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Children's astronomical beliefs: a preliminary study of Year 6 children in south-west England

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Astronomy is now an established part of a National Science Curriculum operating in maintained schools throughout England and Wales. Children in the primary age phase (Key Stages 1 and 2, 5 to 11 years) have an opportunity to investigate an area of science which has influenced the nature of scientific thought and progress as a whole, highlights certain aspects of human, scientific and technological achievement, and forms a significant part of their everyday lives. Exploring the ideas of 10- to 11-year-olds concerning the planet Earth, Earth concept, the Sun, Moon and stars, day and night, the seasons, phases of the Moon and the solar system reveals the importance of everyday sensory experiences, including direct observations of the sky, cultural and social transmission, and formal instruction, in the construction of meaning to account for certain astronomical phenomena. Findings presented here carry implications for the teaching and learning of astronomy including potential research directions and curriculum developments in the UK and elsewhere in the world where astronomy education is offered to children of this age and older.

Introduction

The formal inclusion of astronomy as an 'established' subdomain within the science component of a centrally organized National Curriculum operating in maintained schools throughout England and Wales (DES/WO 1989, 1991, SCAA 1994) should be welcomed not only for providing children with a new and exciting experience but as a long overdue recognition of the contributions that astronomy has made to the nature of scientific thought and progress as a whole. In the primary sector at least (5 to 11 years), it might be suggested that few areas of a science curriculum could claim to capture the interest, curiosity and imagination of children, and capitalize fully on their sense of awe and wonder at what it has to offer, as much as 'space' does. Studies from around the world, notably those conducted in the USA, have suggested, however, that learning in this field is far from easy. Just as with teachers (Mant and Summers 1993, Noce *et al.* 1988, Targan 1987) and other adults (Lightman *et al.* 1987, Acker and Pecker 1988, Durant *et al.* 1989) the conceptual, procedural and contextual demands imposed as information concerning astronomical events shifts from 'concrete' to abstract, or increases in complexity and conflicts with everyday sensory experiences, including direct observations, seem obvious, presenting particular problems and challenges to be addressed. If we accept a constructivist epistemology, within which learning, in its simplest sense, takes place, in part, through a process of conceptual challenge and change and the on-going construction or reconstruction of meaning (e.g. Posner *et al.* 1982, Driver and Erickson 1983, Osborne and Wittrock 1983, Driver and Bell 1986, Driver 1989),

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what the learner already knows is of great importance. Strongly held beliefs, such as those which children might derive from what they see around them and in the sky, can act as 'critical barriers' (Hawkins 1978) to 'scientific' conceptualization or allow for the generation of a range of alternative viewpoints. Many of these, from various areas of science, are well documented (e.g. Driver *et al.* 1985, 1994, Osborne and Freyberg 1985, Carmichael *et al.* 1990). With this in mind we might anticipate that from a very young age a child might think the Earth large and 'flat'. The Sun might mysteriously 'appear' in the sky in the morning and 'disappear' later in the evening. The Moon and stars might only 'come out' at night. The Earth might even be conceived to lie at the centre of all 'heavenly' activity. This is indeed the case.

As early as 1929 and 1930, Piaget, in *Conceptions of the World* and *Physical Causality*, reported various evolutionary schemata on such matters, including an inventive flat Earth day and night account by children of nine and ten who had determined that

> America is like a lower story compared with Europe and that to reach America the Sun had to cross the sea by a tunnel which pierced what formed the floor of Europe and the roof of America. (1929: 296)

Piaget also commented, perhaps prematurely, that to teach a Copernican view of the solar system to young children would be 'completely useless' as they 'cannot possibly understand it', their explanations giving rise to the 'quaintest distortions' (1929: 296, 1930: 85). Many children today, of course, have increased access and exposure to quite sophisticated astronomical information (science fiction as well as science 'fact') via television, computer, video and other sources including school. In constructivist terminology, Piaget's 'distortions' would be referred to as 'alternative frameworks' (Driver and Easley 1978) or personal 'constructs', that is the views and models individuals hold to explain the world around them. Despite a general reconsideration of Piaget's work (Marin and Banneroch 1994), his original empirical descriptions remain a valuable and under-used source of information.

More recently, research has taken two main routes, developing alongside the rise of the alternative conceptions movement (Gilbert and Swift 1985) which grew in acceptance and gained general momentum in the mid-1970s.

Earth concept

Earth concept (a term directed towards Earth shape, the Earth as a discrete cosmic body, and Earth gravity) was introduced by Nussbaum and Novak (1976). As part of an on-going programme to design and evaluate audio-tutorial science lessons for individual instruction, they developed a structured interview procedure which they thought allowed them to 'penetrate' children's cognitive structures. Working with fifty-two 2nd graders (7 to 8 years) from an elementary school in Ithaca, New York, five qualitatively different notions associated with Earth concept were identified, ranging from 'egocentric' or 'naïve' (Notions 1 and 2, see below) to more 'scientific' (Notions 4 and 5, see below). Modifying and extending this work to two hundred and forty 4th to 8th graders (9–14 years) in an experimental school in Jerusalem, Nussbaum (1979) determined similar outcomes between the Israeli and the American children, thus highlighting a cross-cultural likeness between the two samples. Significantly, Nussbaum demonstrated that despite different frequency profiles for different age levels, which generally became more 'scientific' with increasing age, many older children still retained a number of 'non-scientific' views.

The five original notions were altered slightly and are summarized as follows:

Notion 1. The Earth is flat in all directions. People live on the flat surface. Gravity acts downwards in all directions. Children with this notion may also possess a dual-Earth concept believing that they live on one Earth but another might exist above or below them.

Notion 2. The Earth is shaped like a ball. People live on the flat upper surface of a lower hemisphere inside the Earth while the upper hemisphere is made of air and/or the sky and may contain the Sun, Moon and stars. Gravity acts downwards towards the flat surface of the lower hemisphere.

Notion 3. The Earth is shaped like a ball surrounded by sky and cosmic space. People live on top of the ball. Gravity acts downwards regardless of Earth shape.

Notion 4. The Earth is shaped like a ball surrounded by space. People live all around the ball. Gravity acts towards the surface of the ball but not towards its centre.

Notion 5. The Earth is shaped like a ball surrounded by space. People live all around the ball. Gravity acts towards the surface of the ball and towards its centre.

Similar studies appeared to confirm the five notion cross-age/cross-cultural picture. The first of these was by Mali and Howe (1979) with two hundred and fifty 8-, 10- and 12-year-olds from urban Kathmandu and rural Pokhara Valley in Nepal. A later study by Sneider and Pulos (1983), involved one hundred and fifty-nine 9- to 14-year-olds from the San Francisco Bay area of California. Mali and Howe's work is particularly interesting since at the time the Nepali people still had limited exposure to western scientific paradigms and many held the traditional belief that the Earth is a large, flat mass supported on four corners by an enormous elephant. Vosniadou and Brewer (1990, 1992) refined Nussbaum's notions even further suggesting that, from extensive studies carried out on American and Greek children, individuals as young as five may hold rectangular or disc-like flat Earth beliefs. More importantly, because they used different techniques, their work dispelled any suggestion that the regularity and consistency of outcome was an artefact of experimental design.

Earth–Sun–Moon system

Surprisingly little systematic work has been carried out in this area. Klein (1982) investigated the explanations and development patterns of twenty-four 7- to 8-year-old Mexican-American and Anglo-American children in a Minnesota public school with reference to certain Earth and Sun concepts including the causes and effects of day and night. Similarly, Jones *et al.* (1987) investigated the relative size, shape and spatial relationships of the Earth, Sun and Moon with sixteen 3rd grade and sixteen 6th grade children from Hobart, Tasmania. Both studies demonstrated that the majority of younger children had a limited 'scientific' understanding of any of the concepts examined. Many of the older children from Tasmania, however, had moved some way from an Earth-centred cosmic model, common amongst the 3rd graders, to a Sun-centred one following some specified teaching and study. The cross-age studies of Baxter (1989), with 9- to 16-year-olds, and Osborne *et al.* (1994), with 5- to 11-year-olds (both with children in England) have provided some of the most comprehensive and useful insights into various astronomical events including day and night, the seasons and phases of the Moon and have highlighted a variety of models and explanations. Both studies indicate that children's knowledge of astronomical events seems to be in a state of emergence across the age ranges considered. Additionally, the Osborne study demonstrates the positive aspects of selective intervention. Shorter accounts of interest for children of various ages, including primary, from the USA, India, Greece and Samoa can be found in Cohen and Kagan (1979), Sadler (1987) and Vosniadou (1991).

One thing that is apparent from the literature is that despite the fact that conceptual routes and mechanisms are poorly understood, children's ideas can and do change. The extent to which this takes place depends on the quality of their own experiences, their cultural backgrounds including interaction with parents and peers, the onset of and extent to which formal instruction occurs, and developmental maturity including age (e.g. Nussbaum and Sharoni-Dagan 1983, Osborne *et al.* 1994). For children to move beyond notions of how things appear to look around and above them (and the exotic 'intuitive' accounts of astronomical phenomena that occur as a result) towards a more 'scientific' adult world view requires not only an ability to embrace a hierarchy of key 'enabling concepts' and specialized higher level organizational and problem solving skills, but to be able to change radically from an 'egocentric' reference frame to a more remote or objective one. The term 'enabling concept' is introduced and used here simply to recognize and draw attention to the importance of information associated with a knowledge and understanding of major concept areas. Many children will, if asked, provide some explanation to account for the cause of day and night. The degree to which it resembles anything 'scientific' or describes finer details associated with day and night will depend upon the extent to which each child has acquired and can put to use details relating to such factors as Earth shape (including hemispheres); the existence, location and orientation of the Earth's axis; the rotation of the Earth about its axis once every day; and the journey of the Earth around the Sun once a year. The presence or absence of any of these 'enabling concepts' may lead to some departures from a 'scientific' day and night model which may be significant.

The aim of this article is to provide information that contributes to the ever-growing body of literature confirming and extending what is already known about children's astronomical ideas. Other details concerning planet Earth, the Sun, Moon and stars and the solar system are presented for the first time. Where the children obtain these ideas and what influences them are highlighted. An attempt is made, using 'enabling concepts' and influences, to place children's models or 'constructs' of day and night, the seasons, phases of the Moon and the solar system into 'intuitive', 'scientific' and 'synthetic' categories as defined by Vosniadou (1991). The results suggest that children in the primary age phase are capable of dealing with complex and abstract information in this field. Brief consideration is given to the implications for classroom practice, pre-service and in-service provision, future research directions and curriculum development. Summative studies of the type presented here are particularly useful since, in the UK at least, children typically move from one teaching and learning environment in the primary sector to a very different one at secondary level. Outcomes determined at the primary–secondary interface could inform and improve the teaching and learning process on both sides of the divide.

Method

Preliminary findings of the research presented here were obtained using a structured, semi-formal, Piagetian-type procedure involving interviews about concepts (Piaget 1929, White and Gunstone 1992); interviews about instances and events (Osborne and Gilbert 1980); and drawings (Symington *et al.* 1981, Hayes *et al.* 1994). Modified clinical interview procedures have been used extensively in eliciting children's ideas about science-related phenomena since Piaget originally argued to determine a child's notion of *reality* and *causality*

> The good experimenter must, in fact, unite two often incompatible qualities; he must know how to observe, that is to say, to let the child talk freely, without ever checking or side-tracking his utterance, and at the same time he must be constantly alert for something definitive, at every moment he must have some working hypothesis, some theory, true or false, which he is seeking to check. (1929: 9)

Productive questions, focused activities involving pictures and props, and allowing individuals the opportunity to produce their own annotated drawings proved a particularly powerful and relatively non-threatening combination of techniques for probing children's knowledge, understanding and reasoning, and for exploiting their explanatory strengths in different areas. At various points within the procedure, children were able to spend time concentrating on specific tasks and discussing their ideas. Cross-referencing or triangulating between responses allowed expressed ideas to be clarified and refined in a manner considered unattainable by any one technique alone. Limited concept mapping (Novak and Gowin 1984) with reference to the solar system was carried out at a later date (not reported here).

Pilot

Pilot interviews were conducted with a small group of Year 6 children not involved in the main study. Throughout this phase, every effort was made to identify and minimize distractions and contradictions associated with the use of language and the nature and sequence of questions and props to obtain authentic responses. As a result the procedure was changed and modified.

Main study

Forty-two 10- and 11-year-olds (twenty-one boys, twenty-one girls) from three schools in the east Devon district of south-west England were involved in the main study. The schools were selected on the basis of their willingness to participate, their location in urban, semi-rural and rural settings, and their wide socio-economic catchment. Specific individuals were chosen by class teachers, schools were asked to provide a wide cross-section of abilities. Interviews, which lasted 45 minutes to one hour, were conducted in a friendly atmosphere on a one-to-one basis in a quiet area of the classroom or as near to it as possible. Establishing an initial rapport included reassuring each child that the outcome would not be passed on directly to the teacher. Minor departures in procedure took place as a result of responses obtained. During the interviews, observations and comments were written and audio-taped and drawings were retained.

The interview content and format are summarized as follows:

1. Planet Earth and Earth concept
   Earth shape. Earth sketch and colour. Earth shape, gravity and cosmic body challenge. Picture recognition. Earth definition.

2. The Sun
   Sun shape. Sun sketch and colour. Awareness of position and movement in the sky. Sun definition.
3. The Moon
   Moon shape. Moon sketch and colour. Awareness of position and movement in the sky. Moon definition.
4. The stars
   Star shape. Star sketch. Awareness of star position and movement. Star definition.
5. Features of the Earth–Sun–Moon system
   Relative size of the Earth, Sun, Moon and stars. Explanations of day and night, the seasons and phases of the Moon.
6. The solar system (and wider universe)
   Content, structure, origin and age. Planetary shape and recognition.

Results

Planet Earth and Earth concept

In common with other authors, eliciting and interpreting children's ideas about planet Earth and Earth concept was a lengthy and time consuming process. Details about planet Earth are summarized in figure 1. All interviews began formally with a sequence of four questions: What shape is the Earth? How do you know that? Can you pick a shape from the tray that best fits what you think the Earth looks like? Why did you pick that shape and not any of the others? Only twenty-one verbal responses indicated directly a 3-D shape, the rest – 'round', 'round like a circle' and 'circular' – leaving grounds for doubt. 'Round with lines on' came from a globe; 'not completely round' from one child who knew from books that the Earth is not a perfect sphere. Nine offered personal explanations influenced by the travel of relatives, history, space exploration and independent reasoning. Typical of these include the following:

> At first I thought it was a flat circle, then I started to think, well, if ... I've got an auntie who travels around the world by sea and by air and she ... mmmm ... went round the world by sea once and I thought to myself if she can get round by sea, if it (Earth) was in half, she must have had to use air at some point or she would have come across a flat surface. So that was when I started to think it was round.
>
> If you sail around and start at one place you'll come back to the same place.
>
> In the old days they thought the world was just flat and if you sailed too far you'd fall off the edge of the world.
>
> You can't go along and drop off the edge, there's no edge.
>
> If it was square, someone would fall off the edge ... no they wouldn't because of gravity.
>
> People have gone up in rockets and taken pictures of the Earth. We've got two at home.

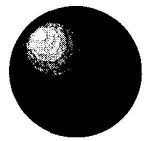
All of the children selected a sphere from a tray which contained a selection of 2-D (disc, square, rectangle) and 3-D (sphere, hemisphere, cylinder) shapes. Justifying their choice tended to prompt 'it just is' or a general comparison with the other shapes available: 'because the world is a whole not a half', 'it's a solid ball like an orange', 'it's round in all directions the others are flattened', 'it has no flat sides, the Earth is not flat'. Earth sketches were almost exclusively circles variously annotated with

What shape is the Earth?

round	13
sphere	11
round like a ball (ball shaped)	7
round like a circle	4
circular (circle)	4
round like 3D	1
round with lines on	1
not completely round (egg shaped)	1

Choice of shape

sphere 42



Sketches of the Earth

a b c

40 1 1

What colour is the Earth?

blue (dark)	38 :	sea, water, sky, rivers and lakes, land
green (little bit)	29 :	land, grass/hilly, trees, countries, fields, crops, islands/cities, earth
white (whispy)	22 :	clouds, mist, waves of water, Iceland
grey	11 :	clouds, roads, fog, mist, buildings
brown (little, light)	10 :	land, cliffs, mountains, where no grass grows, nature/stuff like that, desert
yellow (lightish)	5 :	desert, land, fields, mountains
brown (greeny)	2 :	earth, land
purple (dark, light)	2 :	mountains and cliffs
other (mixture)	3 :	land, things that are far away, dark patches

Life on Earth

yes 42

Recognition from picture

Earth 42

What is the Earth?

planet 42

Figure 1. Children's ideas about the Earth (n = 42).

countries and continents or shadow (figure 1a, b). The one exception (figure 1c), slightly flattened, was drawn by the child mentioned earlier who knew the correct Earth shape. Pointing out that their drawings looked very different to what could be seen from the classroom windows, most accounted for this in terms of Earth size: 'it's big', 'you wouldn't see a ball just a round circle'. Although blue, green and white were offered as commonest Earth colours if seen from 'space' (corresponding mostly to sea, land and clouds), the broad range of colours and reasons suggests some difficulties associated with scale and distance.

Following the gravity work of Baxter (1989), the children were asked to add stick people, clouds and rain to a blank copy of their Earth sketches. People were universally thought to live 'all over' or 'anywhere on land'. Exclusions were supported with reference to clothing, 'you wouldn't wear bikinis at the poles', or weather and climate, 'it's freezing on top of the Earth', 'at the middle it's too hot', 'you couldn't live in the desert or Antarctica'. All were aware that clouds appear high in the sky, describing them as 'up above', 'on top of the Earth' or 'above the Earth'. Rain was known to 'fall straight down from the clouds' unless it was windy. Completing the task, however proved difficult and confusing, more as a result of perspective and attempting to represent 3-D information on a flat piece of paper than

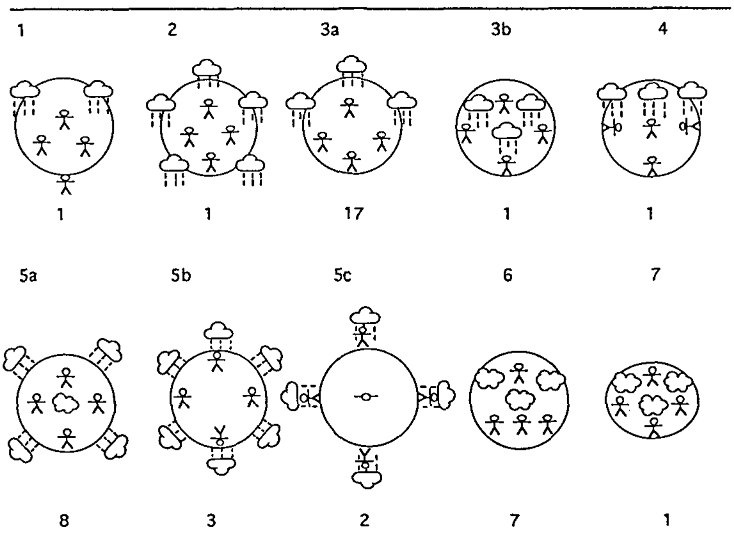


Figure 2. Children's drawings concerning Earth shape, where we live and gravity (n = 42).

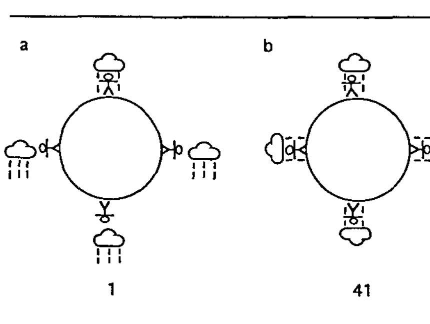


Figure 3. Challenged ideas about Earth shape, where we live and gravity (n = 42).

for any other reason. The outcomes, shown in figure 2, are categorized on the basis of similarity and likeness of graphical representation only. In categories 5a, 6 and 7, rain is present but 'you can't see it for the clouds'. In an attempt to ease and clarify this situation, the children were presented with a picture of the Earth with four stick people placed at different points around its circumference and asked to add clouds and rain as before, a technique similar to the 'rock dropping' exercise used by Nussbaum and Novak (1976: 541). Results are presented in figure 3. Drawing their attention to the lowermost figure in the picture, the children were asked to comment on why it looked 'odd', standing 'upside down' with rain, in all but one case (figure 3a), 'falling upwards'. The following responses were typical:

> It always rains onto the Earth.
>
> He looks like he's upside down but he feels ... thinks he's standing on top of the Earth.

> When you go to the bottom it's like the top really, the clouds are up in the air. You don't stand like exactly with your feet in the air.
>
> The people don't fall off because of gravity.
>
> Because there's gravity all over the world.

Both 'common-sense' and 'scientific' accounts indicate a range of knowledge and understanding of the existence, effects and implications of gravity. As Nussbaum and Novak pointed out, it is still difficult to determine each child's frame of reference—a remote view of the whole Earth or an isolated part of the picture immediately surrounding each stick person—from such an activity. As well as possibly being able to rotate the picture mentally in order to complete the task, it was noted here that some of the children actually turned it, though this may have been done to make drawing easier. Nevertheless, rain was almost exclusively thought to fall towards the surface of the Earth wherever you stood on its circumference.

Towards the end of this stage in the interviews, the children were asked what they could normally see in the sky during the day and during the night. Responses included clouds, Sun, blue sky and aeroplanes (rarely the Moon and 'planets') for day; the Moon, black sky/darkness, clouds, mist and aeroplanes (rarely 'comets' or 'shooting stars', owls and bats and 'planets') for night. More importantly, when asked if the stick people standing around the Earth in the previous picture would see the same things, all of the children agreed.

Comparing the outcomes of planet Earth and Earth concept work presented here against the five categories outlined by Nussbaum reveals that in all but one case the children displayed ideas that most closely resemble Notion 4, the one exception (figures 2.1, 3a) most closely resembling Notion 3. In the light of the considerable international body of research evidence available on this topic, the results seem somewhat exceptional and may be due here to the interpretation and use of only two probes (sketches and stick people, clouds and rain). It was not considered necessary or appropriate to carry out tasks which would have determined the presence of any Notion 5 responses with the children in this survey.

In connection with the solar system (presented later), planetary recognition was attempted with pictures of the planets spread out in front of the children. All forty two picked out the Earth instantly on the basis of land and shape recognition, cloud cover and colour: 'it's got countries on, you can see Africa', 'you can see clouds and land', 'it's got blue and green on'. Although all knew that the Earth is 'a planet' which supports and hosts life, their definitions of 'planet' were revealing:

> A planet is round, all different colours. They don't give out any light like the Moon or a star does. Don't know what colour a star is, I've got it on a wallchart at home.
>
> Something in space you can live on.
>
> Something like the Earth.
>
> Round things with land and sea on, others are big balls of gas.

A similar procedure, though not as in-depth as that used for the Earth, was adopted for the Sun, Moon and stars.

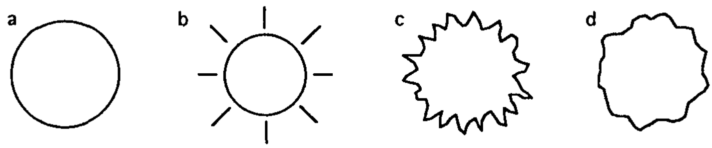
The Sun

Children's ideas about the Sun are summarized in figure 4. In this case, only seven children offered 3-D shape responses to the question What shape is the Sun? Most described it as 'round'. Only two suggested that this is how the Sun appears

What shape is the Sun?	
round (-ish, ragged)	30
sphere	5
like a ball	1
like the Earth	1
circle	1
could be oblong	1
unsure	3

Choice of shape	
sphere	25
hemisphere	2
disc	2
cylinder	1
unsure	12

Sketches of the Sun



a	b	c	d
20	10	9	3

What colour is the Sun?	
mixture (red, yellow, orange)	31
yellow	8
orange	3

Awareness of Sun position/movement	
yes	32
no	7
unsure	3

What is the Sun?	
a big/huge ball of fire (gases, flames and heat)	28
planet on fire (hot/fire planet)	4
burning star	2
like a planet but a bright star	1
a meteorite	1
a place where nobody can go	1
unsure	5

Is the Sun a star?	
yes	24
no	13
unsure	5

Life on Sun	
no	41
unsure	1

Figure 4. Children's ideas about the Sun (n = 42).

in the sky, the rest quoting secondary sources of information to account for their response. A few were very specific:

> It's a round shape with flames coming out of it, but you can't see the flames unless you get up close.
>
> It hasn't got a particular shape, it's not exactly round.

Although many selected a sphere from the shapes on the tray, five chose others and twelve remained unsure. Most of those who chose a sphere could only offer 'it must be round' or 'it just is' as explanations, although occasionally more detail was provided:

> When we go around it (referring to the Earth's journey around the Sun), it always stays the same circle (shape), so it can't be a circle unless it turns as well.
>
> It hasn't got an equator or poles.

Reasons for choosing the other shapes suggested a degree of uncertainty and logic:

> It just is. It looks round (pointing to a disc), but it could be like this (pointing to the rest of the shape behind the flat surface of the cylinder).
>
> You can see the front but you don't think there's a back (hemisphere).

The large number of children who couldn't select a shape from the tray could be attributed to the lack of appropriate shapes provided; this is, reflected, perhaps, in their Sun sketches. Just under half drew a plain circle (figure 4a), some illustrating their circles with 'rays of sunlight', 'gases', 'flames' and hotness' (figure 4b). These were typically derived from the shafts of light which radiate from clouds on certain days. Nine drew irregular shapes with 'mountains of fire' (figure 4c) and three with 'hot rays coming off' (figure 4d). Sun colour was described, as might have been expected, as red, yellow and orange. Slight variations included such features as the 'clouds which make it white'. Some children were aware of daily variations. For example, it could be 'orange in the morning, yellow at lunch-time, and pinky in the evening'. One, however, suggested that 'sometimes it's really hot and bright orange, when it cools it's dull yellow', confusing Sun temperature and appearance with time of day and air temperature. Concerning the apparent position and movement of the Sun in the sky, thirty-two demonstrated verbally or with the use of a sketch or gesture that the Sun appeared at 'sunrise, close to the ground' in the morning, rising in the sky to its highest point at, commonly, 'midday', descending again 'towards the ground at sunset', moving from 'one side of the sky to the other'. In only four cases were east and west mentioned correctly. Several children indicated at this point that 'the Sun doesn't move, we (Earth) move'. Included amongst the seven who seemed unaware of such movements was a view that 'it just comes out of the clouds'. These views are reflected in explanations and models of day and night.

What is the Sun? prompted mostly descriptive responses; twenty-four knew that the Sun is a star, others commonly confused it with a planet. Life on the Sun was thought impossible in all but one unsure case, mainly because it is 'too hot' or occasionally because there is 'no air'. One child commented:

> No, they'd (people) burn up even if they were a few miles away.

The Moon

Children's ideas about the Moon are summarized in figure 5. Only fourteen children gave clear 3-D shape responses to the question What shape is the Moon? Twenty-four described it as 'round'. Thirty selected a sphere from the tray, three a cylinder, one a hemisphere and one considered all three as options. Those who chose spheres justified their choice with reference to the Moon's appearance in the sky, by direct comparison with the Earth or by what they'd seen on television. The cylinder and hemisphere appealed to some because 'it's flat on top like it looks', 'it just looks flat to land on' or 'it just looks flat and bumpy as it does in the sky'. The child who insisted it could be all three suggested:

> It could be a sphere but I'm not sure. The cylinder is as it appears in the sky, but you can't see the other side so it could be like this (hemisphere).

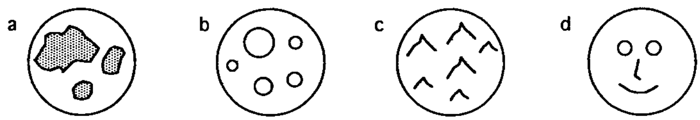
All were aware of several Moon phases describing them as a 'banana-' or 'earring-'shaped (crescent), 'semi' or 'half' moons (quarter), 'three-quarter' moons (gibbous) and 'full', 'whole', 'round', 'blob' or 'orange' moons (full). The degree of recall over regularity, predictability and cycle period varied. Moon sketches were virtually all circles, often described as 'bumpy with stones, craters and meteorites' or having 'darker shades with crater holes' (figure 5a). Any irregularity in shape was the result of 'lumps and craters', 'ditches' or 'round holes like little volcano things' (figure 5b). Others viewed the Moon as 'round with all mountain things on it'

What shape is the Moon?	
round (not completely)	24
sphere	10
like a ball	4
unsure	4

Choice of shape	
sphere	30
cylinder	3
hemisphere	1
all three	1
unsure	7

Awareness of Moon phases	
more than one	42
all (except new)	25
accurate cycle	16
cycle period	7

Sketches of the Moon



a	b	c	d
28	8	5	1

What colour is the Moon?	
white/grey (-ish, bits of blue in)	34
grey/white/black (blue)	5
pale yellow (like the Sun)	2
greenish yellow	1

Awareness of Moon position/movement	
yes	15
no	26
unsure	1

What is the Moon?
the Moon is the Moon
it's like the Earth and other planets
it's a star
it's the sight at night when people go to sleep
it's something up in space
it's got no atmosphere, it's a dusty ball

Life on the Moon	
no	40
unsure	2

Figure 5. Children's ideas about the Moon (n = 42).

(figure 5c), and one child drew the Moon with a face (figure 5d). Moon colour was predictable, mostly white or grey, with only minor variations. The Moon was seen to shine because:

> The sky is dark and it's bright because the Sun reflects in the Moon.
>
> It's a planet that reflects the sunlight and it gives out light.

Most children seemed unaware of the Moon's apparent position or movement in the sky although a variety of explanations were provided:

> We go around the Sun, the Moon goes around us so it does move.
>
> The clouds cover it up.
>
> In a car it seems to move. It stays in the same place because it's big.
>
> It comes down at dawn.

Seventeen said that they'd seen the Sun and Moon (occasionally with stars) in the sky at the same time, mostly in the morning or evening when it was still light although one remembered having seen this 'in the summer'. It was clear that the appearance of both was unusual:

> That would be an eclipse.
>
> My sister saw it at 4 o'clock. She said that it's still out (Sun) and so's the Moon, it should go away.

As with the Sun, most of the children provided descriptive responses to What is the Moon?, many suggesting that it is 'like the Earth and other planets' or 'a star'. All but two thought that life on the Moon was impossible because there was 'no gravity' or 'no air'. Others thought it 'too cold' or that there was 'no food or water'. Some suggested there were 'no plants or trees to make oxygen'. The two exceptions suggested the presence of 'aliens'. At this stage, many referred to space travel, visits to the Moon, the necessity for space suits and the possibility of future space stations.

Stars

The children's ideas about stars are summarized in figure 6. In response to What shape is a star?, a variety of descriptive suggestions were offered. Shape selection was omitted. Sketches confirmed earlier descriptions (figures 6a–f). Not surprisingly, most children were unaware of apparent star movements in the sky; those that were all quoted examples of 'shooting stars' or 'aeroplanes'. Two were recorded as saying:

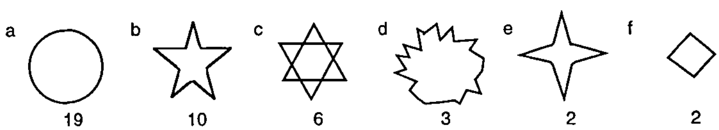
> Not when I look up, but they do a little bit I think.
>
> I saw them move really slowly when sailing.

Confusion existed as to what stars might be. Although many considered them to be 'like the Sun', some suggested that they were 'like a planet' or in one case 'like the Moon'. Others remained uncertain:

> A ball of fire with gases, like a little mini-Sun.
>
> Stars are little things but far away, round and with glowing things on them.
>
> Stars are small planets, couldn't stand on them though, they're too far away.
>
> Rocks with gases inside that shines.
>
> Formed after the Big Bang, they've got poisonous gases inside.

What shape is a star?
they're not like as people draw them all triangular, they're circular
it looks like a star in the sky but when you go close it's more round
in the sky people always reckon they've got edges, but to me they're blobs
round like the Moon but not pointed
when you look up it's a full-stop
they'd be bumpy with craters and things

Sketches of stars



Awareness of star position/movement

yes	6
no	33
unsure	3

What is a star?

like the Sun	22
like a planet	9
like the Moon	1
unsure	10

Life on stars

no	30
unsure	12

Figure 6. Children's ideas about stars (n = 42).

When asked about the difference between a star and a planet many suggested the following:

> They're the same.
>
> Planets are a lot bigger.
>
> Stars are tiny, you can't land on a star.
>
> Stars are something that just stay up in the sky at night.
>
> Stars aren't solid, stars shine, planets don't.

Life on stars was generally thought impossible either because it was too 'hot' or 'dangerous'. One child commented:

> They're big enough for people to live on but you couldn't in space.

The Earth–Sun–Moon system

This stage began by asking the children if they thought that the Earth, Sun and Moon are all the same size or different (figure 7). Twenty-six indicated correctly, from a range of secondary sources of information, that the Sun is larger than the Earth which is in turn larger than the Moon (figure 7a). Other responses varied: wrongly remembered from books and charts, based on direct observation, or guesses (figure 7b–f). Comments accompanying some suggestions included:

> I saw it in a book, the Sun must be humungous but you can't tell, it's the same size as the Moon in the sky.
>
> The Moon is smallest because other planets have moons.
>
> The Earth's a big place, the Sun is not big when you look up, the Moon is a small blob.
>
> The Sun's bigger than the Moon to give off more light.
>
> They're the same round shape, they look the same size (Sun and Moon).

Similar types of response and comment were obtained when asked about the relative

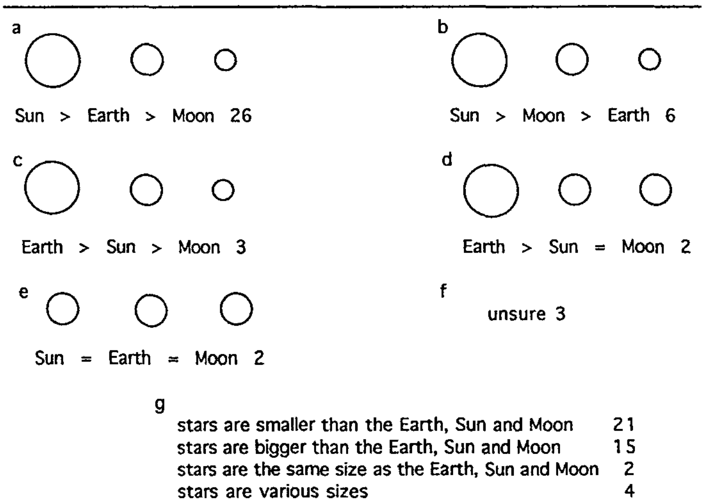


Figure 7. Relative size of the Earth, Sun, Moon and stars (n = 42).

size of stars (figure 7g). Some of the children were very aware of the effects of astronomical distance, others not:

> They look small 'cause they're far away, but they might be bigger than the Sun.
>
> When you look out the window at night the Moon's really big and you can see those silvery white dots beside it.
>
> The Sun's the biggest in the galaxy, others are smaller than the Earth.

Models of day and night, the seasons and phases of the Moon were determined from sketches and from conversations while the children demonstrated and explained using props (yellow sponge ball – Sun, free standing globe – Earth, white polystyrene sphere – Moon). In some instances only verbal responses were obtained. Variations were noted and refinements made possible from the children's own finished drawing collected at a later date. Complete details are provided with supporting statements in figures 8, 9 and 10. All of the children were aware of the day and night cycle, could name and describe all four seasons and describe more than one phase of the Moon. Although most provided a correct answer to the length of a day and a year, the relationship and significance of the Earth turning on its axis and moving in orbit around the Sun was often lacking.

Despite the enormity of each key concept area, the results contained enough detail and similarity to loosely identify and categorize commonly held models or 'constructs' as 'intuitive', 'scientific' and 'synthetic' (Vosniadou 1991: 225). In this classification, mental models are regarded as dynamic images generated to answer questions and solve problems; they provide information about the content and structure of each child's knowledge base. 'Intuitive' models are described by Vosniadou as those views held which show as little deviation as possible from the world as it is directly experienced (e.g. a 'flat' Earth, Earth > Sun = Moon). 'Scientific' models are those views which are in general agreement with currently accepted theories (e.g. a 'spherical' Earth, Sun > Earth > Moon). 'Synthetic' models are those views which are a combination of the two (e.g. a 'hemispherical' Earth, Sun > Moon > Earth). Although useful in many ways, this classification is not without its problems. More complex conceptual areas which require a greater array of 'enabling concepts' to facilitate complete understanding provide internal inconsistencies which require clarification.

For the purposes of this work, the children's models are placed into these categories largely on the basis of the presence or absence of certain movements and what could be determined about the influences which might have given rise to them alone: day and night, the rotation of the Earth around it's axis; seasons, the movement of the Earth around the Sun; phases of the Moon, the movement of the Moon around the Earth. It should be noted that the assignment of children to the 'scientific' category in no way suggests that they had a complete grasp of every 'enabling concept' required; rather they possessed a general picture of events. A knowledge of Earth tilt, for example, prevented one child from demonstrating complete and accurate models of day and night, and the seasons, but the child was aware of the period and significance of the Earth's rotation about its axis and the period and significance of the Earth's movement around the Sun. Although in specific instances there appeared to be a high degree of consistency between major concept areas, for example, the involvement of clouds (figure 8 Construct 5; figure 9 Construct 7; figure 10 Construct 3), exceptions appeared regularly including children who held 'scientific' ideas. The lack of coherent models used in any consistent way between concept areas is not an uncommon feature (e.g. Clough and Driver 1986). This fragmentary knowledge of the Earth–Sun–Moon system carries important implications for the teaching and learning process.

The solar system

During the final stage of the interviews, the children were reminded of their earlier work and the discussions involving the Earth, Sun, Moon and stars. They were then asked about what else existed in 'space' beyond the Earth. Other planets or worlds, meteors, comets, asteroids, black holes, galaxies, the solar system, Milky Way, moons and junk were mentioned and described with different degrees of accuracy. Amongst the planets, Mars, Saturn and Jupiter (with the Earth) were widely

Construct 1
Earth turns slowly on its axis once a day or every 24 hours (rare 80 days, 1 week). The Sun remains stationary while the Moon, usually diametrically opposite, may be stationary or travel around the Earth. Sun>Earth>Moon in 17 cases. Remote reference frame. Able to counter most immediate observational distractions. Major sources audio-visual and literature.
"The Earth turns around, the Sun's on one side, the Moon's on the other."
"The world gradually turns around. We move away from the Sun so it gets gradually darker."
"We have day when they (Australians) have night."
"Sometimes in Antarctica it's pitch dark all the time."

Construct 2
Earth is stationary or turns slowly on its axis. Day and night are caused by the Sun and Moon moving alternately up and down as shown, time period uncertain. Limited direct observational evidence of Sun and Moon in the sky. Sun>Earth>Moon in 1 case.
"The Sun rises suddenly up and down. The Moon rises suddenly up and down. The Earth turns. It goes right down and disappears round the other side of the Earth. Different people get it there. They're down in Africa or somewhere, then we swap."

Construct 3
Earth turns slowly on its axis once every 24 hours. The Sun remains stationary. During the day the Moon moves behind clouds and the stars move higher into the sky. Sun>Earth>Moon. Limited direct observational evidence of Sun and Moon in the sky.
"The Earth turns so the Sun goes to a different country. The Moon goes behind clouds. The stars go higher in the sky in daytime so they're not seen."

Construct 4
Sun and Moon are diametrically opposite and travel around a central stationary Earth once a day or every 24 hours (rare 12 or 25 hours). Sun>Earth>Moon in 2 cases. Classic geocentric viewpoint based on primary observational evidence.
"The Sun goes to a different country, the Moon comes to us."
"The Moon and Sun goes round slowly. It's always day somewhere and night somewhere."
One variation included the Sun and Moon travelling in opposing directions on slightly different concentric paths.

Construct 5
Earth is stationary. At night the Sun moves behind some clouds, the Moon appears from behind others. Situation reversed during the day, whole period lasts 24 hours. Sun>Earth>Moon in 1 case. Limited direct observational evidence of Sun and Moon in the sky.
"The Sun goes behind clouds at sunset, the Moon comes out from behind other ones."

Construct 6
Earth is stationary. The Sun and Moon move as shown obscuring each other once every 24 hours. Sun>Earth>Moon. Limited direct observational evidence of Sun and Moon in the sky.
"At night the Sun goes behind the Moon, in the day the Sun is in the way of it. The Sun is bigger than the Moon, but the Moon's closer so blocks out the light at night."

Construct 7
Earth travels around the Sun once every 24 hours. Position of the Moon uncertain. Sun>Earth>Moon. No statement other than "it just does". Poorly defined construct, response may have been derived from nature of task and opportunity to use props.

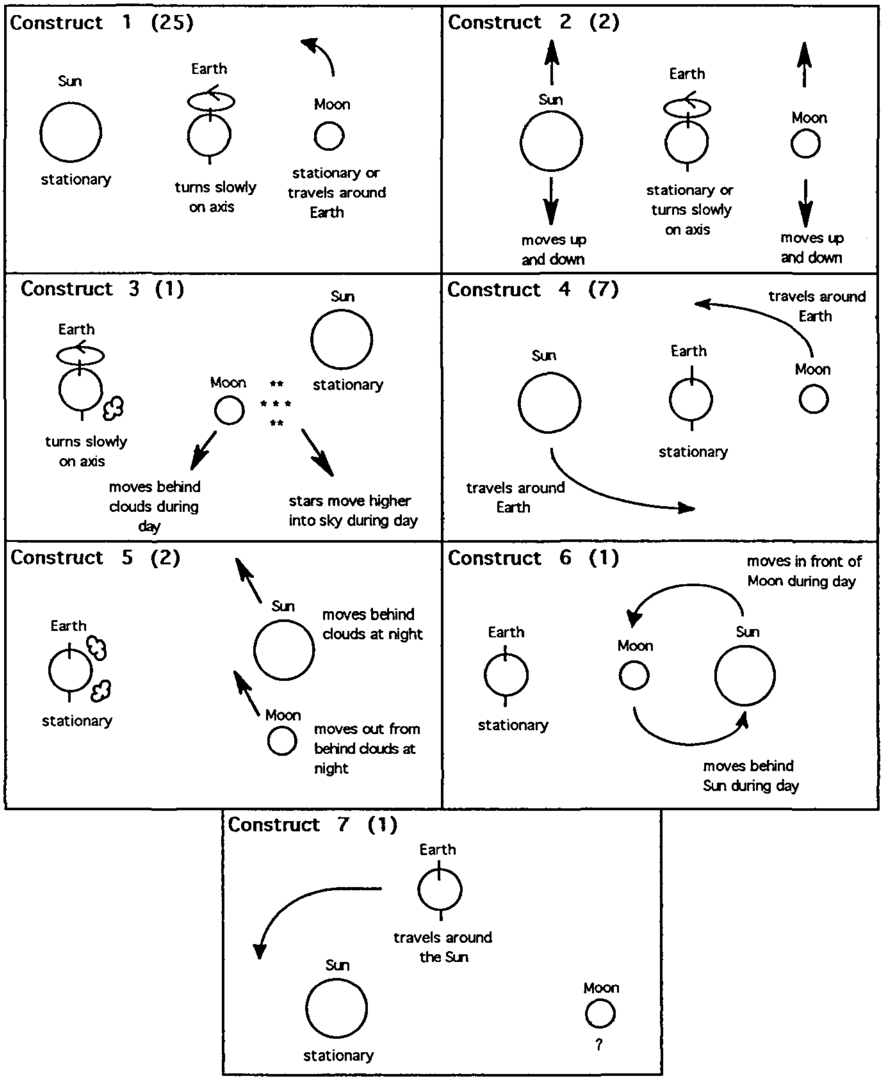


Figure 8. Children's ideas about day and night. Numbers in brackets indicate number of children holding that view. Construct 1 'scientific'; 2 and 3 'synthetic'; 4 to 7 'intuitive' (n = 42, unsure = 3).

recalled, described and identified from photographs: Mars for its colour, Saturn for its rings and Jupiter for its 'wavy lines', 'spot' and gaseous nature. Some confusion did exist with reference to relative planetary size and shape, though Jupiter and Saturn were often regarded as the largest, and most generally 'round':

> Star charts and maps show them as flat but they're really spheres.
>
> You think they're round but they could be like this (points to hemisphere).
>
> Could be cylinders or hemispheres for landing on.

The children were invited to produce and describe in detail a 'map' of the solar system including, wherever possible, as many of the planets and any other features

Construct 1
Earth travels around a stationary Sun once every year (365 days, 12 months, 52 weeks, rare 360/354 days). Seasons are caused by the Earth's axial tilt or by being slightly closer to, or further from, the Sun in the summer and winter months. The Moon may move in front of, behind or around the Earth. Sun>Earth>Moon in 6 cases. Remote reference frame. Major sources audio-visual and literature.
"The Earth goes around the Sun every year, it's got something to do with that. The Sun stays where it is. The Moon goes round after it or before it, it wouldn't stay exactly the same."
"Australia has summer when we have winter."

Construct 2
Sun is stationary otherwise "we'd burn or freeze", position of Moon uncertain. The Earth moves as shown once a year, the seasons caused by its proximity or distance from the Sun. No statement other than "it just does". Sun>Earth>Moon.

Construct 3
Earth and Sun are stationary, position of the Moon uncertain. Seasons are caused by the Sun physically heating up and cooling down during different times of the year (year lasts 12 months, rare 9 months, 122 days). Sun>Earth>Moon in 3 cases. Based on primary observational and experiential evidence.
"The Sun gets hotter in the summer, colder in the winter."
"In winter the Sun's not as bright."

Construct 4
Sun and Moon are diametrically opposite and stationary. Earth turns on its axis once a year (365 days, 52 weeks), the seasons caused by spending several months approaching, facing and turning away from the Sun. Sun>Earth>Moon in 1 case. Construct strongly influenced by infant classroom activity involving children holding and turning descriptive picture boards to demonstrate cyclical nature of seasons.
"The Earth turns around. It spends a couple of months in each one (quadrants?). The seasons are not the same all over the world."
"The Earth turns once a year. In the summer we face the Sun, in the winter we face the Moon."
Two variations included a stationary Earth, the seasons "moving to another part of the world every so often".

Construct 5
Earth is stationary, position of the Moon uncertain. Seasons caused every "300+ days" or "light year" by the Sun moving physically closer or further away from the Earth. Sun>Earth>Moon in both cases.
"The Sun moves closer a couple of miles to heat up the Earth."

Construct 6
Earth and Moon are stationary. Seasons are caused by the Sun travelling around the Earth at different rates in one year (365 days, 12 months, 52 weeks all given). Sun>Moon>Earth in both cases. Based on primary observational and experiential evidence.
"The Sun moves round slower then stays for a while in summer."
"The Sun goes a bit slower, the nights get shorter."

Construct 7
Earth is stationary, position of the Moon uncertain. Seasons are caused by the Sun spending more or less time behind clouds. Sun>Earth>Moon in 1 case. Based on primary observational and experiential evidence.
"In winter the Sun goes behind a cloud and stays there. It gets cold and snows."
"It snows in winter and it keeps you cold. The Sun in summer keeps you warm."

Construct 8 (verbal)
"When the world turns it's probably the ozone layer."

Construct 9 (verbal)
"The Sun needs a rest. We wouldn't have any water otherwise."

Construct 10 (verbal)
"If we had the Sun all the time, plants and crops wouldn't grow. In the summer there's a dry season."

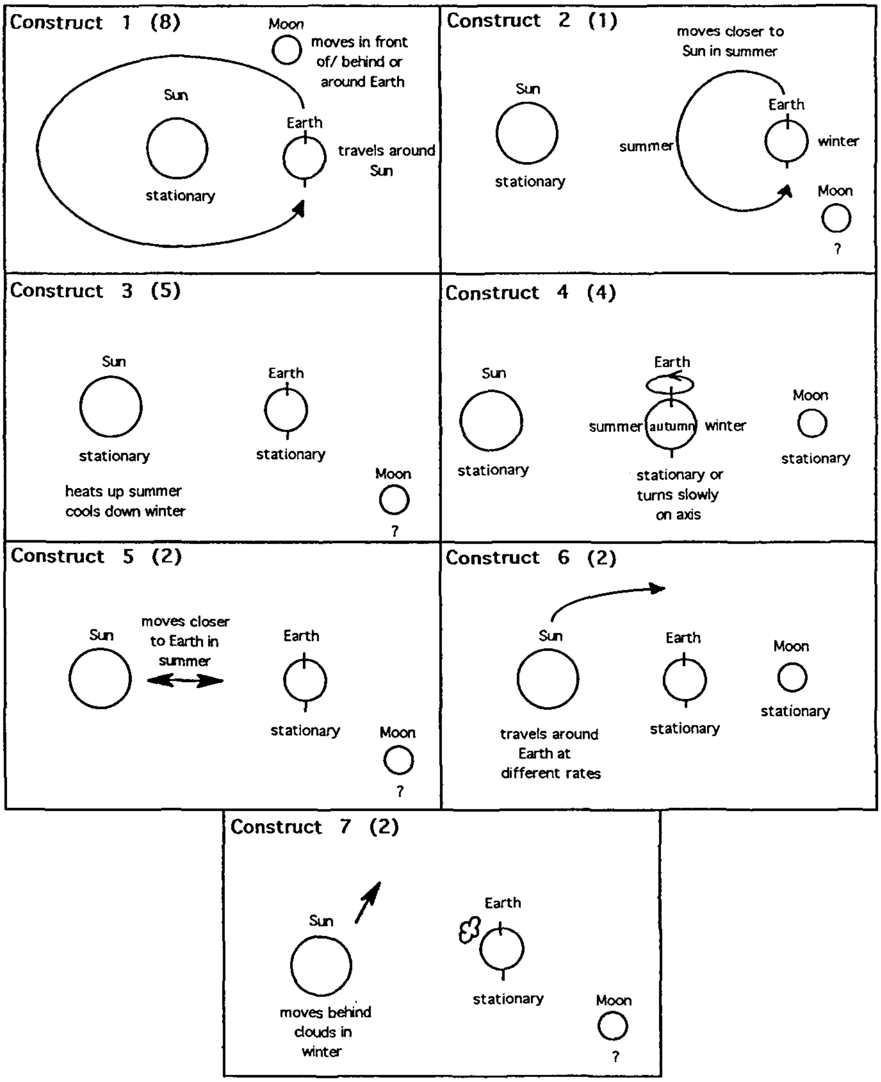


Figure 9. Children's ideas about seasons. Numbers in brackets indicate number of children holding that view. Construct 1 'scientific'; 2 'synthetic'; 3 to 10 'intuitive' (n = 42, unsure = 15).

they could remember. Results are summarized in figure 11, placed into Vosniadou's three categories on the basis of structure (content, location, movements etc.). Twenty-three of the children were found to hold 'scientific' models (Construct 1 and 2), influenced by the availability of classroom resources and modes of display. The rest held alternative ideas as shown involving six further models. Interplanetary distances, relative or absolute, were, on the whole, poorly known. Figures, often given as 'thousands' and 'millions' of miles, were recited with little or no meaning. In one case, the average Earth–Sun distance was almost correctly remembered as '95 million miles'. In another it was said that 'the coldest ones (planets) are blue and furthest away'. The presence or absence of planetary motion and the forces responsible were variably interpreted:

> Wind.
> In space there's no gravity so they stay put.
> Gravity, they just float there as there's nothing to push them along.
> They're attached to sunlight like magnets.
> The Sun pulls them in all together.

Where orbital movements were known, the periods were often uncertain although most children seemed to hold a view that those planets closest to the Sun must travel around it in a shorter time than those further away. Absolute and relative ages of

Construct 1
Earth and Sun are stationary. The Moon travels slowly around the Earth. Phases are the result of the illuminated portion of the Moon seen as viewed from Earth, repeating regularly, in some instances, over a period of about 28 days or 1 month. Solar eclipse often identified as possible when Moon passes between the Sun and Earth. Sun>Earth>Moon in 10 cases. Remote reference frame. Major sources audio-visual and literature.
"You'd see half the Moon here, a full Moon here and back to a half Moon here again."
"Each night it changes into a different shape."
One variation described a continual lunar eclipse: "When the Moon is full the Sun reflects in it and when it's not a full Moon a shadow from the Earth is cast on it to make it look like it changes shape."

Construct 2
Earth and Sun are stationary. The Moon travels around the Earth once every 24 hours causing phases and nightly period of cycle. Sun>Moon>Earth. Limited direct observational evidence of Moon in the sky.
"As the Moon moves we se a bit then a bit more. Some nights it doesn't go to a complete circle."

Construct 3
Sun and Moon are stationary and diametrically opposite. Earth may be stationary or turn slowly on its axis. Phases caused by passing clouds. Cycle and regularity of pattern confused. Sun>Earth>Moon in 6 cases. Based on primary observational evidence.
"Clouds make it into different shapes."
"When there's no clouds it's full like the Sun."

Construct 4
Sun and Moon are stationary. Earth turns slowly on its axis. All phases appear every night by an increase in the illuminated portion of the Moon viewed as the Earth turns onto it. Sun>Earth>Moon in all 3 cases. Construct influenced by action of classroom globe and nature of task. Limited direct observational evidence of Moon in sky.
"As the Earth turns you see more and more of it."

Construct 5
Sun and Moon are stationary. Phases caused by Earth shadow cast onto the Moon as it passes slowly by. Cycle and regularity confused. Sun>Earth>Moon in 1 case. Construct may have been influenced by previous classroom activities associated with formation of shadows. No evidence to suggest Earth does anything other than pass between Sun and Moon.
"As the Earth moves, the Sun's rays skim the planet and we see the light and the shadow from the Moon."

Construct 6
Earth and Moon are stationary. The Sun travels around both every 24 hours illuminating different parts of the Moon causing phases and nightly period of cycle. Sun>Moon>Earth. Based on primary observational evidence of Sun in sky, limited direct observational evidence of Moon.
"As the Sun moves it shines on different parts of the Moon we see."

Construct 7 (verbal)
"Could be the power of the wind moving the Moon. The full Moon (most commonly remembered phase) is too heavy for the wind to move."

Construct 8 (verbal)
"I was told the man on the Moon does it somehow. He opens a door and chips bits away."

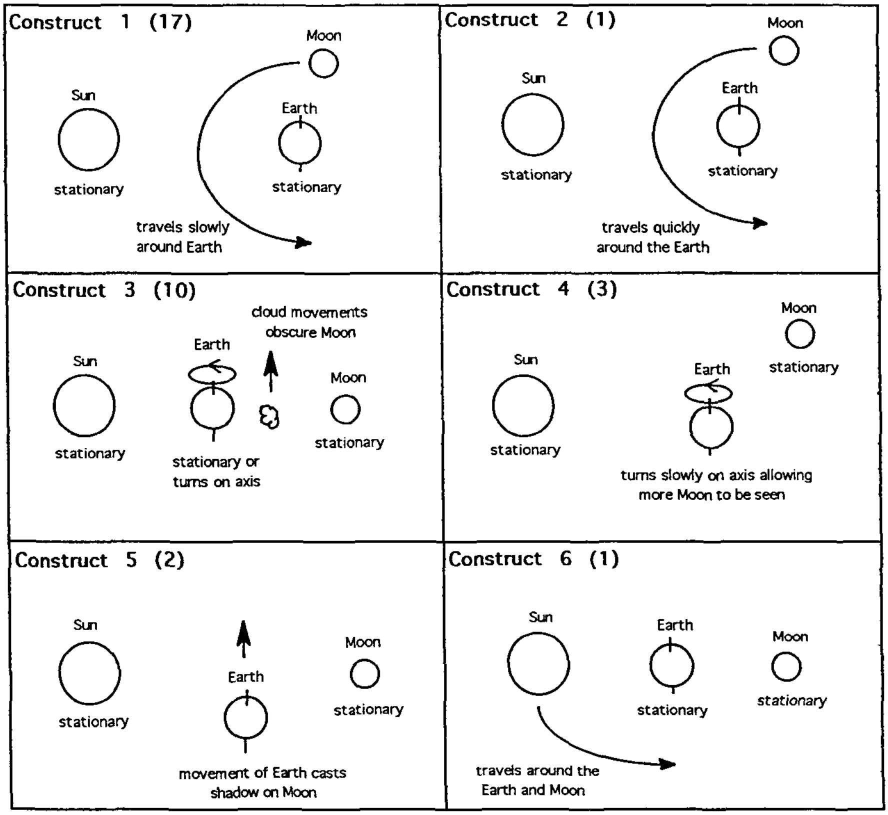


Figure 10. Children's ideas about phases of the Moon. Numbers in brackets indicate number of children holding that view. Construct 1 'scientific'; 2 'synthetic'; 3 to 8 'intuitive' (n = 42, unsure = 6).

the solar system including 'thousands' and 'millions' of years old (rarely 'billions') were obtained, again with little meaning, as was reference to other areas of the curriculum:

> Before Jesus was born and the Stone Age people were around.
>
> The Earth is one million years old from the age of the dinosaurs when plants and volcanoes started up.
>
> Thousands of years old, before Tudors and Stuarts started up.

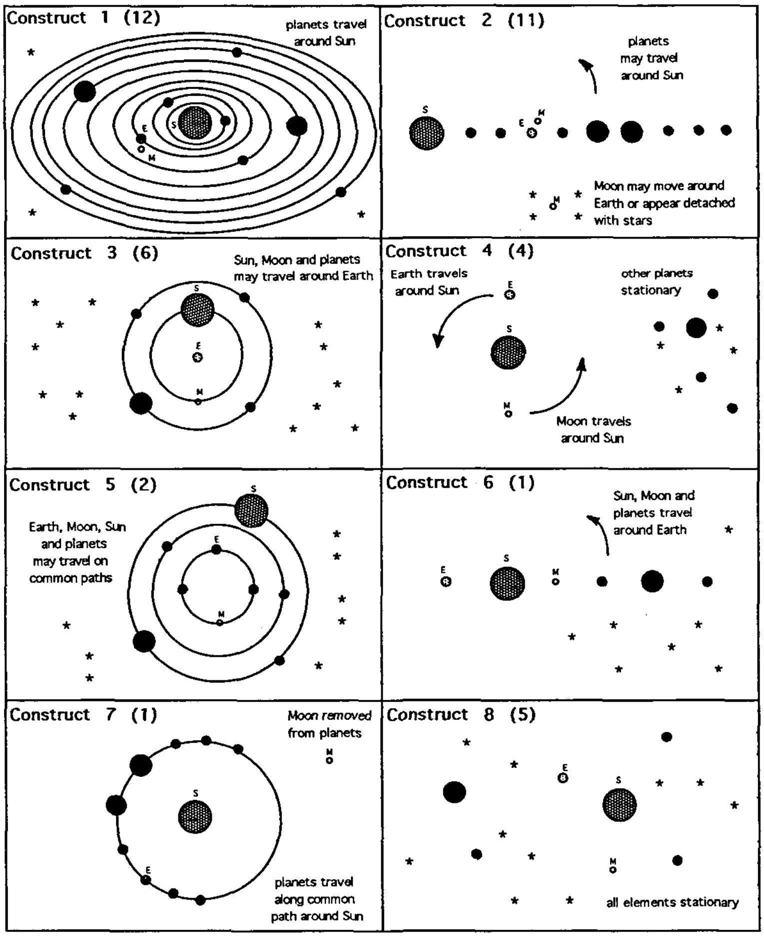
A variety of theories were evident regarding the origin of the solar system and wider universe:

> Don't know. They're just there. Been there all the time.
>
> God might have done it. He created Adam and Eve. It says that he created the Earth and the planets but I'm not sure.
>
> The Big Bang millions of years ago. All the planets and things in the universe was one big lump. All the gases made the universe explode and it whooshed out.
>
> The Sun smashed into something and it made the planets.
>
> They're made from little bits of rock flying about which joined together.

Life on other planets was generally thought unlikely apart from perhaps a few 'aliens' because it was 'too dangerous' or there was 'no atmosphere', 'gravity' or 'oxygen'.

Summary and implications of the study

Astronomy should be viewed as an important and essential part of any primary science curriculum. Results of preliminary investigations presented here are consistent with a constructivist view that children's ideas are strongly influenced by primary and secondary sources of information including direct observations of what they see, or think they see, all around them and in the sky; by certain forms of cultural



Construct 1
Complex, Sun-centred, concentric ring model. Rings may be circular or elliptical. Most or all of the planets recalled with details and placed largely in an acceptable order with respect to a central, stationary Sun around which they travel. The Moon is associated with the Earth. Orbital path descriptions included one child's account that "Pluto is a comet which orbits Uranus because it enters Neptune's orbit". Orbital periods varied. "The closest ones go round the quickest, the ones further away take longer." "Mercury takes 55 days, Pluto 10 years or something like that." "Astrobelt" (asteroids) often shown located between Earth and Mars or Mars and Jupiter. Stars lie almost always beyond the outer ring. In two instances, the rings, which symbolize the paths or orbits of the planets around the Sun in books and on charts, were thought to actually exist, most considered them "invisible".

Construct 2
Complex, Sun-centred, linear model. Most or all of the planets recalled with details (including axial tilt of Uranus) and placed largely in an acceptable order with respect to the Sun around which they may or, rarely, may not travel. The Moon may be associated with the Earth or, occasionally, detached with the stars as shown. Orbital periods varied. "Mercury goes around very fast, the Earth in 1 year and Pluto, the smallest, in 275 years." Arrows appeared above each planet and the Sun in one drawing. These were believed, from a classroom mobile, to "hold the planets and things up in space".

Construct 3
Earth-centred, concentric ring model. Both Sun and Moon share a common inner ring, the other planets (poorly recalled) share outer rings. Most generally travel around a central Earth. Stars generally lie beyond outer ring. Classic geocentric viewpoint. Relative size of the Earth, Sun and Moon well known, other bodies uncertain. Informed in one case that "a tenth planet might be there 1 million light years away but I don't know the details".

Construct 4
Simple, Sun-centred model. Earth and Moon diametrically opposite and may remain stationary or travel around the Sun as shown. Other planets (poorly recalled) clustered with stars and distant to the Earth-Sun-Moon system. Relative size of the Earth, Sun and Moon well known, other bodies uncertain.

Construct 5
Simple concentric model. Earth, Sun, Moon and planets (poorly recalled) share common rings. In one case, all elements were thought to move, in the other "the rings are invisible but hold the planets together". No central body to system. Stars largely shown beyond outer ring. Relative sizes uncertain.

Construct 6
Earth-centred, linear model. Sun, Moon and other planets (poorly recalled) all travel around a central, stationary Earth. Stars may lie within or beyond system. Relative sizes uncertain.

Construct 7
Sun-centred, 'processional' model. All planets recalled with details travel largely in acceptable order around a central stationary Sun. The Moon lies detached beyond the planetary procession though not with stars (absent). Relative size of planets uncertain, Sun largest feature of system.

Construct 8
Random (occasionally Sun-centred random) model. Earth, Sun and Moon often in close proximity scattered amongst other planets (poorly recalled) and stars. All elements shown stationary. Relative sizes uncertain, planets regularly shown larger than the Sun. Black holes, comets, the Milky Way and space ships often appear on drawings.

Figure 11. Children's ideas about the solar system. E = Earth, S = Sun, M = Moon. Numbers in brackets indicate number of children holding that view. Construct 1 and 2 'scientific'; 3 to 7 'synthetic'; 8 'intuitive' (n = 42).

and social transmission; and by periods of focused instruction (figure 12). Using a combination of elicitation techniques which helped refine and validate authentic responses, the results confirm and extend the findings of other researchers and contribute to our own knowledge and understanding of children's ideas in this field. In addition, specific details relating to the nature of planet Earth, the Sun, Moon, stars and solar system are presented for the first time. Despite minor, but potentially significant, variations associated with the sample group's responses concerning some astronomical phenomena (including examples of precausal, teleological, animistic and anthropomorphic explanations and accounts), the results are considered highly encouraging. Many of the children were found to possess an impressive factual and procedural knowledge, including the ability to demonstrate and use a range of key 'enabling concepts' and to provide 'scientific' causal reasoning within a remote and objective reference frame ignoring obvious visual distractions. This suggests that a true understanding of complex and abstract information is attainable by older

Personal	(experiences / direct observations)	73
Audio-visual	(video, TV, News, films)	60
Literature	(books, comics, newspapers, magazines, maps, pictures, posters, charts)	34
Computer		25
Play		18
Holiday	(including visits to museums,planetaria)	14
Teachers	(directly telling)	7
Globes		5
Hearsay		3

Figure 12. Children's mentions of stimulus in the course of interview (n = 42).

children in the primary age phase. Virtually all of the children seemed aware that the Earth, Sun and Moon are separate 'spherical' bodies. Sixty-two per cent were able to place them in the correct order of relative size. Details concerning stars were less clear. A complete knowledge of Earth gravity, its presence, effects and implications, was only partially evident. The presence, effects and implications of gravity elsewhere, e.g. on the Moon or associated with the solar system, were known in some instances, but were generally confused. Sixty per cent displayed adequate 'scientific' accounts of day and night (7% 'synthetic', 26% 'intuitive', 7% unsure); 19% for the seasons (2% 'synthetic', 43% 'intuitive', 36% unsure); 40% for phases of the Moon (2% 'synthetic', 43% 'intuitive', 15% unsure); and 55% for the solar system (33% 'synthetic', 12% 'intuitive'). Although direct comparisons are virtually impossible, it is tempting to suggest that the significant improvement of numbers of children displaying 'scientific' viewpoints in some of the areas described, compared to the pre-National Curriculum survey of English children by Baxter (1989), is a direct consequence of the introduction of the National Curriculum.

Placing children's models or 'constructs' into 'intuitive', 'scientific' and 'synthetic' categories is important if sensible world-wide comparisons are to be made. Establishing 'working' boundaries between categories is not easy, however, since this relies specifically on the identification and recognition of a hierarchy of key 'enabling concepts' and influences in each area studied. Clearly, determining which features of any model or 'construct' are more valuable, or allow for better conceptualization than others, is essential. The criteria used here to achieve this are still somewhat vague and require further attention. Systematic network analysis which allows wide ranges of responses to be recorded might provide an answer. Used successfully to identify specific elements of children's ideas by Osborne *et al.* (1994), individual and class networks could be matched against organized conceptual networks and a means of scoring or sorting to facilitate classification established. The results could also provide useful information concerning which alternative elements and viewpoints are most prevalent and thus help guide focused intervention or instruction.

One particularly interesting feature of the sample group's responses was the extent to which they expressed themselves using both technical and figurative language. In most cases a technical vocabulary was well used, individuals not simply reciting words in a way expected of 'scientists'. Some confusions did exist. In one instance, for example, the Earth was described as 'turning on its axle at the poles'. The misuse of 'axle' for 'axis' is quite understandable, but further investigation revealed that the poles, accurately located, were thought to exist literally, as huge metallic structures sticking out of the top and bottom of the planet. This image was arrived at from the classroom globe and pictures of the Earth in certain classroom books. Solomon (1986) has reported that the use of simile and metaphor as well as other forms of comparison, can be an essential part of children learning science, helping them to clarify their thoughts particularly when working in new or unfamiliar territory. Although many forms of comparison could be described as productive (direct and descriptive, or in a position to promote conceptual change), e.g. the Earth is 'round like a ball', the Sun is 'a big ball of flames', some were less so, e.g. the Earth is 'round like a circle' or 'round with lines on'; the Sun is 'a planet on fire'.

In a wider sense, comparisons involving relative size, distance, age and time were found to be more useful and familiar to children than absolute measurements which, despite being provided when asked for, clearly meant very little to them. Interestingly, in the same way that comparisons can be valuable to children, the use of taught analogy has had some success amongst primary teachers in helping them to improve their 'visualization' of certain science concepts and to come to terms with the demands being made by the introduction of a National Science Curriculum (Summers 1992).

But can the quality of learning in the field of astronomy be improved? With the comments and concerns of Millar (1989) and Watts and Bentley (1991) very much in mind, it is certainly one aspect of science education that requires further attention, since there is now a statutory obligation to deliver and assess primary science in England and Wales. Flexible and effective teaching and learning models appropriate for different age ranges and specific situations must be developed. Closer collaboration between science education researchers and classroom practitioners is necessary. The notion of principled teaching strategies based on a constructivist model of learning involving elicitation, intervention, challenge and promotion of conceptual change is not new (e.g. Nussbaum and Novick 1982) but neither has it been explored or exploited to realize its full potential. Astronomy teaching and learning models would need to consider and investigate a combining of what is known about 'scientific' conceptual models, children's ideas, 'enabling concepts', the strengths and limitations of available resources, activities and teaching methods, the use of teacher and child language, impacts from other area of the primary curriculum, and how these might be best integrated without being driven by 'scientific' content and process alone or losing sight of what a primary education entails. They could certainly be considered to begin to address many of the uncertainties uncovered in this work, and those in others, including treating the solar system as a dynamic entity of which the Earth–Sun–Moon system is only a small but important and integral part, and ensure a now all too familiar call for children to receive some parity of experiences nationwide. Such models could be introduced and disseminated through pre-service and in-service provision which should seek to not only raise teachers' own knowledge and understanding of 'scientific' phenomena, but to provide them with an insight into the ideas that children might possess, how to find them out and how best to tackle them.

Above all, teachers, researchers and curriculum designers at all levels must be more sensitive to the 'relativistic' views of the child and how they differ from 'scientifically' informed adult world views. Only when this has been fully recognized and acknowledged can curriculum development and assessment frameworks be fully informed ensuring a more human and profitable experience (Cheung and Taylor 1991, Harlen 1992, Jenkins 1992, White 1992, Watts and Bentley 1994).

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