. What concerned the teacher, the changes of state of water in the adapted experiment, were not really the focus of pupil attention nor seen by pupils as providing interesting and significant results.

The children's ideas

The children's ideas remained basically unaffected by the alternative views presented by the teacher. the teacher's views were presented in a way which tended to make them either not particularly intelligible, plausible or useful, or led pupils to constructions which were not intended. The children's idea that 'the gas in the water comes out when the water is heated' was not challenged. In fact when the interviewer discussed a child's idea at the end of the lesson, the pupil's original ideas appear to have been reinforced. Presumably to Paul his ideas about the bubbles were not only intelligible and plausible to him but also useful in that they 'explained' the observations. Moreover if Paul thought the 'particles in the liquid' which the teacher talked about were the bubbles, then the teacher's statement like 'they jiggle the top particles off in the form of a gas', simply reinforces his view. While the teacher had appreciated that the pupils had constructed a purpose and an activity different to that intended, it would appear that the teacher had not really appreciated the lack of impact of this lesson on the way many of the pupils in the class viewed the changes of state of water.