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Children's understanding of familiar astronomical events

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In this paper I describe the notions used by children aged 9–16 years to account for a number of easily observed astronomical events. General features in the development of the notions are identified and historical parallels are noted.

The data presented come from a wider study intended to develop materials and approaches for teaching astronomy as part of the science curriculum of all pupils. An indication is given as to how the findings of the survey are being used in developing appropriate curriculum materials.

Introduction

Children's first perceptions of a wider world outside their home often feature some of the easily observed astronomical events. Day and night, changes in the Sun, Moon, stars and seasons are compelling components in the lives of young people both in terms of direct experience and as features in many nursery rhymes and story books. It is now well established that children construct their own ideas and meanings for the events they observe in the natural world long before they receive any formal education. Research into childrens' concepts of the Earth as an astronomical object confirms this view. Nussbaum and Novak (1976), Nussbaum (1979), Mali and Howe (1979) and Sneider and Pulos (1983) have all shown that childrens' ideas of the Earth in space and the gravitational field develop from a naive flat Earth notion through a series of phases to the accepted view. The cross-cultural studies of Mali and Howe (1979) and Klein (1982) have shown that similar notions are present in different cultures, and that they generally exhibit the same phases during their development.

Parallels have been drawn between the ideas that children (and scientifically naive adults) use to account for a range of physical phenomena and those that have appeared in the history of science (McCloskey 1983). Galileo's letter to the Grand Duchess Christina suggests that he too was aware of the untutored view of the ordinary man when he claimed that certain passages in the Bible – namely those on the shape of the Earth – should not be taken literally because they were couched in a language 'according to the capacity of the common people who are rude and unlearned'.

In this paper I describe those theories that children use to account for a number of the easily observed astronomical events and indicate how these theories can resemble ideas supported in the Middle Ages and how they can undergo a similar evolution during their development. Further, I indicate how the findings are being used in developing appropriate curriculum materials.

The data presented come from a wider study intended to develop materials and a strategy for teaching astronomy as part of the science curriculum of all pupils in UK schools.

Methods of investigation

In this study children's theories about four astronomical domains were investigated:

(i) planet Earth in space and the gravitational field;
(ii) day and night;
(iii) phases of the Moon; and
(iv) the seasons.

The sample of pupils aged between 9 and 16 years was taken from pupils attending a comprehensive school in a semi-rural area of south-west England and its four feeder junior schools. Astronomy does not feature in the curriculum of these schools at present, although the place of the Earth in the solar system would be included in school geography. Therefore, most notions pupils hold represent personal constructs, or are the product of informal education.

A two-stage process of data collection was used. First a sample of 20 pupils aged between 9 and 16 were interviewed individually about their theories concerning the four domains.

The sample covered the full range of abilities (based on their teachers' judgements) and included five pupils from each of the age groups 9–10, 11–12, 13–14 and 15–16, including equal numbers of girls and boys.

The interviews were audiotaped and transcribed, and records of pupils' drawings were kept. The commonly occurring conceptions used by these pupils were identified from the diagrams and explanations given. These were used to construct an astronomy conceptual survey instrument. This consisted of a series of statements with supporting diagrams. Pupils responded to the statements and their accompanying diagrams by placing a tick on the face which best represented their view (Harty and Beall 1984) (see the example in figure 1).

The instrument was administered to a representative sample of 48 boys and 52 girls from the same four age groups as the interviews. Prior to administering the survey, pupils were given practice items so that they became familiar with the method of recording their responses. They were also told that the spoken statements were a collection of peoples' ideas, some correct and some incorrect, and that the researchers were interested in what they thought. The survey was then conducted in silence.

Results of the survey

For clarity of presentation results from the interview for a particular domain are followed by the results obtained by using the astronomy conceptual survey instrument for that particular domain. The prevalence of particular notions in each of the four age groups is represented diagramatically. The results from the survey instrument represented in the prevalence diagrams show the percentage frequency of pupils ticking either the 'I know it is true' or the 'I think it is true' box in response to each notion. (In some cases pupils selected more than one notion.)

Planet Earth and gravity

Pupils were asked in interview to imagine that they had taken off from Earth in a space rocket. They had been travelling away from Earth for a day and looked out of

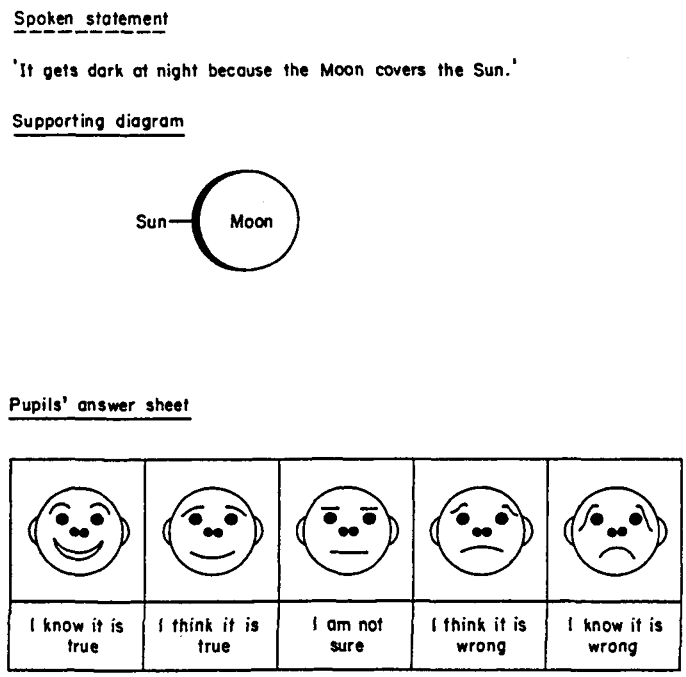


Figure 1. Example of question in the survey instrument.

the window towards Earth. They were asked to draw how they thought the Earth would look.

After completing their drawing they were then asked to draw in some people to show where they could live, some clouds, and then rain falling from the clouds.

Pupils' drawings fell into four distinct notions (see figure 2); the prevalence of each notion is shown in figure 3. The four notions uncovered were similar to those first proposed by Nussbaum (1979). The most popular notion, and one which gained support with age, was that of the round Earth but with notions of vertical up and down still persisting. Support for notions 1 and 2 declined with age. It is notable how few pupils even in the older age group used notion 4, the accepted notion. A majority of pupils produced a world view which showed people living all over the Earth with up directed towards the North. This suggests that Newton's idea of gravity does not feature in most pupils' thinking. (This is supported by other studies, for example Watts and Zylbersztajn (1981) and Preece (1985).)

Day and night

Interviewees were asked to explain, with a diagram or by using polystyrene spheres, which were provided, why it gets dark at night.

The responses were of six distinct types (see figure 4). The frequency with which pupils in the survey selected each type of response is given in figure 5.

As children got older the prevalence of ideas relating to directly observable features (e.g. the sun being covered by hills or clouds) decreased slightly and explanations involving the movement of astronomical objects were more frequently

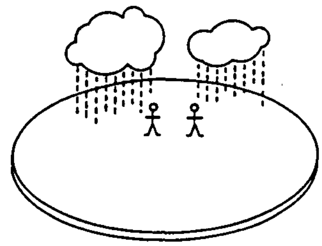
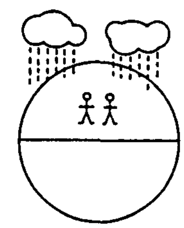
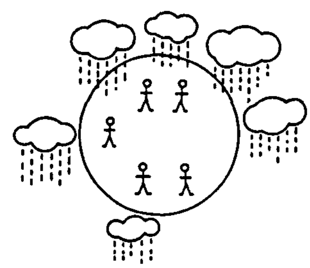
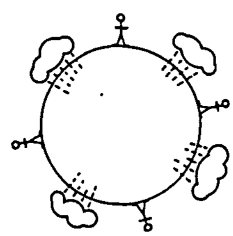
Notion	Drawing
Notion 1 Earth shaped more like a saucer.	
Notion 2 Earth sphere shaped but idea of up and down still persists. People only live on upper half.	
Notion 3 Earth sphere shaped. People living all over the surface but idea of up and down still persists.	
Notion 4 Correct view. People living all over the Earth and 'down' towards the centre of the Earth.	

Figure 2. Pupils' notions about planet Earth and gravity.

selected. For some age groups the total percentage exceeded 100%, suggesting that in these cases pupils were not so sure about which notion they ascribe to.

Phases of the Moon

Pupils were asked in interview to draw some of the Moon shapes they had seen and were asked to say if there was any regularity to its changes from shape to shape. After making their drawings they were asked to explain – using the polystyrene spheres or by drawing – how the Moon was able to change its shape.

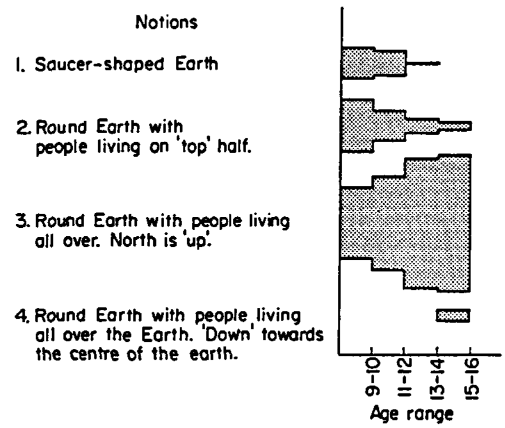


Figure 3. The prevalence of pupils' notions about planet Earth and gravity.

These questions and tasks uncovered five different notions (see figure 6), of which the four alternative notions on the Moon's phases involved an object either obscuring part of the Moon or casting a shadow on its surface. There appeared to be some confusion between a lunar eclipse and the Moon's phases as the most commonly occurring notion for all age groups was notion 4 (see figure 7), which entails the Earth's shadow being cast on the Moon.

The seasons

Pupils were asked if they could name the four seasons. They were then asked to explain what caused it to be cold in the winter. Figure 8 shows the pupils' notions and the drawings they used to explain their ideas. The results of the survey are given in figure 9.

Again, like the alternative notions for the cause of day and night, young childrens' notions on the cause of the seasons involved near and familiar objects. Older children appeared to replace these ideas with notions which involved the astral bodies moving their position. At first this motion was 'up', 'down' or 'across', later being replaced by orbital motion. The most common notion, notion 3, places the Sun further away during the winter (a notion which may have its origins in children's experience of altering their distance from a heat source).

Discussion

Although the results of the survey show a reduction in the more naive views as age increases, misconceptions persist in many pupils up to 16 years of age, supporting the claim that children's naive concepts frequently pass on into adulthood. This has recently been demonstrated in a survey by Durant *et al.* (1989), which indicated that a large proportion of the general public in the UK are confused about many basic scientific notions (including the motions of the Earth and Sun).

The data from the survey show how children's early notions tend to be based on observable features. These notions are used less frequently by older pupils; however, they are not *exchanged* for the accepted theory. Intermediate notions involving the

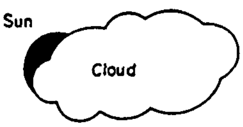
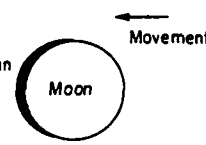
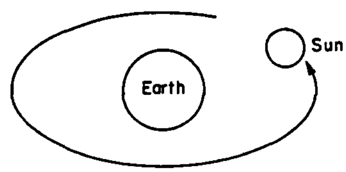
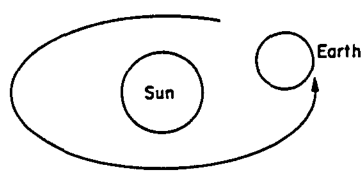
Notion	Drawing
Notion 1 Sun goes behind hill.	
Notion 2 Clouds cover the Sun.	
Notion 3 Moon covers the Sun.	
Notion 4 Sun goes around the Earth once a day.	
Notion 5 Earth goes around the Sun once a day.	
Notion 6 Earth spins on its axis once a day.	

Figure 4. Pupils' notions about day and night.

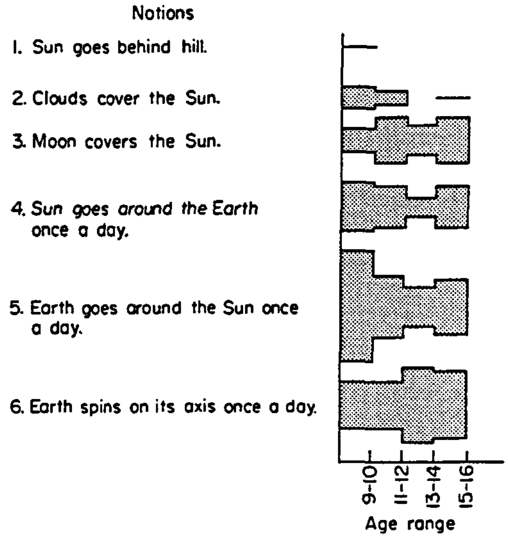


Figure 5. The prevalence of pupils' notions about day and night.

motions of astronomical bodies are most frequently used; these are later changed to the accepted view, but only in the case of some pupils.

The selection by pupils of more than one notion in particular cases probably reflects an unresolved dilemma in the pupils' thinking between notions they have been introduced to through schooling and their own physical observations.

Although the surface features of the ideas that children use to explain the easily observed astronomical events vary from one context to another, a number of phases in the underlying conceptual representations which tend to underpin the responses can be identified.

The first phase is characterized by a static view of the Earth. This is frequently drawn saucer-shaped, North being 'up' and South being 'down'. Any changes in astral bodies are caused by familiar and near objects like hills and clouds.

The second phase is characterized by a round Earth, but the naive idea of 'up' and 'down' still persists. The Earth is commonly thought of as central and static. Astral bodies can move to cause observed phenomena but their movement is represented as 'up', 'down', 'right' or 'left'.

In the third phase the same notions about the Earth and gravity still persist. However, astral bodies are now seen to move in orbits, though this motion is considered to be Earth-centred.

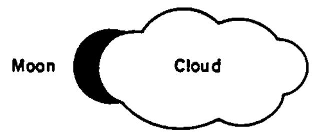
The fourth phase is that of the present heliocentric view and its associated gravitational ideas.

The phases in the children's notions given above bear some resemblance to ideas about the solar system which have been used in the past. This is most marked in the development of children's concepts of Earth and gravity. The saucer-shaped Earth drawn by a number of children is similar to the view proposed by Lactantius (*c* AD 225) in the third volume of his *Divine Institutions* (quoted by Draper 1875), in which he argued against the rotundity of the Earth using naive arguments similar to those that young children use today. Snow and rain, he claimed, cannot fall upwards and people cannot walk with their feet above their heads.

Notion	Drawing

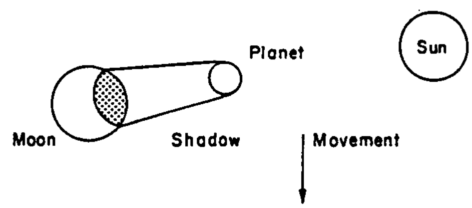
Notion 1

Clouds cover part of the Moon. No pattern but full Moon is seen in summer when there are fewer clouds.



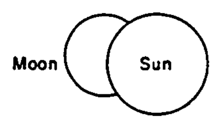
Notion 2

Planets cast a shadow on the Moon. Pupils thought there may be some regularity to the changes but were not sure what it was.



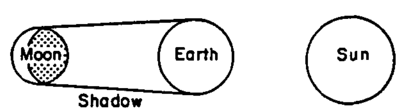
Notion 3

Shadow of the Sun falls on the Moon. Pupils unsure about regularity.



Notion 4

Shadow of the Earth falls on the Moon. Some regularity observed; four related it to a period of one month.



Notion 5

Phases of Moon explained in terms of portion of illuminated side of the Moon visible from the Earth. One pupil related it to a period of one month.

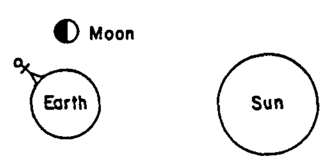


Figure 6. Pupils' notions about the phases of the Moon.

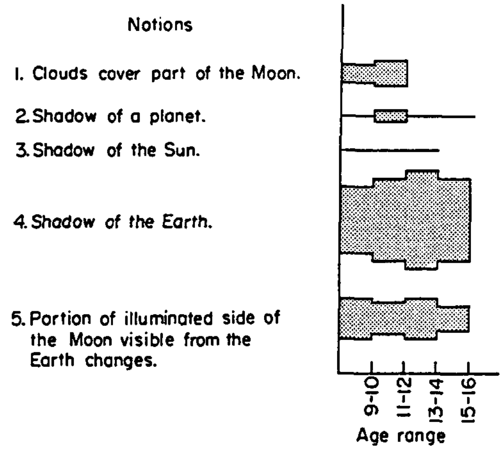


Figure 7. The prevalence of pupils' notions about the phases of the Moon.

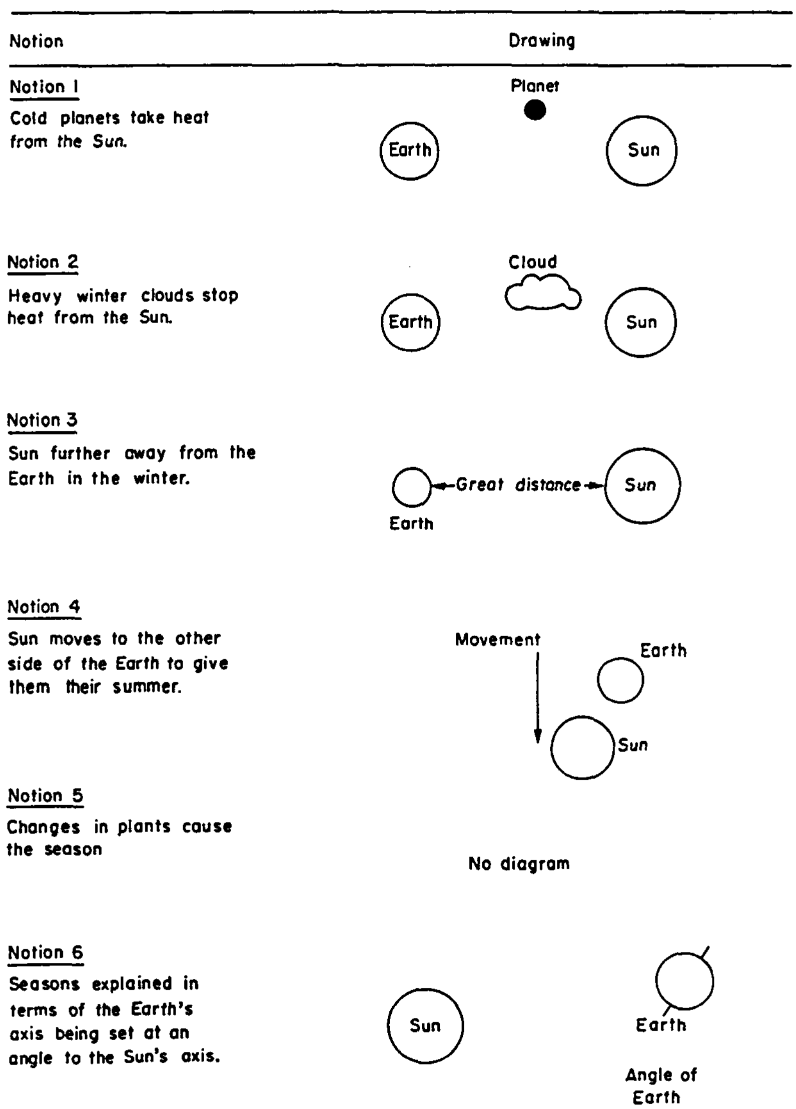


Figure 8. Pupils' notions about the reason for the seasons.

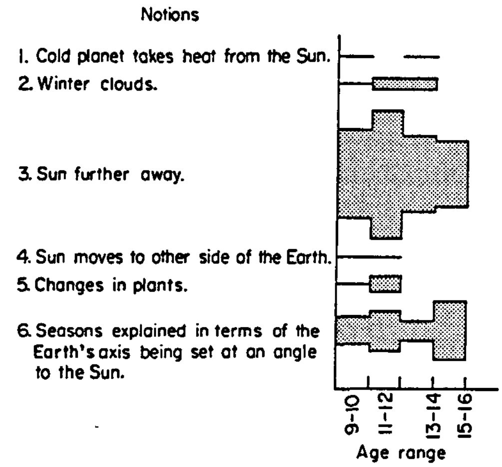


Figure 9. The prevalence of pupils' notions about the reason for the seasons.

That pupils hybridize their view with science instruction has been reported by a number of researchers (Gilbert *et al.* 1982, Solomon 1983). The findings of this survey suggest that this may particularly be the case with some pupils' concepts of day and night. The idea that the Sun goes around the Earth once a day to give day and night is typical of the geocentric view before the Copernican revolution. Some children who adopted a heliocentric view of the solar system were using the same idea for the cause of day and night, but instead placed the Earth in a daily orbit around the Sun, a view which is a mix of the old geocentric view and the heliocentrism of Copernicus.

Implications for teaching

The findings of this survey are particularly relevant in the UK at present as the introduction of the national curriculum will bring about the introduction of astronomy into the science curriculum of most pupils for the first time in the history of the English educational system.

First, the findings provide information about the longer-term progression in the ideas that pupils may bring with them into the learning situation, and gives some indication of the most suitable age at which to introduce certain astronomical topics. As has already been mentioned, many young pupils use near and familiar objects to explain the astronomical events investigated. These early naive ideas appear to be replaced by notions which involve astral bodies moving up, down or across. These ideas are later replaced by notions which embrace the idea of orbital motion. Thus it appears that while younger children may be encouraged to observe as many of the astronomical events as possible, it is recognized that the construction of a heliocentric view involves a number of complex factors and it may not be appropriate to expect understanding of such a notion before early adolescence. Indeed it may be important to recognize that pupils may construct intermediate notions before moving to a heliocentric view.

If we accept the view that learning involves pupils in a process of conceptual change, then a knowledge of the initial conceptions that pupils bring with them into lessons becomes important as it provides a basis for the design of teaching materials which address 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 experiences.

Astronomy teaching materials have been developed based on the survey information and are undergoing small-scale trials. The materials use the strategy of asking pupils to write down their explanations for a specific astronomical event, such as the change from day to night; their view is then discussed with other pupils in their group. When the members of the group have decided on the most likely explanation, they set up models to test their idea. (Polystyrene spheres attached to cotton can represent the Earth, Moon and planets, while a torch can be used to represent the Sun.) Using this approach, pupils can challenge their own ideas and revise them in the light of their new experience. The survey instrument is being used to identify common conceptions prevalent in the teaching group before they embark on the topic and is drawing both teachers' and pupils' attention to pupils' initial conceptions on astronomy.

The fact that many pupils' notions have historical parallels is forming a useful teaching point. Presentations of ideas held in the past are being used to demonstrate the tentative nature of science. The reference to historical ideas possibly makes pupils feel more comfortable when they realize that their notions, although incorrect in the light of scientific advancement, were once the popular view. They are also giving pupils insights into the kinds of evidence that encouraged scientists over the years to change their theories.

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References

Draper, J. W. 1875, History of the conflict between religion and science. In Lactantius, *Works*, Gregg International 1970 edition, pp. 63–67.

Driver, R. and Oldham, V. 1986, A constructivist approach to curriculum development in science. *Studies in Science Education*, Vol. 13, pp. 105–122.

Durant, J. R., Evans, G. A. and Thomas, G. P. 1989, The public understanding of science. *Nature*, No. 340, pp. 11–14.

Gilbert, J. K., Osbourne, J. and Fensham, P. J. 1982, Childrens' science and its consequences for teaching. *Science Education*, Vol. 66, No. 4, pp. 623–633.

Harty, H. and Beall, D. 1984, Towards the development of a children's science curiosity measure. *Journal of Research in Science Teaching*, Vol. 21, No. 4, pp. 425–436.

Klein, C. A. 1982, Children's concepts of the Sun: a cross cultural study. *Science Education*, Vol. 65, No. 1, pp. 95–107.

McCloskey, M. 1983, Intuitive physics. *Scientific American*, No. 248, pp. 122–130.

Mali, G. B. and Howe, A. 1979, Development of Earth and gravity concepts among Nepali children. *Science Education*, Vol. 63, No. 5, pp. 685–691.

Nussbaum, J. 1979, Children's conceptions of the Earth as a cosmic body: a cross age study. *Science Education*, Vol. 63, No. 1, pp. 83–93.

Nussbaum, J. and Novak, J. D. 1976, An assessment of children's concepts of the Earth utilizing structured interviews. *Science Education*, Vol. 60, No. 4, pp. 535–550.

PREECE, P. F. W. 1985, Children's ideas about the Earth and gravity. *The Teaching of Astronomy. Perspectives 16* (School of Education, University of Exeter), pp. 67–73.

SNEIDER, C. and PULOS, S. 1983, Children's cosmographies: understanding the Earth's shape and gravity. *Science Education*, Vol. 63, No. 2, pp. 205–221.

SOLOMON, J. 1983, Learning about energy: how pupils think in two domains. *European Journal of Science Education*, Vol. 5, No. 1, pp. 49–59.

WATTS, D. M. and ZYLBERSZTAJN, A. 1981, A survey of some children's ideas about force. *Physics Education*, No. 16, pp. 360–365.