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# A constructivist approach to astronomy in the National Curriculum

## **John Baxter**

Pupils do not come into their lessons as empty pots ready to be filled with pearls of wisdom. Frequently they have formed their own notions for many of the basic astronomical events. In this article this point is discussed in the light of research findings, and is illustrated with some examples of pupils' thinking.

One of the most cogent images depicting the birth of man's modern understanding of the universe features a medieval monk pulling back the sphere of primaeval perception to reveal the cosmos which lay hidden behind his primary impressions (see figure 1).

The monk's view, although dangerously contraversial at the time, has permeated almost all cultures over the past 400 years, and it is now commonly assumed that adults and children have drawn back the same sphere-like veil to gain a similar view. But over the past decade there has been a growing body of evidence that throws doubt on the assumption that adults and children are post-Copernican in their notions of planet Earth in space. The research shows that pupils frequently come to their lessons having constructed their own explanations for many of the easily observed astronomical events, and that these children's notions or 'alternative frameworks' (Driver 1983) are at variance with the accepted view.

Nussbaum and Novak (1976) have shown that children's concept of planet Earth in space develops from a naive flat-Earth notion through a series of phases towards the accepted view. Baxter's (1989) survey of children's understanding of basic astronomy supports the findings of Nussbaum and Novak (1976), and show that pupils' ideas are commonly pre-Copernican in structure, frequently resembling ideas supported in the past, as man's understanding of the solar system developed. This confirms McCloskey's (1983) claim that as students' understanding of a scientific topic develops they recapitulate the main features of its historical development.

Although the surface features of the ideas children use to explain day and night, phases of the Moon, planet Earth in space and the seasons vary from one context to another, a number of phases in the underlying conceptual representations that tend to underpin pupils' explanations can be identified. These are represented in figure 2.

Gunstone *et al* (1981) have shown that pupils' notions are tenacious and highly resistant to change; they are, therefore, likely to pass into adulthood. This has been confirmed by the survey of Durant *et al* (1989) which revealed that adults are frequently confused about many aspects of science including astronomy.

It appears that misconceptions about basic astronomy are not peculiar to Great Britain: a poll carried out in France (Acker and Pecker 1988) showed that about 33% of the public still believe that the Sun orbits the Earth. Similarly naive notions have been observed in America by Sadler and Luzader (1988). Seemingly, Aristotle and Ptolemy are alive and well in the way people formulate their own notions about the basic astronomical events.

Research into children's ideas about other areas from science (Russell *et al* (1989), evaporation; Linder and Erickson (1989), sound) shows that, as with astronomy, pupils construct their own explanations for the phenomena they observe. This growing body of data on alternative frameworks has given rise to the 'constructivist' or alternative conceptions movement (ACM) (Gilbert and Smith 1985). The main axiom of the ACM is that a child's alternative framework is analogous to a scientific

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Figure 1. A version of the 'medieval' view of the cosmos. (This woodcut is not what it is often claimed to be. It is pure art nouveau, first published by Camille Flammarion in 1888.)

theory, and will only be exchanged when it is challenged and fails to hold good in the light of new evidence.

Gilbert et al (1982) and Solomon (1983) have observed that 'telling' pupils the right answer does not necessarily result in their discarding their alternative framework in exchange for the taught notion. Frequently it results in the formation of a hybrid notion, a mix between the pupil's alternative framework and the taught idea.

Millar (1989) points out that the ACM has brought science education research into the classroom. But research into alternative frameworks usually involves lengthy interviews with pupils to uncover their particular notion. Pupil numbers and limited time preclude this as a classroom activity, and a majority of teachers are still distanced from the research, as the transition from research data to classroom practice is not always clear. There are two levels at which the ACM can influence and enhance classroom practice:

Level 1. By developing teachers' awareness of the commonly occurring alternative frameworks for the particular topic being introduced. This can be achieved by including a summary chart of research data in the teachers' guide to a topic, as in the RLDU 'Earth in Space' pack (Baxter and Sage 1990, see figure 3). Teachers can then organize their teaching around the presentation of evidence to show that these commonly occurring alternative frameworks do not hold good when challenged.

Level 2. During a level 2 approach pupils identify their own particular explanation for the topic being studied, and then put the notion to the test to discover if it holds good; thus following the scientific process:

IDEA  $\rightarrow$  TEST  $\rightarrow$  CONCLUSION.

## Phase

## Phase 1

Planet Earth saucer-shaped and static. North 'up' and South 'down'. Changes in astral bodies caused by familiar and near objects.

Diagram typifying pupils' notion



#### Phase 2

Earth round but commonly thought of as central and static. Naive notion of gravity still persists. Astrat bodies can move to cause observed phenomena but their movement is represented as 'up', 'down', 'right' and 'left',



#### Phase 3

The same naive notions about the Earth and gravity still persist, but astral bodies are now seen to move in orbits. This orbital motion is seen as Earth-centred.





## Phase 4

The present heliocentric view and its associated gravitational ideas.

Figure 2. Phases in the conceptual representations that underlie pupils' explanations.

## TOPIC AND TYPICAL AGE

## MISCONCEPTIONS

PLANET EARTH IN SPACE

**AND GRAVITY** A.T. 16 Level 2, 7, 9.

## 7 - 9 Years

Ideas of pupils reflect the primitive view. Pupils will use arguments similar to the Church Fathers in support of their notion.

## 9 - 12 years

Round Earth notion well established but people shown living on the top half with their heads pointing towards the North Pole

### 12 - 14 years

People shown living all over the Earth but notion of up and down still persists.

#### 14+ years

People shown living all over planet Earth and positioned so that their feet are pointing towards the Earth's centre. Correct notion of up and down



Although most pupils from the age of nine years will say that the earth is round, questioning often uncovers flaws in their concept of the Earth in Space concept.







Many pupils - and adults - think that there is no gravity on the Moon. When asked "Why don't spacemen on the Moon float away ?" the most common answer is that they have lead in their boots. Floating, sinking and gravity are commonly confused. It is often thought that as there is no atmosphere on the Moon there is no gravity

Figure 3. Summary chart of research data from the 'Earth in Space' pack. (© County of Avon.)

Clearly, a level 2 approach will be more likely to challenge all pupils' alternative notions, but, as the examples given below demonstrate, the process of updating an alternative idea by designing a test to challenge the child's original notion is not a straightforward process of:

IDEA  $\rightarrow$  TEST NOTION  $\rightarrow$  REFORMULATE.

## Using a level 2 approach to challenge pupils' notions about the seasons

The examples of pupils' responses given in this paper were obtained from a group of third-year pupils of average ability attending a comprehensive school in the South West of England. Astronomy features for two 35 minute periods for six weeks, and forms a part of the third-year modular science course.

During the early stages of the astronomy module pupils are introduced to the idea that scientific theories are always undergoing change. Examples are taken from early notions on planet Earth in space; a time when many of the most highly respected thinkers believed that the Earth was saucer-shaped (see Lactantius circa AD 225). By making reference to examples from history, pupils are made to feel more comfortable about identifying their own notions when they discover that their ideas, although incorrect in the light of scientific advancement, were once the popular view.

The examples of pupils' responses using a level 2 ACM approach given below were obtained during a typical lesson. The discussions with pupils were brief and more closely represented the discussions that take place between a teacher and pupil during the course of a normal science lesson.

Figure 4. Richard's diagram.



Pupils were first asked to draw and write about what they think causes the seasonal changes. They did this in silence. Each pupil then made the seasons model (see RLDU 'Earth in Space') and used it to challenge their idea. If their idea did not hold good, they were asked to write about how they had to change their thinking.

As expected, most pupils thought that the Earth moves away from the Sun during the winter although most of the other alternative frameworks identified during the pupil survey reported in Baxter (1989) also appeared. For most pupils the idea that the Earth is farther away from the Sun during the summer was such a contradiction of their everyday sensory experience that it tended to dominate their thinking. It was common for pupils to give this as the cause of the seasons. The examples below make this point, and also demonstrate that concept change is sometimes resisted.

Here, the teacher (T) is asking Richard (R) about his work on the seasons (see figure 4).

- T: 'Richard, what did you say was the cause of the seasons: can you explain your drawing?'
- R: 'Well, it's this part of Earth facing the Sun. When this is, it's summer.'
- T: 'O.K., what about winter then?'
- R: 'Well, it's the same only this part' (points to other side of Earth) 'that turns and they get summer.'
- T: 'Why did you think it's colder here?' (Points to part of Earth not facing the Sun.)
- R: That's 'cause it's further away from the Sun there.'
- T: 'Did you have to change your idea after using the model?'
- R: 'Yes. The nearer the Sun is to Earth it's winter.'
- T: 'But you have written something here about the angle of the Earth. Does this make any difference?'
- R: 'Yes, it turns us away in the winter when we are closer.'

Clearly, Richard, in common with many pupils, was so taken with this challenge to his own sensory experience that he was unable to see beyond this new piece of information.

The other point that emerges from Richard's own explanation for the seasons is that he has chosen to forget about the cause of day and night (he had worked on this topic during'the last lesson and was quite clear on this). His diagram shows the Earth taking one year to spin on its axis. This is a common feature of pupils' alternative frameworks on astronomy: one notion contradicts another. Richard was not challenged on this part of his answer as he had used the model before the teacher got around to him. But in all probability he would have done as the great majority do: use the notion of the spinning Earth to explain day and night, and make the Earth, or the Sun, move away.

A similar trend is seen in Linda's explanation (see figure 5). There was no discussion with Linda. Her explanation is very similar to Garry's, and it is difficult to see how she can explain both the seasons and day and night.

After using the model she has changed her idea but places an emphasis on the Earth being closer to the Sun during the winter. Like Richard, the idea has dominated her thoughts. She has also retained something of her original idea in as much as she still retains the 'facing the opposite way' part of the explanation. This desire to support their original notion is a common feature, and it appears that many pupils will go to considerable lengths to see the new evidence as supporting their idea.

Anthony (see figure 6) is very protective about his original idea, claiming that it was 'almost right'. The part played by the Moon in his first idea is clearly wrong, but he chooses the more gentle phrase 'I think I was wrong'. He has either not noticed (which is unlikely as the teacher circulated around the groups drawing pupils' attention to the angle) or refuses to acknowledge the importance of the angle of the Earth's axis to the plane of its orbit. His attempts to protect his original idea are noticeable in the short interview

Figure 5. Linda's diagram.



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Figure 6. Anthony's diagram.

carried out just after he had written about how his idea had changed.

- T: 'Anthony, did you have to change your idea about the cause of the season?'
- A: 'Well a bit, but not much, I got it almost right.'
- T: 'What bit of your thinking did you have to change?'
- A: 'Well, it was just that bit about the Moon, but I didn't say it was the reason, just it may be.'
- T: 'Use your model to show me how we get different seasons.'

He picks up the model and orbits the Earth around the Sun.

- A: 'Well, it's like I said, the Earth orbits the Sun and we get the seasons.'
- T: 'Where will the Earth be when it's winter North of the equator?'

He places the Earth in the correct position with the angle of inclination directed away from the Sun.

- A: 'It's winter now.'
- T: 'What's special about this position; what makes it winter?'
- A: 'Earth has gone around to here, and here is where winter is.'
- T: 'O.K., but what makes it winter here' (takes model and moves Earth to summer position) 'and not here?'
- A: 'It can't be winter there 'cause we're facing the Sun.'
- T: 'What makes us face the Sun?'
- A: 'Well, it's this angle here' (points to the wire axis).
- T: 'Can you now tell how we get the seasons again, but this time mention the angle.'
- A: 'We go around the Sun like I said and we get winter here 'cause we're angled away from the

Sun. And when we get to there it's summer and we're facing the Sun. This is where summer is and this is where winter is' (he orbits the Earth around the Sun while saying this).

The evidence from these brief interviews suggests that pupils, like many scientists, attempt to interpret their results so that they support their original idea. Those pupils who attempt to protect their original idea appear to be faced with a crisis (like scientists during the demise of Ptolemaic cosmology), and like scientists (Donnelly 1986) appear to be actively hostile to changes in theoretical structure. Paradigm shifts seem to be equally painful for both scientists and pupils.

The tendency for pupils' explanation for one astronomical phenomenon to contradict their explanations for another is a common feature of pupils' alternative frameworks about astronomy. This fact can be used as the first test pupils apply to their notion. For example, after pupils have given their explanation for the cause of the seasons, they can be asked if their explanation will work in the light of what they know about the cause of day and night. For many pupils this will be the first piece of evidence to lead them towards updating their original notion.

A level 2 strategy may take on the following sequence:

(i) Pupils to write and draw about their explanation for the cause of the seasons. This is to be carried out on their own, in silence.

(ii) Teachers ask pupils to look at the explanation they have just given and ask them to see if their idea contradicts their explanation for the cause of day and night.

(iii) Make and use the RDLU seasons model to discover if their notion holds good.

(iv) Update their notion if necessary. Write about how their new idea is different from their original one.

Figure 7. New view of the cosmos (with apologies to Camille Flammarion).



The above sequence offers itself for modification; for example, after stage (i) pupils can explain their ideas to their partners, thereby improving communication skilss (see Science in the National Curriculum p 71) and confronting their original notions. Stages (ii) to (iv) can then follow.

## Discussion

There is a growing body of research data (several hundred published studies, Millar 1989) which demonstrate that pupils do not come into their lessons as empty pots ready to be filled with pearls of wisdom, but that they have already formed their own explanations for many of the topics they study in school science, including astronomy.

If we accept the view that learning involves pupils in a process of conceptual change, then a knowledge of the initial conceptions that they bring with them into lessons becomes important, as it provides a basis for the design of teaching material which addresses those ideas (Driver and Oldham 1986). Such initial conceptions form a starting point from which pupils can test their ideas, and modify them should they not hold good in the light of their new experience.

If we adopt a teaching strategy which has as its starting point the pupils' own explanations, then the teacher becomes a researcher, also observing and collecting age, gender, regional and ethnic alternative frameworks, for use during the lesson in progress or at a future date, thereby placing research firmly in the classroom—where arguably a good proportion belongs.

Attainment Target 16 of the National Curriculum for science offers a number of opportunities to utilize pupils' notions about basic astronomy at either a level 1 or level 2 ACM teaching strategy. By placing pupils in a situation where they confront their original ideas, much of the astronomical ignorance that appears to pass into adulthood can be challenged, and our pupils will be encouraged to emerge from their pre-Copernican world view. Perhaps then we can recarve Flammarion's woodcut (see figure 7) knowing that our pupils have pulled back their own sphere-like veil to catch a glimpse of the real universe which lies beyond their primary perception.

#### References

- Acker A and Pecker J C 1988 Public misconceptions about astronomy The Teaching of Astronomy. Proc. 105th Coll. International Astronomical Union (Cambridge: Cambridge University Press) pp 228-37
- Baxter J 1989 Children's understanding of familiar astronomical events Int. J. Sci. Educ. 11 502-13
- Baxter J and Sage J 1990 The Earth in Space (Bristol: Resources for Learning Development Unit, RLDU)
- Donnelly J 1986 The work of Popper and Kuhn on the nature of science Science in Schools ed. J Brown et al (Milton Keynes: Open University Press) pp 19-31
- Driver R 1983 The Pupil as Scientist (Milton Keynes: Open University Press) p 3
- Driver R and Oldham V 1986 A constructivist approach to curriculum development in science *Studies in Sci. Educ.* 13 105-22
- Durant J R, Evans G A and Thomas G P 1989 The public understanding of science Nature 340 11-4
- Gilbert J K, Osbourne J and Fensham P J 1982 Childrens' science and its consequences for teaching *Sci. Educ.* **66** 623-33
- Gilbert J K and Swift D J 1985 Towards a Lakatosian analysis of the Piagetian and alternative conceptions research programmes *Sci. Educ.* 69 681-96
- Gunstone R F, Champagne A B and Klopfer L E 1981 Instruction for understanding: a case study Aust. Sci. Teach. J 27 (3) 27-32
- Lactantius c AD 225, see Draper J W 1875 History of the conflict between religion and science *Lactantius:* works (Farnborough: Gregg International) 1970 edn, pp 63-7
- Linder C J and Erickson G L 1989 A study of tertiary physics students' conceptualisations of sound Int. J. Sci. Educ. 11 491-501
- McCloskey M 1983 Intuitive physics Sci. Am. 248 122-30
- Millar R 1989 Constructive criticisms Int. J. Sci. Educ. 11 587-96
- Nussbaum J and Novak J D 1976 An assessment of children's concepts of the earth using structured interviews Sci. Educ. 60 535-50
- Russell T, Harlen W and Wall D 1989 Children's ideas about evaporation Int. J. Sci. Educ. 11 566-76
- Sadler P M and Luzader W M 1988 Science teaching through its astronomical roots *The Teaching of* Astronomy. Proc. 105th Coll. International Astronomical Union (Cambridge: Cambridge University Press) pp 257-76
- Solomon J 1983 Learning about energy: how pupils think in two domains Eur. J. Sci. Educ. 5 49-59