Some lessons from children's ideas about what it is like inside the Earth

Anthony Blake and Douglas Newton

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What is understanding in elementary science?

Understanding occurs when children establish relationships between elements of information. This happens in their heads and is, essentially, outside the control of the teacher. When faced with something new to understand, the child must infer relationships between its elements and with existing knowledge to form some coherent and durable mental structure. Although we cannot understand for others, as teachers, we support the process by, for instance, making prior knowledge readily available, helping learners translate it into a more relevant form, highlighting patterns and relationships and by making the child think in ways that require inferences to be made, as when they must make a prediction (Newton, 2000).

A child's existing ideas frequently differ from standard scientific understandings. For instance, some children believe it is 'hollowness' that makes things float. To such a child, this alternative view is a perfectly good understanding of flotation and is one that has served them well. Nevertheless, as their formal and informal experience grows, alternative conceptions and theories often change. In reality, they might be replaced by others or continue in parallel with alternatives and simply fade into the background as their limited realm of application makes itself felt. Attempting to establish an understanding that is more or less scientifically acceptable, however, is not always easy. Children often hold on to their alternative frameworks and attempt compromises with what you want them to establish. For instance, they usually begin by thinking that the Earth is flat. Later, they believe it to be like a truncated sphere, having a flat top for people to stand on. In essence, this is a 'synthetic' view of the Earth as it synthesises a flat Earth view with a spherical Earth view. Only much later do children begin to accept a full sphere (Vosniadou, 1994).

There is some agreement about characteristics of children's alternative conceptions:

- knowledge of the physical world develops from birth and concepts and theories are personally constructed; their status is temporary in so far as additional experience or instruction may modify such conceptions,
- concepts and theories are based on the child's prior knowledge and experience of the world around them,
- these frameworks are important to the child,
- the frameworks may differ radically from accepted scientific frameworks, and,
- they can be very persistent. (Osborne and Freyberg, 1985; Clemison, 1990; Wandersee, et al. 1994).

Children's conceptions about the Earth's interior.

Research on children's knowledge of the Earth's interior and deep structure, has been carried out by Lillo (1994), Sharp, et al. (1995) and by Oversby (1996). Lillo found that most Spanish, 10 to 11 year-old children drew concentric layers. Some children also believed that there is a magnet at the centre of the Earth or a molten core which fed surface volcanoes. Sharp concluded that 9 to 10 year old children believed the Earth's interior to be solid, uniform and dark and either hot or cold depending on the effect of the Sun. Oversby discovered that primary children have no appreciation of how earth scientists actually find out what is inside the Earth.

The Earth we live on is a fundamental part of our existence and, therefore, a worthwhile object of study and understanding. Given the largely unexplored nature of children's learning in this area, we decided to investigate the nature of children's ideas of the Earth's interior andwhether children exhibit particular kinds of understanding at different ages that could reflect different mental models of the Earth's interior.

What was done

One hundred and seven, mixed ability children between 7 and 11 years of age from a non-selective inner-city primary school in northern England were tested.

The children were given a sheet of paper showing a circular outline that had four 'tunnels' leading to the centre of the circle. These tunnels were at right angles to one another. The children were asked to draw on the sheet what they thought the inside of the Earth looked like. To ensure that they understood the task and were able to conceptualise what a cross-sectional drawing represented, an apple analogy was used. An apple was cut in half and the children were asked to discuss and draw a cross-section through it, labelling the parts. Although drawings can be a valuable communicative medium for children (Hayes, et al. 1994), some caution is needed when they are used to deduce children's mental representations. As one study of children's drawings of scientists observed, drawings may reveal certain ideas children hold, what is not drawn does not necessarily imply the absence of these mental structures (Newton & Newton, 1998). Tentative conclusions need to be supported by other sources of evidence.

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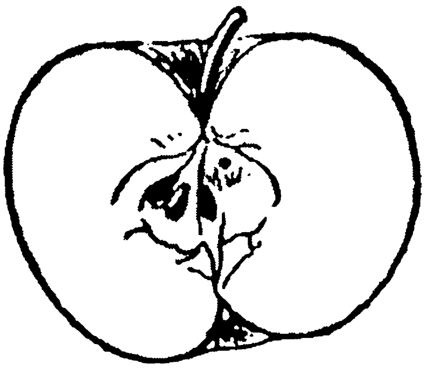


To probe more deeply into children's understanding of the Earth's interior, twenty of the children were also interviewed. The four class teachers chose a child they felt was representative of the rest of class in each of the following broad ability bands: *Above Average; Just Above Average*; *Average*; *Just Below Average* and *Well Below Average*. Interviews lasted between 20 and 30 minutes, and were taped for later analysis. The children were asked to answer questions about the structural uniformity and internal temperature of the Earth, both in writing and in oral, semi-structured interviews. For example, one question was, 'If I dug four tunnels to the centre of the Earth at right angles to each other would I always pass through the same materials?' Another was, 'If I dropped a snowball down one of the tunnels, what might happen to it?' These aimed to discover if children could respond in a consistent way commensurate with a particular mental model. Such questions have been found effective in substantiating inferences about children's mental models (Vosniadou & Brewer, 1992). To illustrate, if a response to the tunnel question was 'yes' and the child's drawing depicted a uniform, concentric-layered interior, such consistency might suggest they were using their model to process their response rather than simply saying the first thing that came into their head. If, on the other hand, the response was inconsistent with the drawing, this could suggest that the child did not have a well-formed mental model of the Earth's interior.

Findings

Children's alternative views of the Earth's interior

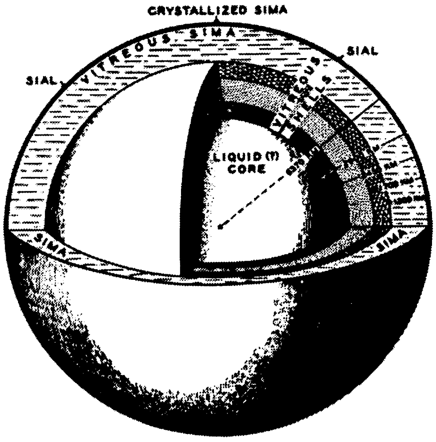
The children's drawings confirmed the expectation that their understanding of the Earth's internal structure is generally unlike that of the earth scientist. The usual scientific understanding of the Earth would include the notion of a uniform, concentric layered and differentiated interior, with a central core, as well as the concept of internal heat. The absence of these characteristics and the inclusion of idiosyncratic features, like magnets and internal seas, suggests a different understanding of the Earth's deep structure.

The majority of the children's drawings exhibited both a central area (80 out of 107) and layers (64 out of 107). Many of these drawings revealed misconceptions, like a central sea, rock, fire or magnet, or a sea at the 'bottom' of the World. The notion of some fairly uniform, concentric layering and a central area increased with the age of the children, as did the use of technical terms like crust and core. The idea of internal heat, represented by the presence of a central fire or lava, however, was supplied by less than a third of the children. These were mainly from classes who had already done some work on volcanoes. Of the children drawing layers, most did not provide details of the crust/surface area. For the minority of mainly older children who did, rock and/or soil/ mud tended to be depicted.

In the non-layered drawings, provided by the majority of the younger children, many lacked scale. Accordingly, these children depicted living things and artefacts inappropriately. The inclusion of sub-aerial features like the Sun, clouds, buildings, roads, trees and people, raises questions about their concept of a cross-sectional drawing, despite the use of the apple analogy. Their Earth's interior often comprised soil, mud or water or even empty space. A few depicted some differentiation of the interior. Their drawings showed horizontal layers or, on occasion, concentric layers. The content of these layers little resembles the current scientific model but some children incorporated a source of internal heat by depicting a central fire in the core region. This tended to increase with age for the majority of the older children drawing concentric layers and including labels like, 'rock', 'lava', and 'gas'. In many instances, however, these children had problems in labelling layers or else retained the idiosyncratic content observed with the younger children: soil/mud; gravel; water; air; fire; magnets and even 'gravity'.

For all drawings, layered and non-layered, various ideas were expressed about the mantle/core areas. Within the mantle area, living and dead material, soil and mud, as well as rock, were frequently depicted. Almost one third of all drawings contained bodies of water, such as an underground sea. The older children were less likely to portray living and dead material, soil and mud, and were more likely to depict layers of rock. Their drawings contained a smaller number of idiosyncratic features (for example, Sun/clouds/sky). Of the 75% of drawings with a core or central area, children drew a variety of features there. A central fire, rock, soil/mud and lava were most frequently shown. The younger children generally preferred soil/mud while the older children were more inclined, if they drew anything at all, to depict rock. An interesting observation is that a quarter of the oldest children depicted a magnet or 'gravity' being located at the centre of the Earth, perhaps in an attempt to synthesise a variety of partially grasped ideas. Only two children showed surface volcanic eruptions sourced by lava from the mantle or core area.

To elicit ideas about how far it was to the centre of the Earth, the children interviewed were asked to estimate how deep one of the tunnels might be. Answers varied widely from 55 feet to millions of miles (and from 100 metres to 10,000 kilometres). The younger children preferred low estimates which, in the main, were under 1000



miles. One of these made a valiant effort to provide a more meaningful response, stating that the distance was less than his holiday flight to Ibiza!

Levels of understanding about the Earth's interior

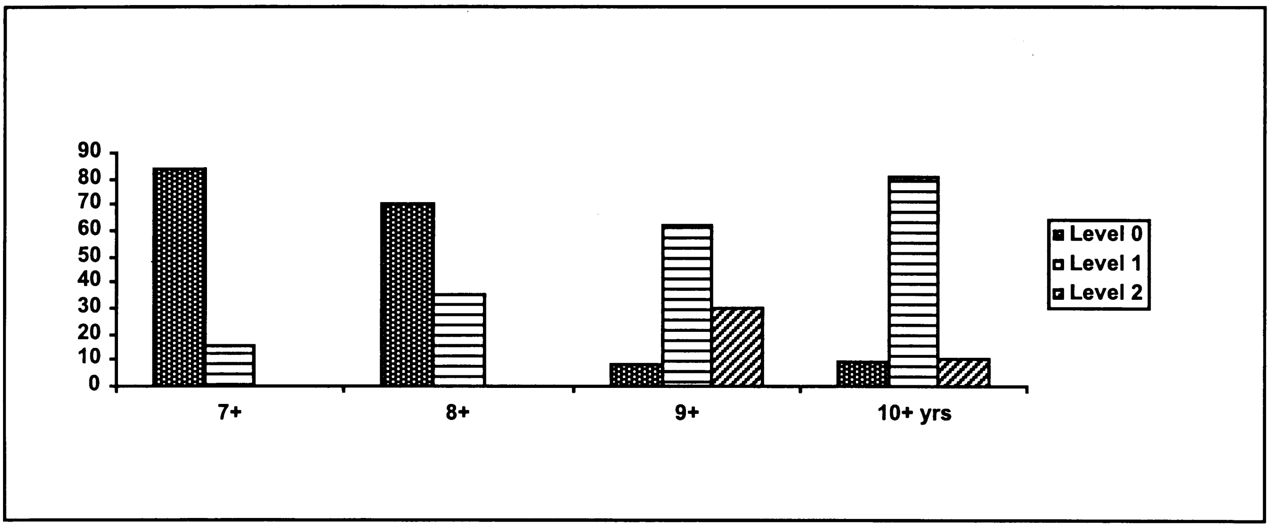
The drawings were evaluated in terms of the descriptive framework they revealed. Features used to categorise these frameworks were the presence of: layers, uniformity of the layers, a central or core area, and the use of technical terms like core/mantle/crust. On this basis children were described as operating mainly within one of four framework levels. These frameworks are hierarchical, with higher levels subsuming earlier levels and approximating more to a conventional scientific understanding:

- **Level 0** drawings would show an absence of appropriate ideas about the deep structure of the Earth, with features like roads, houses, sky, stars and suns portrayed.
- **Level 1** drawings reflect some understanding of the Earth's interior, indicated by the presence of layers. Little or no technical vocabulary is used and misconceptions such as central fires, magnets and underground seas are often present.
- **Level 2** drawings reveal a much better understanding of the Earth's deep structure, with the idea of a differentiated interior demarcated by concentric layers showing internal uniformity and the idea of internal heat. A more technical vocabulary is employed (core, crust) but with some misconceptions (for example, a molten core).
- **Level 3** drawings reveal an idea of the interior consistent with a scientific understanding. Uniform, concentric layers identified correctly as crust, mantle and inner/outer core are identifiable.

The majority of the drawings of the younger children were consistent with Level 0. As might be expected, the numbers at Levels 2 and 3 increased with age. No child in the sample, however, displayed a Level 3 understanding. Responses to the probe questions supported the conclusions about the drawings.

Concluding thoughts and implications

It is not surprising that many of the children's ideas are at odds with those of scientists. With no opportunity to observe the Earth's deep structure directly children are obliged to rely on their existing experience of sub-surface soil content and road work excavations or on relevant secondary sources of information. The younger children in particular attempted to apply everyday experience to the question of the deep Earth's interior and incorporate animals, pipes and bodies of water. Exposure to scientific information in, for instance, formal instruction (Russell, 1993) seemed to make itself felt in the Level 1 and 2 drawings, largely produced by the older children. They tended to include scientifically-consistent features



Percentages of children at different and showing various levels of understanding of the Earth's interior

such as a differentiated, concentric-layered interior and to use scientific words to label them. Only one child attempted to represent the Earth's interior as a three dimensional image, probably replicating some textbook illustration.

Knowing the way children think about the Earth has obvious relevance when teaching about the Earth. Knowing what ideas children commonly bring with them to a lesson on earth science forearms the teacher so he or she is ready to address them. There is, however, a more general message. Children can bring ideas with them and, instead of abandoning inappropriate ideas and accepting what they are taught, they reconcile the new with the old in a synthesis that is plausible to them. This means that teachers need to monitor the effects of their teaching closely. It is possible for children's answers based on a synthetic mental model to pass muster as more scientific than they are. What children may do is use that part of the synthesis that gives teachers what they want to hear. A fuller picture of a child's understanding often needs more than a routine question or two. An opportunity for extended science talk may help here as it provides a chance for children to express an understanding in different contexts and, at the same time, reveal more of the framework they have constructed (Lemke, 1990). Such talk might be stimulated by, for instance, a picture, a story, an artefact, an event, or some practical work. Opportunities may not, however, present themselves spontaneously. They need to be deliberate and allow sufficient time for extended talk on the part of the children. If they are rushed or impatiently handled, they can deteriorate into quick question and answer sessions that reveal little about what truly underpins a child's scientific thinking.

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