MAKING SENSE OF SECONDARY SCIENCE

RESEARCH INTO CHILDREN'S IDEAS

Rosalind Driver, Ann Squires,
Peter Rushworth and Valerie Wood-Robinson

Routledge Education Classic Editions

ROUTLEDGE

Making Sense of Secondary Science

What ideas do children hold about the natural world?

How do these ideas affect their learning of science?

Young learners bring to the classroom knowledge and ideas about many aspects of the natural world constructed from their experiences of education and from outside school. These ideas contribute to subsequent learning, and research has shown that the teaching of science is unlikely to be effective unless it takes learners' perspectives into account.

Making Sense of Secondary Science provides a concise, accessible summary of international research into learners' ideas about science, presenting evidence-based insight into the conceptions that learners hold, before and even despite teaching. With expert summaries from across the science domains, it covers research findings from life and living processes, materials and their properties and physical processes.

This classic text is essential reading for all trainee secondary, elementary and primary school science teachers, as well as those researching the science curriculum and science methods, who want to deepen their understanding of how learners think and to use these insights to inform teaching strategies. It also provides a baseline for researchers wishing to investigate contemporary influences on children's ideas and to study the persistence of these conceptions.

Both components of *Making Sense of Secondary Science* – this book and the accompanying teacher's resource file, *Making Sense of Secondary Science: Support materials for teachers* – were developed as a result of a collaborative project between Leeds City Council Department of Education and the Children's Learning in Science Research Group at the University of Leeds, UK.

The late **Rosalind Driver** was Professor of Science Education at the University of Leeds where she directed the Children's Learning in Science Project (CLISP), including the project which led to the publication of *Making Sense of Secondary Science*.

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Making Sense of Secondary Science

Research into children's ideas

Classic Edition

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About this book

Pupils come to science lessons with ideas about the natural world. Effective science teaching takes account of these ideas and provides activities which enable pupils to make the journey from their current understandings to a more scientific view.

This overview of research, which presents information on the ideas pupils bring to lessons, has been used in the development of the Learning Guides in the companion volume, *Support Materials for Teachers*.

Research into children's ideas in science has been carried out in the UK and elsewhere in the world for many years. Many thousands of studies have been reported and more are still in progress. It is impossible, in this publication, to give a full account of all the research that has been done. We hope, however, that the overview that this book provides will give readers an indication of some of the major results in the domains of relevance to the National Curriculum. References to original studies are given for those readers who wish to refer in more detail to the studies themselves.

Introduction to the Classic Edition

The universality of learners' prior ideas and the issue of progression through the science curriculum make this material relevant to both primary and secondary teachers, although it was given the title *Making Sense of Secondary Science*.

This survey of research into children's intuitive, 'prior', ideas was undertaken, not as a project in its own right, but as a necessary prelude to analysing the challenges that pupils face in developing the formal ideas we try to teach them. The focus of the team of teachers who worked with the authors was on these challenges and on the preparation of the accompanying *Making Sense of Secondary Science: Support Materials for Teachers* resource; this research summary provided the underpinning for the science learning experiences.

The publication, as a Classic Edition, of the research summary part of our work shows that it has stood the test of time. It is very pleasing to us, as the three surviving authors, that the influence of the ideas that children bring to their science experiences is recognised as an essential element in their learning. It would have been particularly satisfying to the late Rosalind Driver whose experience and dedication directed the work. It is also gratifying that the book is recommended reading for many teacher education courses worldwide and that it is cited in thousands of research papers, journal articles and student assignments.

It is important to be aware, however, that research has continued worldwide, reinforcing the findings of the persistence and universality of prior ideas, sometimes called 'alternative conceptions' (or, unfortunately, 'misconceptions'). No doubt other prior ideas are being identified and will need to be taken into account. What is more, children themselves will have had new influences. For example, the media, the internet and computer games will have influenced their ideas. They will come to their science learning with background experiences in many ways different from those of the children who were the subjects of research twenty or more years ago.

The intuitive ideas uncovered by research do very often persist into adulthood. Students, trainee teachers and even experienced teachers encountering the research may recognise that they hold these conceptions themselves and may find themselves at the start of the learning process in some topics.

Children in primary and secondary schools will certainly be holding these ideas. Teachers who are aware of common prior ideas will be better able to help learners to open their thinking to new experiences and cognitive development. Children will need to express their own ideas by talking and writing. There will be rich opportunities for science learning to link with the wider curriculum and to contribute to initiatives of thinking skills and literacy across the curriculum.

It is important to remember that observant teachers are researchers. Their observations, especially when shared with fellow professionals, are to be set alongside the formal researches summarised in *Making Sense of Secondary Science: Research into Children's Ideas*.

Since the first publication of *Making Sense of Secondary Science*, developments in new technology have made interactive materials available for learners alongside their practical science experiences. These too will be subject to prior ideas.

The professional status of teachers must be respected in the many different educational systems, with their varying degrees of curriculum control. We, as authors, hope that this summary of research conducted in the past, together with the related *Support Materials for Teachers*, will continue to be a useful tool for focusing on the challenges which pupils face in learning science and which make science teaching so interesting.

Introduction

CONSTRUCTING SCIENTIFIC IDEAS: IMPLICATIONS FOR TEACHING AND LEARNING

Children develop ideas about natural phenomena before they are taught science in school. In some instances these ideas are in keeping with the science which is taught. In many cases, however, there are significant differences between children's notions and school science.

Children's conceptions as personal constructions

From the earliest days of their lives children have developed ideas or schemes about the natural world around them. They have experiences of what happens when they drop, push, pull or throw objects, and in this way they build up ideas and expectations relating to the way objects feel and move. Similarly, ideas about other aspects of the world around them develop through experiences with, for example, animals, plants, water, light and shadows, fires and toys. A 9-year-old boy noticed that it took a few seconds after a record player was turned off for the sound to die away. 'There must be miles and miles of wire in there', he said, 'for electricity to go through for the sound to take so long to stop.' This boy had received no formal teaching in science and yet had developed the notion that electricity was involved in making the sound, that it flows through wires and it flows very fast!

Many of the conceptions which children develop about natural phenomena derive from their sensory experiences. Some conceptions or knowledge schemes, while influencing children's interaction with their environment, may not be represented explicitly through language. For example, children playing ball have developed a range of knowledge schemes about the trajectories that balls take which enable them to throw and catch the ball successfully. Only much later will students have formal opportunities to represent and analyse such motions: yet a knowledge scheme which enables the child to interact effectively when throwing and catching balls has been in existence since the early years of life.

Surveys undertaken in various countries have identified common features in children's ideas and developmental studies are giving helpful insights into the characteristic ways in which these ideas progress during the childhood years. Investigations have indicated that such ideas are to be seen as more than simply pieces of misinformation; children have ways of construing events and phenomena which are coherent and fit with their domains of experience yet which may differ substantially from the scientific view. Studies also indicate that these notions may persist into adulthood despite formal teaching.

Common features in children's conceptions

Studies of children's conceptions about natural phenomena are indicating that there may be commonly occurring features in children's notions which can be mapped out and described. Moreover, these children's notions appear to evolve as they become adapted to wider experiences.

A topic which has been well studied is that of children's conceptions of light and sight. How do children understand how they come to see things? Do they relate light and sight? If so, how? If you ask young children, 'Where is there light in this room?', you can anticipate what they may say. Typically, 5- and 6-year-olds will identify light as the source or the effect; they might identify it as this light bulb or that bright patch on the wall. Later, children will identify something in between the source and the effect. You turn the light switch on and the room is filled with a bath of light which enables you to see things. Later, during the primary phase, some children begin to use the notion that light does travel. When you consider the speed at which light travels, the fact that children are spontaneously suggesting this, is an interesting point. They will argue that light sets off from a source, travels and strikes an object, and because the object is illuminated, you can see it. However, they are less clear about what goes on between the eye and the object. Some children do make a link in terms of visual rays from the eye going to the object – a model which embodies an active role for the viewer; we 'look at' things or 'cast a glance' at objects.

The typical textbook diagram of light being scattered from an object and some of it going in the direction of the eye is, according to the literature, a view that is held by a relative minority of secondary schoolchildren.

An important feature is the similarity in the conceptual models that children from different countries and backgrounds are using. Children's science conceptions are not idiosyncratic, nor are they in many cases heavily culturally dependent. They are shaped by personal experience with phenomena. In schools which have pupils from a wide range of social and ethnic groups teachers are likely to find that pupils' ideas provide common ground for building good working relationships.

A study by Nussbaum and Novak[1] of children's conceptions of the Earth in space revealed a series of five conceptions or, as they termed them, 'notions'. They progressed from the Earth as a flat surface with an absolute frame of reference for up and down, through intermediate notions, to the scientific notion of the Earth as a sphere and up and down being defined in terms of the Earth as a frame of reference (see Figure I.1). This study was replicated in Nepal[2] and the same sequence of conceptions was identified. Figure I.2 shows the percentage of Nepalese 12-year-olds holding each of the five notions. It is compared with the percentage of American 8-year-olds. As the authors of the article comment, 'the remarkable thing to us is not that the Nepali children are slower in gaining the concept, but that the development of these ideas is similar in such widely divergent cultures'.

The social construction of knowledge

Over the last few years there has been a growing emphasis on the process of interaction in learning. It is recognised that learning about the world does not take place in a social vacuum. Children have available to them through language and culture ways of thinking and imaging. Phrases such as, 'shut the door and keep the cold out', or 'dew is falling', provide, through metaphor, ways of representing aspects of the physical world.

Whether an individual's ideas are affirmed and shared by others in classroom exchanges has a part to play in shaping the knowledge construction process. In the following example a group of 13-year-olds was invited to develop their model to explain the properties of ice, water

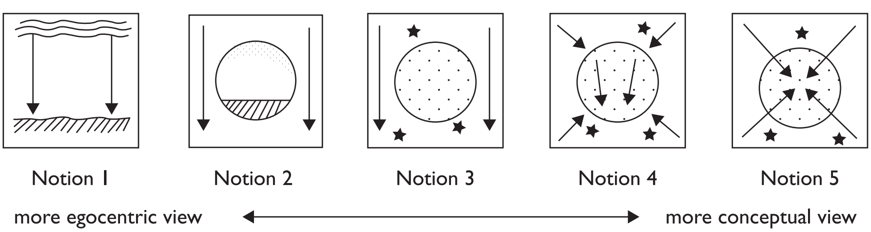

Figure I.1 Children's conceptions of the Earth in space.

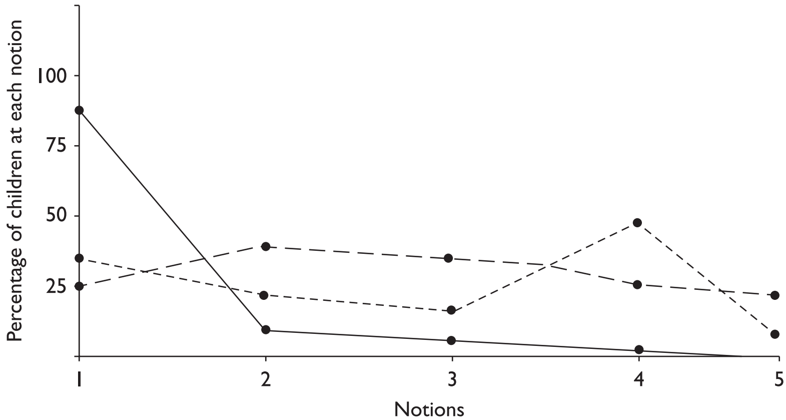

Figure 1.2 Percentage of American and Nepalese children holding each notion of the Earth.

Key: —— American 8-year-olds; .... Nepalese 12-year-olds; —— Nepalese 8-year-olds.

and steam following activities relating to change of state. After an initial discussion in which the idea of molecules was introduced by pupils and adopted, a group started paying attention to the question of bonding.

P1: Water turned to ice? I think it probably strengthens the bonding.
P2: Yeah, that one's not too clear really.
P1: 'Cos we didn't really do an experiment similar to that today. We were just on about melting.
P2: We weren't sure, I mean we are more or less clear how things go from solids to liquids to gases, but not from gases to liquids to solids.
P1: The point is, in the gas the bonding has totally gone.
P2: So how does it happen that bonding comes back?
P1: I suppose it works vice versa, when it's heated it destroys the bonding, when it's cold it, you know, re-makes it.
P3: But how does it re-make it? What does it re-make it with?
[*The question of where the re-made bonds come from continues to exercise the group.*]
P2: If atoms are bonded an atom can't change into a bond to hold the other atoms together, can it?
[*At this point an observer in the classroom intervenes:*]
I: How do you imagine bonding?
P4: Sort of like a string between the atoms.
P1: No it isn't. He [*referring to the teacher*] explained to us about magnetic, magnetism. Some sort of force.
P4: Static electricity or something like that.
P2: Yeah. That kept them together. And I suppose if it was hot then

it wasn't magnetised as much or something and when it was cold it magnetised more.

[*The group seems to have adopted the idea of bonds being due to a kind of magnetic force, and they return to considering how this can account for bonding apparently changing when a substance is heated.*]

P4: When they are hot they vibrate more, so that the static isn't strong.

P2: Yeah, I know, but they vibrate more, and break the bonding and then they finally get to a gas and that's as far as they go . . . but how does it get the bonding back?

[*emphatically*]

P2: When it starts to cool down, they don't vibrate so much.

P1: Ah, yeah. When they cool down, the bonding will be increased so they won't be able to move around as much, that fits in, doesn't it?

[*Note the obvious checking for consistency here. The idea being checked appears to be that due to the greater strength of the bonding at lower temperatures the molecules will not be able to vibrate so much due to being constrained. This idea, however, still begs the issue of how the bonding becomes stronger at lower temperatures as the next pupil's comment indicates.*]

P2: Yeah, but the point is, how do we get the bonding back?

P4: Slow down the vibrating . . .

P2: Slow down the vibrations.

[*One of the pupils at this point has a different insight. He suggests that the force is present all the time.*]

P4: I suppose it's ever present there but . . . yeah, it hasn't got a chance to like grip, grip them, you know and keep them together. Well, where it slows down, you know, it might get to grips with the . . .

P3: A bit easier to keep slower things together.

The outcome of this discussion is a considerable achievement. The pupils have brought together their knowledge that particles are in constant motion and that this motion increases with temperature, with the idea of the force between particles being present all the time, to explain the apparent 'making and breaking' of bonds. The example clearly illustrates that pupils, if motivated and given the opportunity, can bring ideas and prior experiences together to take their thinking forward.

Discussion with peers may serve a number of functions in the process of knowledge construction. It provides a forum in which previously implicit ideas can be made explicit and available for reflection and checking. It provides a situation in which individuals have to clarify their own notions in the process of discussion with others. It can also provide an opportunity for individuals to build on each other's ideas in order to reach a solution.

The extent to which children's conceptual understanding in science is promoted by group discussion has been investigated by Howe *et al.*[3] in a number of science contexts. Her work suggests that the progress in understanding is brought about through the opportunity for each individual to reorganise his or her own ideas through talk and listening.

Pupils need ample opportunity to talk and listen to one another if they are to make sense of their experiences in science classes. The atmosphere of learning will not be that of the 'ordered classroom' with pupils working silently; nor will pupils be engaged in practical 'doing' all of the time. Animated talk and argument are likely to be the hallmark of fruitful science lessons.

The nature of science and implications for teaching and learning

The way in which science ideas are constructed by pupils reflects the nature and status of science as public knowledge: it also is personally and socially constructed. Scientific ideas and theories result from the interaction of individuals with phenomena. They then pass through a complex process involving communication and checking by major social institutions of science before being validated by the scientific community. This social dimension to the construction of scientific knowledge has resulted in the scientific community sharing a view of the world involving concepts, models, conventions and procedures. This world is inhabited by entities such as atoms, electrons, ions, forces, genes and species; it is helpfully organised by unifying ideas and procedures of measurement and experimentation.

Science ideas, which are constructed and transmitted through the culture and social institutions of science, will not be discovered by individual learners through their own empirical enquiry: learning science involves being initiated into the culture of science. If learners are to be given access to the knowledge systems of science, the process of knowledge construction must go beyond personal empirical enquiry. Learners need to be given access not only to physical experiences but also to the concepts and models of conventional science. The challenge for teachers lies in helping learners to construct these models for themselves, to appreciate their domains of applicability and, within such domains, to use them. If teaching is to lead pupils towards conventional science ideas, then the teacher's intervention is essential, both through providing appropriate experiential evidence and making the theoretical ideas and conventions of the science community available to pupils.

The relationship between evidence and theory is not only an important facet of the nature of science, it is also a critical issue in children's learning of science. Just as scientific theories serve to organise and