

UNIVERSITY OF BATH

School of Education

THE ROLE OF ASTRONOMY AS PART
OF A BROAD SCIENCE EDUCATION
FOR ALL PUPILS

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ABSTRACT

This thesis is a report on a research programme aimed at promoting the more widespread teaching of astronomy by addressing two principle issues: demonstrating its value as a part of balanced science and showing that it can be taught in a style compatible with mainstream science teaching.

A literature search, carried out to identify forces which influenced past levels of astronomy education, revealed that throughout history astronomy has been held within priesthoods and that calls for its more widespread teaching were related to the Nation's economy or security. This search identified early theories about astronomy which parallel ideas frequently subscribed to by both pupils and teachers today, and revealed areas from astronomy's history which can be used as a vehicle to develop childrens' concept about planet Earth in space.

Postal surveys indicate that the amount of astronomy presently taught in schools (1986) has undergone little change from the past; astronomy only features in 47% of English secondary schools and the coverage tends to be superficial. Heads of Science departments are dissatisfied with their school's provision for astronomy education, their pupils' and their own understanding of the subject; 68% requesting Inset before they can teach astronomy with confidence.

Surveys of childrens' understanding of astronomy show that they frequently construct their own explanations (alternative frameworks) for many of their observations, and that these alternative frameworks

are commonly preCopernican in structure and are often carried into adulthood.

Pupils' alternative ideas were used as the central focus for the production of astronomy teaching materials. This material has received favourable evaluation and has achieved one of the principle aims of the study.

The significance of this research is reviewed against the statutory requirements of the National Curriculum (1988) [i] for science and recommendations are made about Attainment Target 16 sequencing changes, cross-curricular links, Inset and the role of various agencies in an attempt to identify the best way forward for astronomy education.

[i] The National Curriculum for Science 1989 comprised 17 Attainment Targets, each attainment target being associated with a particular area of science. Astronomy featured in Attainment Target 16, 'The Earth in Space'. In May 1991 the Secretary of State for Education and Science proposed reducing the number of attainment targets from 17 to 5. In this proposal almost all the astronomy content of the original Attainment Target 16 has been included in the new Attainment Target 3 'Earth and Environment'.

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CHAPTER 1

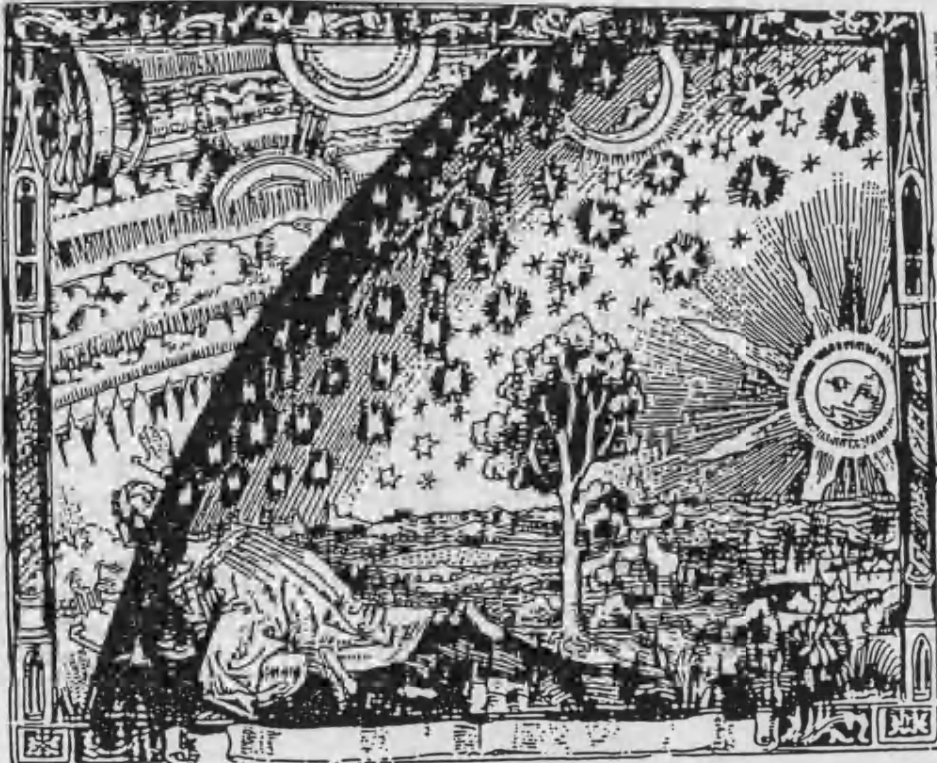
HISTORY

The glory of God is to conseed a thing, but the glory of the king is to find out as if, according to the innocent play of children, the Devine Majesty took delight to hide his works, to the end to have them found out; and as if kings could not obtain a greater honour than to be God's play-fellows in that game.

*Francis Bacon
The Advancement of Learning (1605)*

1.00 Introduction

One of the most evocative images portraying the birth of man's modern understanding of the universe features a medieval monk pulling back the sphere of primeval perception to reveal the cosmos which lay hidden behind his primary impression [i].



The monk's view, although dangerously controversial at the time, has pervaded almost all cultures over the past four hundred years, and it is now commonly assumed [ii] that adults and children have drawn up the same sphere-like veil to gain a similar view.

In this thesis I will demonstrate that this assumption about childrens' understanding of astronomy is flawed, and that they, and adults, frequently hold notions about the universe which have undergone little change from those ideas supported by their ancestors living before the time of Copernicus.

I will propose that an understanding of humankind's early cosmography gives an insight into how childrens' ideas about certain aspects of astronomy develop, and provides a suitable context against which they can challenge their view. Nunn (1919) emphasised this potential when he claimed that the history of science is:

".... a most useful guide to the teacher in choosing his exposition and for seeing the childs point of view."

The development of our understanding of astronomy has a long history and, like other branches of science, its advancement has been influenced by both social and intellectual pressures; Russell (1974) maintains that:

"Science has not developed only, or even chiefly, in response to pressures from within, but has been moulded by external forces of various kinds."

These influences have often directed the growth of understanding along paths compatible to the persuasion of particular pressure groups. Possibly the most well known example of external pressure group influence on astronomy is the maintenance of geocentrism by the Catholic Church (see chapt. 1.02-1.04).

Teaching astronomy - or any science - in isolation from its past fails to utilise the valuable resource offered by the subject's history and leads to misconceptions about the scientific process by presenting science, as Selley (1986) claims:

".... as entirely a pre-existing, non-negotiable body of concepts and theories."

To Gingerich (1988), presenting the historical perspective shows:

".... how science works in an evolving self correcting way
....."

The historical outline of astronomy given in this chapter is intended to serve three main purposes:

- (i) To identify internal and external forces which have influenced the amount of astronomy taught in schools.
- (ii) To demonstrate that the history of astronomy offers a rich fund of material which curriculum planners and writers may focus on to illustrate the tentative nature of scientific proof [iii], the scientific process, and the development of cross curricular material.
- (iii) To equate the growth of astronomical knowledge with humankind's changing view of the universe and his place within the scheme of things.

1.01 Astronomy of Prehistory

If modern interpretations of the function of Stonehenge are correct, - Hawkins (1963), Colton and Martin (1969) and Hoyle (1977) - the ancient Britons seem to have developed a considerable expertise in building megalithic computers for predicting certain astronomical events. It appears that these astronomically aligned constructions were not confined to Britain; both Streit (1977) and O'Kelly (1982) consider the tomb at Newgrange, the stones structure at Carnac and many of those to be found in Ireland, were built with a detailed knowledge of astronomical alignment. Clearly, these structures could not have been built without making precise observations over many years before construction began. Hoyle (1977) claims that these observations must have been handed down from one generation to another. If so, this must have formed an early system of recording and training in astronomy.

Both Thom (1954) and Hadingham (1983) consider ancient astronomy to have been held within a priesthood, with its aims essentially practical; namely the training of an elite on how to construct and use these megalithic structures for predicting dates important to their particular culture. Although the idea of an astronomically sophisticated prehistoric cult imagined by the more enthusiastic followers of Thom's (1954) theories is in doubt, - notably through the work of Burl (1976) - it is generally agreed that structures like Stonehenge were used for religious purposes.

Apart from the construction of these stone edifices, the British had a late start in the science of astronomy; the skills developed in prehistory became forgotten. On this McNally (1982) writes:

"Unfortunately this native wit declined, the decline no doubt accelerated by the coming of the Romans, and all that was left by the end of the Dark Ages was a starlore that finds expression in the work of Chaucer."

1.02 The Influence of the Church

A more formal astronomy education in England can be traced back to Theodre of Tarsus - Archbishop of Canterbury between 669 and 690 A.D. - and his assistant Hadrain. Bede (800 AD) claims they were educators:

".... teaching the art meter, astronomy and the calculation of the Church's feast days as well as the scriptures."

Although the religion changed from pagan to Christian, but astronomy continued to be the handmaid of theology, taught to an elite group and primarily used for calculating the dates of important festivals [iv].

According to Stevens (1921), by 732 A.D. teaching aids in the form of terrestrial and celestial globes were in use and astronomy was included in the quadrivium [v]. Pliny's 'Natural History' was available along with a few other astronomy books, but Stevens makes the point that it is unlikely their influence was very great as there were no more than twenty monastic and church schools in England during the eighth century; and as Lawson and Silver (1973) point out, the primary purpose of education was the training of priests:

".... which entailed only the learning of Latin grammar in order to read the bible, together with a little music to sing chant, and some arithmetic and astronomy for the calculation of the date of Easter and for reckoning the time of the daily offices."

For fifteen hundred years after the birth of Christ theories on astronomy reflected the world view of the Church Fathers, in the words of Blum (1973) astronomy became the:

".... product of informal understanding negotiated among members of an organised intellectual collectivity."

The situation corresponds with Lukacs's (1923) assertion that knowledge of all kinds is the product of interaction between men, reality and interest, and as such, like all knowledge, socially constructed. However, as Hudson and Prophet (1986) state, a particular group may make a cynical use of education, but that group is just as likely to have a genuine passion for its cause. This was most probably the case with the Church Fathers. Dijksterhuis (1961) appears to be aware of this when he argues that the Church Fathers were not antagonistic to the study of nature, but that they followed Saint Augustine who urged that science should remain subjected to the authority of the scriptures as they surpass all the capacities of the human mind; but this Dijksterhuis (1961) claims:

".... imposed on scientific inquiry a restriction which was to last many centuries."

During the first to the eleventh centuries A.D. the world view of the Greeks, exemplified in Ovid's 43BC-17AD Metamorphosis:

".... God's first care was to shape the Earth into a great ball" was replaced by a flat Earth notion. Advances made by Greek astronomers were largely replaced by the biblical view. The work of Aristotle (384-325 B.C.) who demonstrated the Earth is a globe, Eratosthenes (c200 B.C.) who measured the globe, and Aristarchus of Samos (310-230 B.C.) who suggested that the Earth turns in front of a fixed Sun, was replaced in favour of a biblically compatible world picture; that given by Saint Lactantius (c225 A.D.) in the third volume of his 'Divine Institution' (quoted by Draper (1875)) in which he used all the naive arguments in favour of a flat Earth and against the existence of the Antipodes; arguing that it was impossible for people to walk with their feet above their heads and that rain and snow cannot fall upwards.

To demonstrate the views entertained in the sixth century, both Draper (1875) and White (1895) quote Cosmas Indicopleustes, who, in his book 'Topographia Christiana', claimed the Earth is a quadrangular plane enclosed by mountains on which the sky rests. Those mountains on the north side being larger give night when they intercept the rays of the Sun.

The ideas of Saint Lactantius were supported by the writings of Saint Augustine (354-430 A.D.) who, while accepting that the Earth is round, rejected the idea of people living at the Antipodes [vi]. Such views from prominent Church Fathers had the effect of halting the advancement of astronomical knowledge. No-one, according to Draper (1875):

".... did more than this Father (Augustine) to bring science and religion into antagonism."

Although the Church used Aristotle's writings to support the scriptures, this was not without resistance because certain aspects of Aristotle's view - a round Earth - contradicted ideas about the Universe contained within the scriptures - particularly Isaiah XL:22 - which presents the Earth as a Tabernacle. However, as Russell (1974) points out, this resistance was largely resolved during the second half of the thirteenth century by Albert Magnus (c 1200-1280) and Thomas Aquinas (1225-1274), who demonstrated that the philosophy of Aristotle could be equated with Christian theology. The idea that Aristotle had said all that there was to say about the natural world was denied, therefore, his ideas could be rejected without incurring ecclesiastical opposition. There had also been a gradual realisation that the wording of the Bible had both a literal and an allegorical meaning and was aimed at the understanding of the common man.

By the end of the thirteenth century the notion of a round Earth was accepted as the general view, but it was to be another three hundred years before the more radical idea of Aristarchus was to receive serious consideration and challenge the established view of an Earth centred solar system.

1.03 The Copernican Revolution

The notion of a Sun-centred solar system has a long history stretching back to Aristarchus of Samos. However, it was the Indian astronomer Aryabhata (A.D.476) who first took issue with the Aristotelian view, and although he was not subjected to intimidation from the establishment for holding such views - as was Galileo in later times - the ideas of Aristotle were so deeply rooted in India during the fifth to eighth centuries that scholars who venerated Aryabhata in other respects, either ignored his views on this issue or - according to Narlikar (1988):

".... tried to reinterpret in a way which did not conflict with the fixed Earth hypothesis."

The most decisive challenge to the fixed Earth notion came in 1543 with the publication of Nicolaus Copernicus's 'De Revolutionibus Orbium Caelestium', in which he placed the Sun firmly at the centre of the solar system. Although often referred to as a revolution, it did not change man's view overnight. Both Russell (1974) and Kuhn (1957) draw attention to the fact that this highly mathematical revision of classical astronomy did not become a cosmological issue until over one hundred years after its publication. This - according to Kuhn (1957) - was because Copernicus had made it unreadable to all but the most erudite astronomers of the day. In fact 'De Revolutionibus' has never been widely read, the one thousand first edition copies never sold out and Koestler (1959) points out that it has only had four reprints in over four hundred years.

White (1895) claims that opposition to the Copernican world view was voiced by Martin Luther one year before the publication of 'De Revolutionibus'. However, the anonymous preface - which both Russell (1974) and Koestler (1959) say was written by Andreas Osiander (1543) who supervised the final printing - probably placated those theologians able to understand what Copernicus was saying, explaining that several hypotheses can be used to demonstrate the same apparent motions and that:

".... these hypotheses need not be true or even probable; if they provide a calculus consistent with the observations, that alone is sufficient."

There is a parallel with the followers of Aryabhata (see above) who tried to interpret his work so that it would not conflict with the general view; Osiander had been in communication with Copernicus two years before the publication of 'De Revolutionibus' concerning their anxieties on the subject matter it contained. However, whether it was the mathematics or the preface (or both) it was not until the latter part of the sixteenth century that it became a focal point for controversies in religion, philosophy and social theory, but by this time a hard-core of Copernican astronomers had become established and it was only a matter of time before the idea permeated into certain stratas of society and became part of the accepted world view.

1.04 Galileo and the Conflict Thesis

Of all the issues concerning the conflict between science and religion, none has attracted more attention than that between the Catholic church and Galileo for the support he gave to the ideas of Copernicus, details of which are too well documented elsewhere for repetition in this

thesis - see, for instance, Russell (1974), Santillana (1961), Langford (1971). However, Galileo is not alone in the history of this discord, neither is the Catholic church the only religious group to intimidate and slay scientists for holding views contrary to official dogma. Hobden (1988) draws parallels between the trial of Galileo and the assassination of the Samarkand astronomer Ulughbek (1394-1449) even though there is no evidence to suggest that he ever propounded any new cosmological theories as did Galileo.

Galileo's greatest influence on the cosmology of the ordinary man came from his astronomical observations using the telescope; but this was preceded by both Galileo and Hans Lippershy - the inventor - capitalising on its military importance. Lippershy demonstrated - and secured a contract to supply - the instrument to the Dutch governing body who - according to King (1955) - considered it:

".... likely to be of utility to the state"

in their struggle for independence against the armies of Philip II of Spain.

Galileo first received details of the telescope in 1609, and after making improvements to its design, presented his instrument to the Senate along with a letter explaining that it would be of utmost importance in war. As payment he was rewarded with a life-time professorship at Padua and a salary increase to one thousand scudi a year - (King (1955)).

Throughout history advances in astronomy have frequently been associated with progress in military technology. There has been a

modern day parallel to the development of the telescope in that of satellites; they too were first developed because of their military importance and only later used for astronomy.

In 1610 Galileo published 'Sidereus Nuncius', in which he reported his pioneering observations using the telescope; his discovery of the phases of Venus and the motions of Jupiter's satellites. Although - as King (1955) reminds us - he left this publication unrelated to 'De Revolutionibus', it was greeted with strong opposition from church leaders; some refusing to look through the instrument, while others claimed it impossible to see things not mentioned by Aristotle. Koestler (1959) considers that the main reason for the outburst of emotions following the publication of 'Sidereus Nuncius' was its immense readability (although this did not feature as a stated crime during the trial of Galileo). Unlike 'De Revolutionibus', 'Sidereus Nuncius' could be read in a few hours without specialized knowledge. This proved to be a watershed for the dissemination of ideas about astronomy, and marked the beginning of the popularization of astronomy through books written in the vernacular. These books became an important agent of education during the eighteenth century (more so than formal education), and have continued to be so up until the present time.

1.05 The Influence of the Telescope

The availability of telescopes rapidly spread throughout Europe; an instrument appeared at the Frankfurt fair in the autumn of 1608, the following May in Milan and by the end of that year they were being manufactured in London.

The telescope had a profound effect on astronomers and on the public at large. It gave astronomers a deeper look into space, and changed their methodology from carrying out calculations based on the observations of the ancients to observational astronomy. But more importantly, for the spread of heliocentrism, it provided a non-mathematical tool with which those hitherto unconcerned with astronomy could view the heavens. During the seventeenth century the telescope became a popular toy, those until now disinterested in astronomy, scanned the heavens with a new interest, and as Kuhn (1957) claims:

".... it popularised astronomy, and the astronomy it popularised was Copernican."

But the telescope did not convert all astronomers to heliocentrism; Johnson (1937) quotes Blundeville's remarks in the preface of an astronomy book printed in 1694 rejecting the ideas of Copernicus.

"Copernicus affirmeth that the Earth turneth and that the Sun standeth still in the midsts of the heavens, by help of which false suppositions he has made truer demonstrations of the motions and revolutions of the celestial sphere than ever before."

Many found the idea that the Earth is not at the centre of the solar system deeply disturbing. Kuhn (1957) draws attention to the psychological effect that heliocentrism had on man, writing:

"Men who believed that their terrestrial home was only a planet circulating blindly about one of an infinity of stars evaluated their place in the cosmic scheme quite differently than had their predecessors who saw the Earth as a unique and focal centre of God's creation."

Johnston (1937) gives a translation of a poem first published in France in 1578 and which later became popular in England during the first half of the seventeenth century, which shows the incredulity with which the idea of a rotating Earth was received by the general public. (See Appendix I for full translation).

".... and we resemble land-bred novices
New brought ashore to venture on the seas;
Who, at first launching from the shores, suppose
The ship stands still, and the ground it goes."

The confusion caused by the heliocentric view features in poetry and drama from the middle of the seventeenth century, which Treasure (1985) says:

".... abounded with notes of unhappy confusion about God's universe and man's place in it."

The English poet John Donne (c1572-1631) epitomised this remorse which many felt as the ideas of Copernicus crept into every man's mind:

And new Philosophy calls all in doubt,
The Elements of fire is quite put out
The Sun is lost, and th'earth, and no man's wit
Can well direct him where to looke for it.
And freely men confesse that this world's spent,
When in the Planets, and the Firmament
They seeke so many new; then see that this
Is crumbled out againe to his Atomies.
'Tis all in peeces, and all Relation
And in these Constellations then arise
New starres, and old doe vanish from our eyes

By the twentieth century the attitude of poets had changed from confusion to one of resigned acceptance of humankind's insignificance; a view epitomised in the 'Galaxy Song' from the film 'The Meaning of Life'.

"The Universe itself keeps on expanding and expanding,
In all the directions it can whiz,
As fast as it can go, the speed of light you know,
Twelve million miles a minute and that's the fastest speed there
is,
So remember when your feeling very small and insecure,
How amazingly unlikely is your birth,
And pray there is intelligent life somewhere up in space,
Because there's buggers all down here on earth."

We will see in Chapter V that these 'poetic' expressions about man's confusions concerning his place in the universe offer a rich resource for the development of cross curricular work with English departments. This approach can help pupils clarify their own notions on planet Earth in space and offers meaningful material for the realisation of aspects of attainment target 17 of the National Curriculum.

1.06 The Influence of Navigation

Throughout the period that ideas contained in 'De Revolutionibus' were causing theological and philosophical debate, techniques in navigation were being improved so that seamen could plot a course in the expansion of the known world. Although the development of new techniques, improved charts and star maps took place largely in isolation from the geocentric argument, and marked a divide between academic astronomy and its utilitarian application, the need to train seamen in the art of navigation spread the ideas of Copernicus almost as a by-product. Simon (1966) illustrates this divide when he quotes Juan Luis Vives (1493-1540) who, during a visit to England in the 1520's, emphasised the practical importance of astronomy and warned against mathematical abstractions prevalent at the universities which:

".... withdraw the mind from the practical concerns of life and render it less fit to face concrete and mundane realities."

Walters (1958) points out that it was Henry VIII who laid the foundations for the development of navigation in 1514 when he established Trinity House for the advancement and benefit of navigation and commerce. But after his death the economy still needed more

foreign outlets for its manufactured goods and to find a northern route to Cathay, thus cornering the lucrative spice market. England was conscious of the need to master the art and science of navigation if she hoped to keep abreast of Spain and Portugal.

Portugal had taken the lead in navigation, a lead which was compounded with the publication of Pedro de Medina's 'Art de Navigar' (c1570). According to Hutson (1974) this was the first book ever published on navigation, becoming the accepted international work on the topic when it was translated into French as Perre de Medina's 'L'Art de Naviguer'. The book was based on the astronomy of Ptolemy and concerned only with navigation, making no mention of Copernicus.

In 1584 Richard Hakluyt drew attention to England's lack of investment into the training of navigators when he wrote to Walsingham - secretary to Elizabeth I - telling of the mathematical lectureship established in France, and urged the creation of a similar lectureship on navigation in the City of London - which would attract seamen - and one for mathematics at Oxford where learned men could study the theory of navigation and the application of mathematics to this problem.

Four years later, when England was under the threat of invasion by the Armada, Hakluyt's recommendations came to partial fruition. Walters (1958) observes:

"As so often in the history of England it took the stress of war to create what had long been desired in peace."

On the 4th of November 1588 Thomas Hood - the first reader - gave his opening address; although as Waters points out, prior to this he had been commissioned by Thomas Smith and John Wolstenholme - city financiers and merchants - to lecture privately on the application of mathematics to navigation. This marked the beginning of the promotion of astronomical advancement by private enterprise for its commercial potential, a trend which continued until a method of finding longitude was established.

Hood's lectures were given to the general public in both Latin and English and proved so popular they were continued until 1592. Later lectures were financed by the East India Company, a region of trade which Trevelyan (1944) considered "did more even than the American trade to develop the art of navigation".

A more permanent provision for lectures on navigation was made by Sir Thomas Gresham (1519-1579) who bequeathed a sum of money for the erection of a college. In 1575 he outlined his plans, stipulating:

.... that the astronomy professor was to read the principle of the sphere and to explain the uses of common instruments for the capacity of mariners and to apply these things to the art of navigation.

Sir Thomas insisted on instruction in English as their learners would be merchants and other citizens. For the first time in the history of astronomy education instruction was aimed at a wider public and no longer confined to a religious elite. This (along with the increasing number of books written in the vernacular) was to become an important

factor in the transmission of the ideas Copernicus put forward in his 'De Revolutionibus'.

Gresham College was founded in 1597, the lectures were open to the public and were probably the first introduction to the heliocentric view for the great majority in attendance. Johnson (1937) claims that there can be no doubt that most of the Gresham professors were outright Copernicans, and although they published no books dealing directly with the heliocentric argument, their ideas were transmitted by the spoken word to a large audience and must have been a major influence on the acceptance of Copernicism during the late sixteenth century. Lintern-Ball (1981) reminds us that it was a college which did not remain under ecclesiastical control; this probably resulted in the professors being less constrained in stating their world view, consequently their ideas had a wider influence than those at universities, where instruction was in Latin to an elite of landed gentry, many of whom entered the church.

During the second half of the sixteenth century advancement in astronomy became inextricably linked to the economy of the nation, under the patronage of traders. The importance of Navigation during this period is exemplified in the powerful figures beside instruments of navigation in Holbein's (1531) painting 'The French Ambassadors'.



**Holbein's THE AMBASSADORS
(The National Gallery)**

Plate 1

Hill (1965) makes the point that science during this period was the work of merchants and craftsmen, not dons, carried out in London not Oxford or Cambridge. London became the centre for science and the science was utilitarian. During the next two hundred years advancement and education in astronomy had a greater influence on the economy of the nation and on the lives of ordinary people more than at any other time in its history.

1.07 Newton's Universe

During the seventeenth century education in astronomy continued to be primarily concerned with navigation, and for the first half of the century Gresham College played a major role in satisfying the country's need. However, the Dutch Wars during the latter part of the century (like the threat from the Armada in Elizabethan times and the Russians with Sputnik in the twentieth century) acted as a catalyst on the demand for skills related to the protection of the nation. In response, and under the patronage of Charles II, Christ's Hospital Mathematics School was established in 1673 where, according to Pearce (1908), forty boys were taught mathematics and navigation. Hutson (1974) quotes Isaac Newton, who summarised the aims of school, saying:

".... the mathematical children, being the flower of the hospital, are capable of much better learning, and when well instructed and bound out to skilful masters may in some time furnish the Nation with a more skilful sort of sailor"

Newton was aware of the need to extend astronomy education, but within two hundred years of the publication of his 'Philosophiae Naturalis

'Principia Mathematica' in 1687, he had unwittingly placed astronomy back into a priesthood; that of mathematics.

Newton's 'Principia' led to the notion of a 'clockwork' mechanical universe; Santillana (1961) talks of:

".... the mechanical world models produced under the Newtonian aegis"

The Newtonian view of the universe is frequently thought to be the notion most people subscribe to today. Koestler (1959) ends his survey of mans' ideas about the universe claiming that, despite more than two centuries having passed, our vision is by and large 'Newtonian'. This opinion of the state of the ordinary person's cosmology will be challenged by the results of the pupils' knowledge survey reported in Chapter IV of this thesis.

For the first one hundred years after the publication of the 'Principia', navigation was still the main priority of astronomers. Lock (1633-1704) - probably the most famous educational theorist living during the time of Newton - gives some indication of the emphasis placed on navigation during this period when he wrote:

".... children should be instructed in a good part of geography, astronomy and chronology."

In 1714 the Board of Longitude was set up to stimulate innovation in navigation and offered a prize of £20,000 to the person who perfected an accurate and practical method of finding longitude. The major problem was that of designing an accurate clock which would function at

sea; clock making became of national importance and inextricably linked to navigation.

A solution to the problem was found by John Harrison who, between 1735 and 1770, made five chronometers of increasing accuracy, which Whitrow (1988) claims proved to be a landmark in the history of time-keeping. An exact replica of Harrison's chronometer was taken on Cook's voyage of 1772-75 and enabled him to construct maps of the coastline of Australia and New Zealand with great accuracy. This, according to Hutson (1974), proved the worth of Harrison's chronometer. Along with Halley's earlier observations of true North, Harrison's chronometer paved the way for connecting points on the Earth's surface producing the first isogonic map and solved the problem of longitude and navigation.

The solution proved to be a landmark in the history of astronomy education also, attention turned away from innovation in astronavigation; astronomical observations became distanced from practical applications and increasingly abstract in nature, marking the beginning of a return to being a subject studied by an elite.

1.08 The Influence of the Universities and the Popularisation of Astronomy During the Seventeenth and Eighteenth Centuries

The part played by the universities in the diffusion of astronomical knowledge was minimal until the first half of the seventeenth century. The only faculty before 1619 undertaking any advanced instruction in astronomy was that of medicine, and this was for making astrological predictions which played an important role in medical practice in the sixteenth and seventeenth centuries [vii].

Astronomy did not feature in the B.A. at either Oxford or Cambridge during the early part of the seventeenth century, but was part of the curriculum for those who went on to take the M.A. However, it appears that the instruction was superficial and elementary; the principle text books - in Latin - were Sacrobosco's 'Sphaera Mundi' and Proclus's book on 'The Sphere', both of which Johnson (1968) claims contained errors about astronomy:

.... which should have been apparent to any student who went to the trouble of analysing carefully their author's statements."

Within the universities advanced studies were frequently carried out independently by students with an enthusiasm for the subject and Johnson (1968) points out that those who remained as tutors and fellows often updated their ordinary lectures to include advanced work on astronomy. But it appears that the overall quality of scholarship was deficient, and by 1677 (according to John Newton (1677) astronomy education had made little progress [viii].

"I hope it will come to pass that other ages will be supplied with that knowledge which hitherto our writing masters have not been able to teach nor our grammar masters either able or willing to undertake.And that there are not many tutors in either of the universities that do: and yet the usefulness of those arts cannot be denied and therefore my hopes are that some universal encouragement will be given for the teaching of them."

The fact that there were no professorships in the mathematical science at either Oxford or Cambridge until 1619 when the Savilian Professorship of astronomy and geometry were founded at Oxford - similar Professorships were founded at Cambridge some thirty years later - does not mean that the universities were completely without influence on the diffusion of astronomical knowledge during the sixteenth and seventeenth centuries: their influence was ancillary, not through their syllabi, but through the extra-curricular activities and vernacular writings of fellows, tutors and students.

The greatest influence on the cosmology of the ordinary person were those university men who became writers in the vernacular (following the trend set by Galileo's 'Sidereus Nuncius'), able to translate, criticise and present the great scientific ideas in a style more comprehensible to their less educated countrymen. There had been a growing demand for books on astronomy and navigation since the beginning of the sixteenth century. The first treatise exclusively on cosmography printed in English was Cunningham's 'Cosmographical Glasse' (1553), and while it made no mention of Copernicus, Walters (1958) claims that:

".... no matter what criticism is levelled at this book it brought the subject from the recesses of the scholar's closet to the shelves of the gentry and desks of merchants."

Records's 'Castle of Knowledge', written in dialogue form between a scholar and his Copernican master, introduced Copernican astronomy to the British, and by the late sixteenth century the interested layperson

had a growing number of books in the vernacular through which he or she could study astronomy. Hill (1965) considers that the better text books in the vernacular were more up-to-date and superior than the standard texts used at the universities, and points out that public interest in science was high. (William London's Catalogue of the most Vendible Books in England (1657) shows one in every six to be scientific).

Astronomy became liberated from religious and mathematical priesthoods and started to become a subject studied for pleasure and social posturing. By the latter part of the seventeenth century a knowledge of astronomy became the hallmark of the educated person. During this period Lintern-Ball (1981) claims that astronomy developed from being a practical subject for mechanics and navigators into a gentlemanly pursuit for dilettantes. Charles II's interest in science - particularly astronomy - must have been an important factor in developing its fashionable appeal (he carried out guided observations using a telescope and on May 14th 1661 Evelyn recorded in his diary that the King had seen the rings of Saturn and the satellites of Jupiter).

Defoe (c1728) in his 'Complete English Gentleman', epitomises the idea that the educated gentleman should know about astronomy, writing:

".... he had read all that Sir Isaac Newton, Mr. Whiston and Mr. Halley had said in English upon the richest subjects in astronomy"

Bulbring (1890) takes up the same theme quoting Defoe's view of a gentleman when he wrote:

".... having gone thro' a course of astronomy such other parts of needful knowledge as are peculiar beauties in the life of a gentleman he comes into the world a complete gentleman."

Isaac Watts (1725) stressed the importance of astronomy to the notion of the educated person and pointed out that it is a study which should also be undertaken by females:

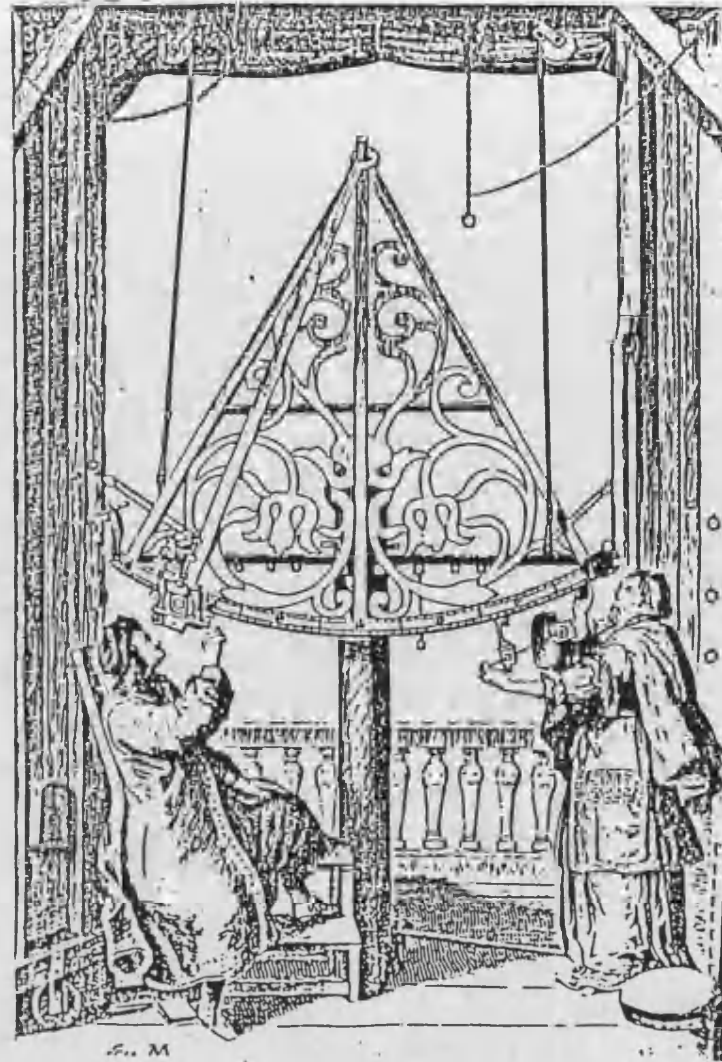
"The knowledge of the lines and circles of the globe of heavens and earth is counted so necessary in our age, that no person of either sex is now esteemed to have an elegant education without them."

Astronomy appears to be the first science considered suitable for study by females. A point exemplified in Nee's engraving 'Allegory of Astronomy' and Steer's 'Science in the 17th Century Home' (see Plates 2 and 3) [ix].



Plate 2

Allegory of Astronomy, by Francois Denis Née
Collection of J.M.Pasachoff.



Enthusiasm for science in the 17th-century home
(National Gallery)

Plate 3

The suitability of astronomy as a part of a female's education was made clear in Le Bovier De Fontanelle's 'Discourse on Plurality of Worlds' (1728), in which an enlightened French heroine learns astronomy through dialogues with her tutor.

Female scientific education was in favour during the eighteenth century, and there was an expansion in the number of books and periodicals available; some like Steel's (1714) 'Ladies Library and the Woman's Almanac' were written especially for women, while others, like the 'Ladies and Gentlemens Scientific Repository', were aimed at both sexes. To some degree the upsurge of interest in female education was influenced by Queen Caroline of Ansbach - wife of George II - who, like Charles II and astronomy, promoted the fashionable appeal of female learning. She became a patron of learning and literature with a thirst for knowledge, supporting musicians like Handel and meeting scientists like Halley and Newton (Howat (1973)).

While the precedent for female education set during the eighteenth century was not maintained during the nineteenth, a firm basis for the development of amateur astronomy had become established, which has, during the twentieth century, established itself as the principle scientific activity open to amateurs; one in which they can play a useful research role (see Iwaniszewska (1988)) [x].

The eighteenth century saw the proliferation of itinerant lecturers, some of whom gave talks and demonstrations on astronomy. Their origins went back to the 1662 Act of Uniformity which excluded

dissenters from the universities and non-conformist ministers of their living. In response many started small private schools, wrote text books in the vernacular or made a living by giving public lectures and demonstrations.

After the foundation of the Royal Society, a number of other societies were formed which facilitated the escalation of public lectures. At first they centred on London, but the provinces became quite well served during the latter part of the eighteenth century, the first - according to Lintern-Ball (1981) - was formed at Spalding around 1712; probably the most famous was the Lunar Society of Birmingham, which was formed in 1775.

The popularisation of science through societies and by itinerant lecturers continued into the nineteenth century, when there were many societies devoted to the dissemination of scientific knowledge. Astronomy featured in some lectures which often presented current ideas to a wide audience, probably becoming the second greatest influence on the cosmology of the ordinary man after the vernacular books and periodicals. However, as an influence on the astronomical knowledge of the population as a whole, their effect must have been very small indeed, partly because of the small fraction of the population attending lectures and also because the great majority of lectures were related to industrial skills. With the consolidation of navigational techniques, the merchants were no longer willing to lay out their money on research into astronomy as there was no return on their investment, and interest in astronomy was exchanged for investment in engineering

[xi]. The Royal Institution's application for its Charter in 1799 demonstrates this trend, stating:

"For forming a public institution for diffusing the knowledge and facilitating the general introduction of useful mechanical inventions."

The eighteenth century saw several amateurs with their own observatories - all of whom were wealthy aristocrats - the most famous being the Earl of Macclesfield who secured the reformation of the calendar in 1752. Public interest in astronomy appears to have been high. A number of factors could have accounted for this, not the least being the first predicted return of Halley's comet in 1758 and a particularly spectacular Leonid meteor storm of 1799 and again in 1833. Herschel's (1738-1822) discovery of Uranus in 1781 captured the public interest, and the construction of his forty foot telescope at Slough became an object of wonder to all who saw it (Ronan (1967)). This led to the notion that the study of astronomy requires large and expensive telescopes, which were only available to rich aristocrats, and as such, a topic not suitable for inclusion in the school science curriculum; a view which has prevailed into the twentieth century (see Westway Chapt. 1.2 p.36 and results of HOD survey Chapt.III).

1.09 The Break with Religion

During the eighteenth century the religious influence was still in existence, a fact exemplified in a letter from the 4th Earl of Chesterfield (December 6th 1748) to his son recommending the study of astronomy as a useful basis for religious instruction:

".... it will give you greater ideas of that eternal and omnipotent Being who contrived, made, and still preserves that universe."

Less than one hundred years later, Carlisle (1821) in his Address to Men of Science, called for astronomy education to dispel the mythology of religion, writing:

"All the astronomical dogmas of Holy Books are founded in error and ignorance of the laws of astronomy, (any astronomer who) supports the dogma of the priest, or the astronomy blunders of any holy book is a disgrace to the science he studies."

Carlisle's Address failed to generate a response from the church which by now was accommodating astronomical advance with religious dogma [xii]. Even Herschel's paper presented at the Royal Society in 1784 on the construction of the galaxy, in which he considered it very probable that the Sun was not placed at the very centre of the milky way, was accepted without any of the theological resistance associated with Copernicus.

In 1822 religious support for the pre-Copernican view was laid to rest when 'De Revolutionibus' and other writings which questioned the Aristotelian model of the universe, were removed from the Index of forbidden books, and the Catholic Church condoned teaching, reading and printing books which promoted the heliocentric view. Thus the most enduring and ardent support for geocentrism was finally relinquished.

1.10 Astronomy in Science Education During the Nineteenth Century

Herchel's forty foot telescope, although generating public interest at the time, marked a major division between amateur and professional astronomers; that of finance. Prior to its construction the telescope won a grant of two thousand pounds from King George III and a further two thousand before its completion, along with an annual allowance of two hundred pounds to pay for its maintenance. Sums of this magnitude distanced the amateur astronomer from the professional; a trend which has continued over the years and was compounded by the fact that the study of astronomy became increasingly more abstract and remote from the needs of the ordinary man. For example, the work of Couch-Adams (1819-1892) exemplified this divide when he established the existence of a new planet - later named Neptune - by mathematical calculations, which only the most erudite of astronomers could comprehend. There is a parallel with the work of Copernicus which, like the calculations of Couch-Adams, were incomprehensible to most people. This served to compound the gap between astronomers and ordinary people; a gap which Newton's 'Principia' had precipitated, thus heralding a new astronomical priesthood. While it can be argued that this trend is common to all sciences, it will be demonstrated in Chapter III that pupils' (and adults') cosmology has remained entrenched in medieval theory more than any other science. There was also a failure during the nineteenth century (and to a large extent, during the twentieth century also) to develop the distinctive characteristics which astronomy offers science education. These are reviewed in Chapter IV.

By the nineteenth century astronomy was being taught as an abstract science, no longer primarily for the purpose of navigation. Rouse

Ball (1889) gives the following example of an astronomy question for a written examination at Cambridge:

"Suppose a body thrown from an eminence upon the Earth, what must be the velocity of projections, to make it become a secondary planet to the Earth?"

The influence of Newton is clear and it is at this point astronomy began to divide into two distinctive groups: (i) the theoretical professionals, (ii) the amateurs, mainly concerned with observational astronomy; the ordinary man became further distanced from these two elite groups.

Although the importance of astronomy to the nation was in decline by the nineteenth century, a number of prominent educationalists considered it an essential part of a complete education. Armstrong (1880) claimed that no single branch of science should be selected but that instruction should comprise the elements of astronomy. Carlisle (1821) appeared to be holding on to the eighteenth century notion about an education in astronomy, claiming that an acquaintance with astronomy will result in the pupils' advancement in both the arts and sciences and thereby "improve their condition in society".

The foundation of the British Association for the Advancement of Science (B.A.A.S.) in 1831 marked the beginning of scientific societies interest in the curriculum. In their annual report of 1867 they considered it desirable that:

".... boys should have some general information about ordinary phenomena of nature, such as the simple facts of astronomy."

And again in their report of 1874 it was considered that an:

".... early place in the course should be given to elementary astronomy."

There is no mention of its role in female education and it appears that the initiative of enlightened educationalists in the eighteenth century did not permeate into the nineteenth. Possibly, the anti-intellectual tendencies of Romanticism may well have influenced attitudes, which would have been compounded by the portrayal of woman by popular writers like Dickens, and epitomised by his Lizzie Hexan in 'Our Mutual Friend'. A woman's role was seen as the guardian of the sanctuary home - Queen Victoria being the role model. Ball (1983) points out that training in housework for girls about to go into service was provided by many charity schools and that teaching domestic economy to prepare girls for their vocation as wives and mothers was very much the hallmark of female education during the nineteenth century.

In 1839 the state took the first step towards involvement in education when Parliament decided to provide a sum of public money to assist in the erection of schools for the poor. However, it appears that this initiative had no positive effect on the teaching of astronomy; the Minutes of the Committee of Council on Education (M.C.C.E.) from its first report in 1839 to the mid 1860's yields little evidence of astronomy in the curriculum (Lintern-Ball (1981)). There were attempts to encourage the teaching of astronomy, the reports of Inspectors Noel (1840-1) and Mosley (1841-5), who both advocated the inclusion of basic astronomy in the curriculum, resulted in the Committee of Council distributing text books on astronomy for teachers at discount prices. Herchel's 'Treatise on Astronomy' was reduced

from 6/- to 3/6d (30p to 18p), and Reid's 'Treatise on Astronomy' reduced from 2/6 to 1/6d (12.5p to 6.5p). But there is no evidence in later reports of the M.C.C.E. to suggest that this initiative had any effect on the curriculum.

The poor position of astronomy was further exacerbated by the Government's Revised Code of 1862, which resulted in the exclusion of all but grant earning subjects - reading, writing and arithmetic - from the curriculum, and astronomy, along with education in the other science, came to a virtual halt. Waring (1985) points out that there were those - including H.M.I.'s - who:

".... viewed the provision of anything more in elementary schools as a 'fancy education', 'educational luxuries that should not be provided at the public's expense'."

The Samuelson Commission of 1884 on technical education is further evidence of astronomy's decline as it receives no mention at all.

Uzzell (1986) considers that expansion of the elementary school curriculum beyond the three 'Rs' was easier in the 1870's when the Education Department gave grants dependant on examination results. However, this placed the teacher under pressure to enter pupils for government examinations and 'get them through'. The effect of this practice on astronomy education - and science in general - is exemplified in the observations of H.M.I. Alderson (1888) when he wrote on the subjects select by the teacher:

".... the teacher is guided by an intelligent forecast of its grant-earning capacity. Having established the probable advantage, he sallies out to buy a textbook, with

the contents of which he may hope in a year to make the class familiar, and the boys are set to work upon diagrams of the human skeleton, of illustrations of the phases of the moon, upon a calculation of the remunerative rather than their scientific and educational value."

It is interesting that he makes no mention of females' education, and it appears that the government's increasing involvement in education did not appear to feature equal opportunities for women. This is exemplified in the report of the School Board Chronicle (1884) which stated:

".... elementary science be given more attention in boys schools (girls, they argued, already had practical training in needlework classes)."

The notion of astronomy being integral to the idea of an educated gentleman - so prevalent during the seventeenth and eighteenth centuries - seems to have fallen into decline amongst the aristocracy; the Clarendon Commission's (1864) enquiry into the work of nine great public schools reported that:

"Natural science is practically excluded from the education of the higher classes in England."

The Devonshire Commission of 1875 came to the same conclusion, stating that it is:

".... a national misfortune that science is almost totally excluded from the training of the upper classes."

The work of Newton had placed astronomy back into the world of a mathematical elite; this, plus the Industrial Revolution's nouveaux riches' desire for their sons' entry into the leisured and cultured

world of the upper classes, resulted in the classics taking precedence over what was perceived as utilitarian science.

The Clarendon and Devonshire Commissions reflected the situation at the universities; at Cambridge astronomy only featured as a small part of the mathematics course, at Oxford it featured in one course of lectures and at Durham the professorship of astronomy was suspended in 1871.

By the turn of the century Lintern-Ball (1981) concludes:

".... astronomy as a taught subject had waned to such an extent that hardly any was being taught in the schools and colleges of England."

But astronomy had never found a place in the curriculum of the masses, by the time the state had intervened in education, astronomy was no longer vital to the nation's wealth.

Teaching strategy changes also levelled against the inclusion of astronomy in the curriculum. By 1882 there was a move away from a descriptive treatment of science - which had been the hallmark of astronomy - towards experiment, observation and an emphasis on every day applications. The 1882 code illustrated this, stating:

".... instruction shall be given mainly by experiment and illustration. If these subjects are taught to children by definition and verbal description, instead of making them exercise their powers of observation, they will be worthless as a means of education. It cannot, therefore, be too strongly impressed on teachers that nothing like rote learning will suffice."

This theme was taken a stage further in the B.A.A.S.'s Committee report of 1891 which recommended that pupils should perform experiments themselves and that: "... merely to attend lessons, listening to and taking notes of what is said" was not enough.

The move towards a more pupil-centred teaching strategy received further impetus from H.E. Arnold's science course which he designed for the B.A.A.S. (Brock (1973)), and the Education Department's Code of 1894, 'Experimental Arithmetic, Physics and Chemistry'. Uzzell (1986) points out that this is the first Code science syllabus to use the word 'discovery' and while not widely adopted, it formed the backcloth against which teaching strategies in the second half of the twentieth century were set.

Education in science became more than a mere handing out of information; pupils were increasingly becoming directly involved in the scientific process, and of the sciences, astronomy was to find this change in emphasis the most difficult to accommodate. This was largely due to the notion that astronomy is synonymous with telescopes and can, therefore, only be studied at night. A view which the survey of teachers' opinions, reported in Chapter II, demonstrated is frequently held by many science teachers today.

The escalating cost of astronomical apparatus, exemplified by the expense involving Herschel's giant telescope and the wealthy background of virtually all astronomers, possibly concentrated educationalists' minds on the high cost of including astronomy in the curriculum. Cost

appears to have been a deciding factor when selecting subjects for the curriculum, Uzzell (1986) observes that in the 1890's:

"Preference, it seems was given to subjects requiring little specialized equipment or accommodation."

These factors combined and manifested themselves in an attitude towards astronomy education which, while extolling its merits in a complete education, considered it an inappropriate and unrealistic subject for inclusion in the science curriculum of all pupils.

1.11 Astronomy During the Twentieth Century

During the first half of the twentieth century there was little change in attitude towards astronomy education to that observed at the end of the nineteenth century; Westway (1929) observed:

"As a subject for serious study astronomy is rarely included in a school science course, one reason being the difficulty of finding practical work of a suitable kind."

The Spens Report of 1938 considered astronomy to be an integral part of the science syllabus, claiming that no course which excludes it can be considered satisfactory. The Science Masters' Association Report of the same year also advocated the inclusion of astronomy, but in their report of 1950 they eliminated it from the main syllabus for the same reasons as Westways, claiming that it is difficult to organise observational work, which if excluded would:

".... render a course in astronomy as a mere handing out of information."

The misgivings voiced by Westways and the Science Masters' Association were reflected in the survey elucidating teachers' concerns about

teaching basic astronomy - see Chapter II. The availability of suitable and relevant practicals was a common worry. It is clear that those who wish to promote astronomy education must convince teachers that there are practical activities which can bring astronomy education into the main stream of science teaching. The fact that this problem has not been addressed since the inception of compulsory education has been an important factor in turning teachers away from including aspects of astronomy in their science teaching.

1.12 The Influence of the Government

For the first half of the twentieth century, astronomy was almost totally excluded from the curriculum of state schools. The efforts of Tancock (1913) and Beet (1946 and 1949) served as a stimulus for those already committed to incorporating elements of astronomy in their teaching, but had little effect on the curriculum received by the great majority of pupils. Between 1900 and 1957, astronomy teaching in schools depended on the enthusiasm of a few dedicated teachers with a particular interest in the subject who were prepared to teach it as an extra-curricular activity. The situation paralleled that in the universities during the first half of the seventeenth century (p24) when almost all astronomy education was taught as an extra-curricular study.

The launching of Sputnik in 1957 was a watershed for science education and for astronomy in particular. The situation paralleled that in Elizabethan times under threat from the Armada and the Dutch Wars of the late seventeenth century. The Russians had stolen a lead in the space race and this was seen as a threat to the West. Kelly (1987)

claims that the launching immediately focused attention on the school curriculum, questioning its suitability for educating pupils for work in an advanced technological society.

Reaction was more marked in America, Federal legislation passed in 1958 and again in 1965 invested large sums into curriculum programmes. During this period Bishop (1973) considers that American astronomy education was partially restored to the position it enjoyed in schools during most of the nineteenth century.

In England the Russian achievement resulted in a challenge to what some saw as the teachers' autonomy over curriculum planning. This challenge came in the form of the politically controlled Curriculum Studies Group, set up in 1962 by the Minister of Education, Sir David Eccles. Although the group floundered - possibly because it failed to reduce the power of the L.E.A's - and was replaced by the teacher centred Schools Council for Curriculum and Examinations, it marked the beginning of the slow evolution towards more central control. A salient point in this evolution was Prime Minister Callaghan's 'Ruskin Lecture' of 1976 which marked the beginning of 'The Great Debate' and spawned the notion of a balanced curriculum for all pupils.

The government were concerned that education was too far removed from the world of work. This point was made clear in their green paper "Education in Schools" 1977 stating:

"There is a wide gap between the world of education and the world of work."

And later on the aims of school:

".... to provide a basis of mathematical, scientific and technical knowledge enabling boys and girls to learn essential skills needed in a fast changing world of work."

In 1979 - under the influence of H.M.I's Gold and Morris - the D.E.S. formed a working party on promoting the teaching of astronomy. Largely as a result of this working party the D.E.S. funded a course, held in January 1981 at the Hatfield Polytechnic, on astronomy specifically for teachers [xiii]. Although further courses have not materialised, the following year the D.E.S. were mentioning astronomy in their pre-National Curriculum models of balanced science. Their consultative document, 'Science Education in Schools' (1982), considered that elements of astronomy can feature in the first three years of secondary school and that primary school pupils need to carry out work which makes them accustomed to observing, looking for patterns and which introduces seasonal changes. This presented the idea that some basic astronomy should feature in the junior school.

The notion that astronomy can act as a vehicle for the development of important concepts in the main sciences was introduced in the D.E.S. document 'Science 5 to 16: A Statement of Policy' (1985). This suggested that they did not see a specific slot in the curriculum for astronomy.

However, after the main astronomical societies had stated a case for the inclusion of astronomy in the 'National Curriculum' (1989) it was featured as an attainment target in its own right. All pupils now

cover aspects of astronomy in their science lessons. While this decision was well received by those who have sought to promote the more widespread teaching of astronomy in schools, the survey of teachers' concerns about teaching basic astronomy, reported in Chapter II of this thesis, suggest that the production of suitable teaching materials and considerable In-service training will be necessary. Without this investment astronomy education in schools may well be, as predicted by Patrick Moore (1976), "a way of killing it".

1.13 Changing Perspective of Astronomy Education

Throughout the 1960's and 70's the school curriculum had diversified, the establishment of the C.S.E. examinations in 1965 and subsequent mode III courses - a number of which contained elements of astronomy - furthered this diversification. In 1966 the London Schools Council introduced an astronomy 'O' level examination, and the following year the Nuffield 'O' level Physics course introduced a unit on Planetary Astronomy. To some degree these courses demonstrated that - contrary to previously held opinions - astronomy could be taught in a style compatible with that followed by other sciences. This demonstration culminated in the L.A.M.P. projects 'Space and Space Travel topic brief no. 8' (1976) which not only presented basic astronomy in a style similar to that followed for other sciences, but as suitable and relevant for pupils less academically motivated.

The title of 'Space and Space Travel' was particularly significant as it signified a move away from classical astronomy towards the technology of space. This approach was in line with the demand for a more technologically based education illustrated in the Nuffield

Foundation Science Teaching Project progress report (1964), which stated that science education:

".... should provide a foundation for adult life and work in an increasingly scientific and technological age."

While this aim may have been met by the L.A.M.P's topic 8, it was not realised in the Nuffield 'O' level Physics unit on planetary astronomy, which Lintern-Ball (1972) claims was out of date as it contained a vast amount of astronomy "over two hundred and fifty years old". The results of his survey suggest that pupils found the astronomy part of this course "boring", and he claims that:

".... astronomy deserves to be presented in a more attractive and appealing way." [xiv]

Lintern-Ball's findings were later confirmed when the astronomy unit of the Nuffield 'O' level Physics syllabus was dropped due to lack of demand.

Some writers demonstrated that astronomy could fulfil a broad supportive role in science education. Prior to the publication of the L.A.M.P. topic brief no. 8, Stoneman (1972) published his book on 'Space Biology' which was the first concerted attempt to demonstrate the potential of astronomy as a vehicle for developing important concepts in Biology. Some time later Slater and Thompson (1987) followed a similar approach when they used ideas on the formation of the universe and stellar evolution to develop important concepts in Chemistry. These examples illustrated that astronomy can usefully cut across traditional subject boundaries and, as stated in 'Science 5 to 16: a Statement of Policy' (1985):

".... provide a suitable context for important concepts to be developed."

Butt (1985) takes up this theme and gives a comprehensive list of subjects which can interact with astronomy, demonstrating its considerable cross-curricular potential. This aspect of astronomy will be developed in Chapter V when a number of astronomy's historical milestones mentioned in this Chapter will be utilised in the development of cross-curricular material.

1.14 Astronomy in Examinations

By the early 1980's astronomy featured in a number of 'O' level examinations, but on closer inspection the situation was not as good as it appeared. Of the ten 'O' level syllabuses containing some astronomy, only the University of London School Examination was exclusively on astronomy. Of the remaining nine, five were specifically on navigation, the other four only made brief mention of astronomy. The situation was almost the same for the C.S.E. Examining Boards. Eight offered examinations which contained elements of astronomy, six of which included it as an optional topic, the remaining two only made a brief mention of the subject. See Appendix II.

It is unlikely that any of these examinations have had any substantial effect on the promulgation of astronomical knowledge because of the small number of pupils involved - the London Schools Examination's Astronomy 'O' level only attracts three hundred and fifty to four hundred candidates each year out [xv].

1.15 Astronomy in the Science Curriculum

The resurgence of interest in astronomy education from 1957 seemed to have a minimal effect on the British curriculum. Lintern-Ball's (1972) survey of ninety schools led him to conclude that the teaching of astronomy in English secondary schools has reached an "abominable state". However, H.M.I. Gold's (1976) review of the situation was not as bleak, he claimed to have observed "large amounts of enthusiasm for the subject in various parts of the country", which he put down to the achievements of the Russian and American space programmes. This observed enthusiasm was questioned when a D.E.S. organised course entitled "Astronomy - The Neglected Science" scheduled to be held in March 1980, was cancelled due to lack of support (Seymour (1984)); which suggests that the observations of Lintern-Ball were closer to the true position of astronomy education in secondary schools than those of Gold.

Gold's (1976) review was particularly significant as it precipitated the formation of a D.E.S. Working Party on Astronomy Education which looked into ways of promoting astronomy in schools. All aspects of astronomy were represented including amateur groups. A full list of participating bodies is given in Appendix III. The group was active from 1979 until the completion of its task in 1981, which culminated in the formation of the Association of Astronomy Education (A.A.E.). Since its inauguration the A.A.E. has served as a focus for those already committed to including astronomy in their teaching, but as yet has not attracted many teachers who may require advice on teaching astronomy. Only 15% of the H.O.D'S taking part in my survey were

aware of the existence of the A.A.E. and it is clear that a lot of publicity work needs to be done [xvi].

By 1979 little, if any, progress had been made towards realising balanced science, or finding a place for astronomy. A survey by H.M. Inspectors of Schools (1979) stated that no school had been found which provided balanced science courses for all pupils up to the age of sixteen, and while they made mention of the wide ranging science courses and activities organised by schools, no mention was made of astronomy.

The A.S.E. 'Alternatives for Science Education' (1979) pointed out that astronomy is competing for a place in the science curriculum, but did not mention it specifically in any of the their three curriculum models. However, some astronomy is implicit in each of the models, especially the history and philosophy and earth science of Models I and II. Later, in their 'Education Through Science' (1981) the A.S.E. recognised the difficulties subject separation posed in accommodating other areas such as astronomy, and it became clear that all the time separate sciences featured in the options system, astronomy would never secure a place in the science curriculum of all pupils. H.O.Ds taking part in the survey reported in Chapter II of this thesis reflected this view, giving lack of space on the timetable as the most common reason for not including astronomy in the curriculum.

Astronomy frequently received favourable mention during the debate on balanced science. The S.S.C.R., in their Science Education 11-16 (1983), recognised that few existing programmes of study created

opportunities for any systematic treatment of areas of science outside chemistry, physics and biology such as astronomy. However, this largest ever 'grass roots' driven programme of curriculum development failed to generate the interest of any astronomical group. The A.A.E. were invited to make a contribution and at a meeting held in December 1985 between the A.A.E's curriculum committee, Mr M. Michell of the S.S.C.R. and myself, it was agreed that the A.A.E. might produce material for use in teacher training establishments. Although further contact was made with the A.A.E. between January and June 1986, nothing materialised from this meeting.

Of the 271 S.S.C.R. working group reports published in Arches (1985) only one specifically mentions astronomy. Nothing materialised from the S.S.C.R. which could lead to the realisation of the recommendations in 'Science 5 to 16: a Statement of Policy' (1985) that astronomy can be used to provide a suitable context for the development of important concepts in Biology, Physics and Chemistry, or which goes some way towards providing suitable practical work, thereby overcoming the criticism directed at school astronomy by Westway (1929) and the Science Masters' Association Report of 1950.

1.16 The Influence of Societies

The British Interplanetary Society became the first astronomical association to become involved in curriculum issues when they set up an education working group in 1963 and produced a 'Teacher's Handbook on Space Education' (1963). This was followed in 1973 by the Council of The Royal Astronomical Society establishing an Education Committee which was instructed to consider ways and means by which the Society

could further "public knowledge of, and appreciation of, astronomy" (see McNally (1975) and Seymour (1984)). Although the R.A.S. Education Committee was later dissolved - it has recently been reconvened to state a case for including astronomy in the National Curriculum - it played an active role in the D.E.S. working party on astronomy education; Dr. R.A. Booth of the R.A.S. was a member of the working party and all of the meetings were held at the offices of the R.A.S. (Gold (1976)).

The British Astronomical Association also set up an education committee in the early 1970's and organises an annual residential course for those with a particular interest in astronomy, but the teaching of astronomy in secondary schools only forms a minor part of their work.

The B.A.A.S. - the first scientific society to become involved in curricular issues in 1833 - has also had little influence on astronomy education. In answer to my inquiry into what action the B.A.A.S. had taken to promote the teaching of astronomy in schools, in a written communication Dr. Morley - Executive Secretary - stated that:

".... astronomical topics feature regularly at our Annual Meeting and other meetings But aside from that, we do little that is specifically astronomical."

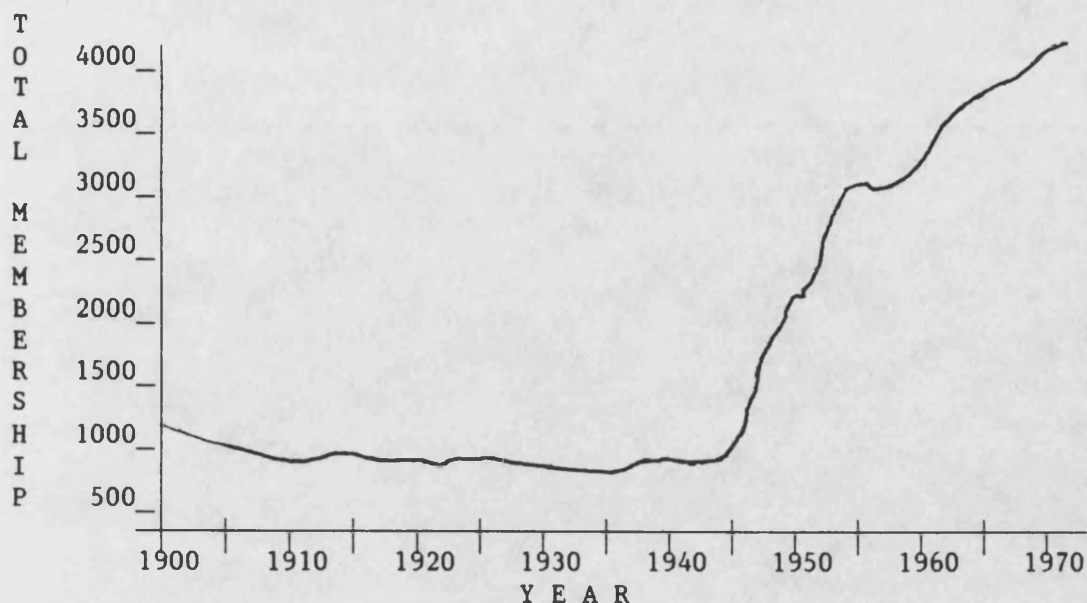
Although most of the astronomical societies have, at some time, made mention of astronomy education, it was not until the present Government introduced their notion of a National Curriculum that the major societies became involved in the school science curriculum at the same time. The British Astronomical Association, Federation of

Astronomical Studies, Royal Astronomical Society and - somewhat later than the rest - the A.A.E., submitted either oral or written evidence stating the case for including astronomy in the education of all pupils. This must have been an important factor in persuading the D.E.S. that some basic astronomy should feature in the curriculum.

1.17 Amateur Astronomical Groups

During the period of educational debate from Sputnik to the National Curriculum, an informal education in astronomy was taking place in the form of activities of amateur astronomical groups. Gold (1976) draws attention to the important work some local astronomical groups play, often visiting schools to give talks and demonstrations, but their greatest influence is in providing an education in astronomy for those with a special interest which could not be satisfied by schools.

Like astronomy education, the membership of astronomical societies has been influenced by the advent of the space age. The graph below shows how the membership of national astronomical societies has changed from 1900 to 1970, showing an increase in both members and societies since the launching of Sputnik and correlates well with the increasing demand for the inclusion of astronomy in the curriculum which have taken place throughout this century.



Membership of Astronomical Societies (After Lintern-Ball 1972)

Astronomy, more than any other science, offers a greater number of facilities for studies outside of the formal educational system. Most large towns and cities have an astronomical society, it is often featured on the television, - the B.B.C's 'Sky at Night' is the longest running monthly television programme, first televised in 1957 - there has been a plethora of books published on the subject since the launching of Sputnik and, according to Seymour (1976), there are seventeen known planetaria in the U.K. These seventeen planetaria have an annual attendance of two hundred and ninety six thousand people per annum, of which ninety three thousand are school children.

During my survey of teachers and interviews with junior school head teachers, some felt that because of the wide range of facilities for the study of astronomy outside of the school, it need not become part of the formal curriculum. An opinion endorsed by Patrick Moore (Gold (1976)) who is against including astronomy as a school subject and favours the encouragement of an interest in astronomy by way of clubs

and societies. However, this approach will not improve the majority of childrens' understanding of astronomy as only a small percentage will be willing to join an astronomy club. Although amateur astronomy clubs cannot influence astronomy education on a large scale, they offer a rich and willing resource (see report of survey, Chapter V) which science teachers will do well to realise.

1.18 Summary

Throughout the greater part of history astronomical knowledge has been held within a priesthood, theory being constructed to comply with religious dogma. Such views supported the ordinary persons' primary view of the heavens and acted to suppress advances in astronomical understanding.

During the more recent history of astronomy there have been two major periods which precipitated calls for an increase in the level of astronomy education:

- (i) The age of advance in navigation.
- (ii) The launching of Sputnik.

Both these occasions have been instigated by either commerce or defence - in the case of navigation, by both - and serve to demonstrate that the science curriculum has often been dictated by the needs of the nation and concerned with supplying people equipped with specific skill important to the economy of the nation.

The call for an education which would increase both the quality and quantity of navigators was, for a majority, a training in the skills of navigation, and although it spread the ideas of Copernicus as a by-

product, it was not concerned with improving astronomical awareness beyond the skills of navigation.

After the launching of Sputnik, attention centred around developing our technology so that it measured favourably against the Russians. The technological race between America and Russia was being run in space, consequently minds were concentrated towards increasing the astronomical awareness of pupils, not with developing a specific skill as in navigation. The fact that astronomy is not a skill directly related to the world of work has resulted in difficulties when it comes to justifying its place in the curriculum; a point which is demonstrated in the survey of teachers' opinions on astronomy education reported in Chapter II of this thesis. Those who have advocated the inclusion of astronomy in balanced science have often failed to articulate why it should feature and what it offers that is unique and cannot be offered by other science subjects like electronics or biotechnology.

In some attempts to justify the inclusion of astronomy in the curriculum one can see relics of its past, as being essential knowledge for an educated person, or classical education. Butt (1985) sees its interaction with the classical literature of Homer, Thucydides and Virgil; and Gold (1985) talks of "worthwhile knowledge". While these are noble reasons for its inclusion, they do not make astronomy any more special than any other branch of science competing for a place in the curriculum. It is no longer possible to justify the inclusion of any subject based on its role in days gone by, or of intuitive feelings of its worth. I will return to this topic in Chapter IV when

discussing the place of astronomy in the science curriculum and the selection of topics for the development of the astronomy teaching units.

From the latter half of the last century astronomy education has taken two distinct routes; that of the professional who pursues an increasingly abstract and costly path, and that of the amateur who - by and large - continues in the same vein as the gentleman astronomers of the eighteenth and nineteenth centuries. During the twentieth century a majority of people have received little, if any, formal astronomy education, and have been increasingly distanced from advances in astronomy, which for most, has always been a subject shrouded by abstract mathematics and studied by an elite.

This review of the history of astronomy education focuses attention on four major questions which needed to be addressed when stating a case for its inclusion in the science curriculum:

- (i) Have the appeals and recommendation for the inclusion of astronomy in the science curriculum since the launching of Sputnik been reflected in the curriculum received by the pupils?

- (ii) Are the advances in basic astronomy since Copernicus part of pupils' cosmology, and what is the state of their knowledge of basic astronomy when they receive no formal education in the subject?

(iii) What are the opinions and concerns of teachers on the inclusion of astronomy in the curriculum?

(iv) What role can astronomy play as part of balanced science and in cross-curricular activities, and can it be taught in a style compatible with that followed by the other sciences?

These questions and my attempts to find answers to them occupy the remainder of this thesis.

NOTES ON CHAPTER ONE

- [i] According to Gingerich (1988) the woodcut is not a sixteenth century work of art as is often claimed, it was produced by the French popularizer Camille Flammarion and first published by him in 1888.
- [ii] It is quite common for books about astronomy aimed at children, or the newcomer to the subject, to immediately take the reader on a journey to the planets and distant galaxies, paying little - if any - attention to the position of the reader's home base in the scheme of things. For example, Seymour's (1983) 'Adventures with Astronomy' introduces the reader to different types of galaxies by the second page. Pople and Williams (1983) 'Science to 16' (probably one of the most widely used school science books which includes some aspects of astronomy) starts with galaxies and stars and assumes that readers are already heliocentric in their world view.
- [iii] The National Curriculum Attainment Target 17 level 8 "understand the uses of evidence and the tentative nature of proof", and in the Programme of Study Key Stage 4: Model A: "study examples of scientific controversies in which scientific ideas have changed."

[iv] The date of Easter was the most important calculation. In the Western Church's calendar Easter is defined as the first Sunday after the full Moon on or after the vernal equinox. Therefore, the priests needed to calculate the date of the vernal equinox, the dates on the solar calendar for phases of the Moon and the dates on which the days of the week fall. This was achieved by astronomical observation and calculation.

[v] An educational course of the Middle Ages which also included arithmetic, geometry and music.

[vi] Unlike Saint Lactantius and Cosmas, Saint Augustine accepted the sphericity of the Earth, but considered it impossible for people to inhabit the Antipodes. Not for the same primitive reasons given by Lactantius and Cosmas, his argument was based on the notion that all men are descended from Adam and Eve and as the southern hemisphere was considered inaccessible, none of their descendants could have travelled there. To Augustine the idea was incompatible with the unity of mankind.

Taken from translations of 'St. Augustine (1), De Civitate Dei XVI, c. 9. PL XLI 487. De Genesia ad Litteram II 9, c. 9. PL XXXIV 270. by Dijksterhuis.

[vii] I will demonstrate later in this thesis that astrology is still persuasive in the lives of many pupils. This belief is nurtured by the plethora of publications and articles in the popular press dealing with astrology, far greater in numbers than those about astronomy.

- [viii] John Newton's definition of astronomy education was confined to its utilitarian use in navigation, not with the more broad development of pupils' cosmology.
- [ix] Fig 2 Allegory of Astronomy by Francois Denis Nee (1735-1818). After a design by Cochin (1715-1790). Taken from copy of a print owned by J.M. Pasachoff and displayed at the International Astronomical Union's 105th Colloquium, Williamstown, Massachusetts, July 26-30th 1988.
- [x] This fact has sometimes levelled against the inclusion of astronomy in the school curriculum, as it is claimed that astronomy education can take place through amateur activity. Moore (1988).
- [xi] This opinion has prevailed through to the 1990's and is typified by Kirby (1990) New Scientist May 5th p.68, who claims that: "... astronomy is probably the branch of science most remote from the near market place so beloved of its government paymaster".
- [xii] Largely through using the same argument as Galileo in his letter to the Grand Duchess Christina (see Koestler (1959)) claiming that the wording of the Bible was couched in a language 'according to the capacity of the common people who are rude and unlearned'.

[xiii] In a written communication with H.M.I. Gold (Feb. 1988) he claimed that - as far as he knows - the Hatfield Course was the only D.E.S. sponsored course of its type. He said the A.A.E. has been pressing for another and that there may be one held in 1989.

By April 1989 no news of a second course has been received.

[xiv] It is difficult to avoid introducing ideas from history as many of the seminal ideas in astronomy originated from the sixteenth and seventeenth centuries. One suspects that those pupils who find the course 'boring' are making a statement about the presentation rather than content.

[xv] During an informal discussion with the Chief Examiner for the London Schools Examinations Astronomy 'O' level (now London and East Anglian Group for G.C.S.E.) when the author attended the A.A.E. A.G.M. 1985, he stated that the number of candidates remains relatively constant at 350 per year.

[xvi] The committee of the A.A.E. has recently undergone considerable change, which in the words of their Vice-Chairperson Undine Concannon - written communication - will herald "a new and dynamic phase". She acknowledges that the A.A.E. needs to seek more publicity and points out that they are in the process of asking L.E.A's to include information about the A.A.E. in their newsletters, and by letters in the educational press.

At the 1989 A.G.M. the A.A.E's secretary, Mr. B. Kibble, said that the recent publicity had resulted in over one hundred inquiries from teachers about the A.A.E., a number of whom had taken out membership which now stands at over one hundred paid up members.

CHAPTER II

The Position of Astronomy in the Science Curriculum: 1986

2.00 Introduction

The launching of Sputnik in 1957 prompted a resurgence of interest in astronomy, but evidence of its effect on the school science curriculum is poorly researched. The only large scale 20th century survey looking into astronomy education was carried out by Lintern-Ball in 1972. The survey was designed to examine the state of school astronomy but - at his own admission - the sample was not representative as the sample was taken from schools affiliated to the British and Junior Astronomical Societies. The great majority of which came from the private boarding school sector. However, his findings suggested a low level of astronomy education, and when considering the bias of the sample and the:

".... modified interest shown by affiliated schools...."

he considers that the picture is not very promising for astronomy education in other schools. To some degree this opinion was vindicated by the H.M.I. survey of 1979 which commented on the wide range of science related courses on offer, but made no mention of astronomy. One concludes that they saw little, if any, evidence of astronomy education taking place.

Both Lintern-Ball (1972), and the H.M.I. survey, (1979) give an entirely different picture than H.M.I. Gold (1979) who carried out a survey of school astronomy during the same year as the H.M.I. survey and claimed to have observed considerable enthusiasm for the subject. But Gold's survey lacked statistical data to support this claim, and

one is left feeling that teachers gave H.M.I. Gold the answers they thought he wanted to hear.

In 1985 both Gold (1985) and Butt (1985) pointed out that astronomy rarely features as a taught subject in schools. Butt claimed that teachers are ill-prepared to embark on introducing astronomy into the curriculum. This, Gold considers, is because teacher training institutions receive no requests from schools for teachers able to introduce astronomy; a situation which he likened to that of the 'chicken and egg'.

2.01 The Postal Surveys

Because of the lack of good statistical evidence about the present position of astronomy in the science curriculum, it was considered necessary to carry out postal surveys to discover the present level of astronomy education, and opinions and concerns of teachers about teaching astronomy. The evidence provided by these surveys provided a frame of reference for the production of teaching material, teachers' notes and Inset material reported in later chapters of this thesis.

The flow diagram given in figure no. 1 presents the development and analysis of the questionnaires as a series of stages, and is intended to summarize the data collection process used for this part of the research and the reporting sequence of this chapter.

STAGE 1

2.02 Collecting Recurring Opinions about Astronomy Education

Informal interviews about the inclusion of astronomy into the science curriculum were held with teachers visiting the Secondary Science Curriculum Review (S.S.C.R.) stand at the Association for Science Education (A.S.E.) annual meeting at York 1986. The most recurrent statements and opinions (those expressed by three or more different people) were noted. It had been intended to audio record each interview, but the high level of background noise prevented collecting the information in this way. See Appendix IV for list of opinions and statements collected at York.

STAGE 2

2.03 Constructing the Questionnaires

In order that the questions and statements which made up the questionnaires reflected the range of opinions and views of practising teachers (rather than the researcher's bias) the most recurrent opinions collected at York were used to construct two questionnaires. The phrasing commonly used by teachers when giving their opinions about astronomy education during the York interviews was included in the wording of the statements which made up the two questionnaires. For example, teachers frequently used the words "satisfactory" or "unsatisfactory" to describe their opinions about the quality of pupils understanding of astronomy or of their schools provision for astronomy education. It was considered that this approach would result in the production of questionnaires which were phrased in a familiar style.

The two questionnaires were targeted at two different levels of science teachers

- (i) Sent out to heads of science departments (H.O.Ds) to discover the present state of, and their opinions about astronomy education.
- (ii) Sent to assistant science teachers to discover their opinions and concerns about teaching astronomy.

The assistant science teachers' questionnaire focused on the three main concerns teachers experience when faced with the prospect of introducing a new course (Gardner and Dorset (1981)).

- (i) Personal concerns: (their own knowledge and ability to deliver the subject material).
- (ii) Organisational concerns: (availability of apparatus and suitable teaching material).
- (iii) Peer group concerns: (fellow teachers', parents', and potential employers' opinions).

Astronomy was defined as those events which are easily observed from planet Earth and which feature in the lives of most people e.g. Sun rise and set, phases of the Moon, tides and gravity.

Both questionnaires were piloted by the curriculum committee of the Association for Astronomy Education and by the science teachers at Court Fields School, Wellington, Somerset.

The pilot run identified ambiguities in the first draft of both questionnaires. Alterations were made based on the results of the pilot. Appendix V gives details of the survey strategy, a copy of both questionnaires and covering letters.

STAGE 3

2.04 Selecting the Sample Schools

Three hundred and ninety nine secondary schools were randomly selected (see Appendix VI) from the Education Authorities Directory and Annual 1985 edition, and on June 24th, 1986 one H.O.D. questionnaire, along with four assistant science teachers' questionnaires, were sent to each school.

The randomly selected schools divided into seven distinct types. See table (1) below.

School Type	No. schools selected	Relative Frequency
Comprehensive mixed	315	0.789
girls	12	0.030
boys	10	0.025
Secondary Mod mixed	31	0.077
Grammar mixed	12	0.030
girls	10	0.025
boys	9	0.022
Totals	399	0.998

Table 1

Responses were coded, entered onto punch cards and then transferred to a 'Delta Plus' data base using an Archimedes 400 Series computer.

STAGE 4

2.05 Analysis of Heads of Science Department Survey

Just under one third (32.8%) of the H.O.Ds returned useable questionnaires. Table No. 2 shows the number of returns received from each school type.

School Type	No. Returns	Relative Frequency
Comprehensive mixed	106	0.809
girls	6	0.046
boys	3	0.023
Secondary Mod mixed	7	0.053
Grammar mixed	4	0.030
girls	3	0.023
boys	2	0.015
Totals	131	0.999

Percentage returns = 32.8%

Table 2

A major factor in determining the low level of returns was the political situation prevailing at the time the questionnaires were sent out. There had been an ongoing pay dispute and teachers were in the process of preparing for what many felt was the premature introduction of G.C.S.E. courses.

Twelve H.O.Ds returned unanswered questionnaires with notes stating that, in the present climate, they did not have the time or inclination to participate in surveys of this nature. However, although returns were lower than hoped for, the one hundred and thirty one returning

schools was a larger sample than that covered by both Gold's (1979) and Lintern-Ball's (1972) surveys and represents the astronomy education of one hundred and eleven thousand, seven hundred and twenty nine pupils.

2.06 Astronomy in the Science Curriculum

Almost half (47.33%) of the returning schools cover some aspects of astronomy in their science curriculum. See table 3 below.

NUMBER OF SCHOOLS COVERING
SOME ASPECTS OF ASTRONOMY IN
THEIR SCIENCE CURRICULUM

School Type	No.	% of each school type
Comprehensive mixed	57	53.77
girls	2	33.33
boys	1	33.33
Secondary Mod mixed	1	14.28
Grammar mixed	0	00.00
girls	1	25.00
boys	0	00.00
Totals	62	Total % 47.33

Table 3

This survey shows a higher percentage of schools teaching some aspects of astronomy than the survey carried out by Lintern-Ball (1973) (33.3%), and goes some way towards supporting the findings of Gold (1979).

2.07 H.O.Ds Opinions About the Inclusion of Astronomy in the Science Curriculum

Further evidence in support of H.M.I. Gold's claim that there is considerable enthusiasm for astronomy was gained from an analysis of the nine positive and nine negative statements about astronomy education included in the H.O.D. survey.

Questions 2, 6, 10, 12, 13, 15, 16, 25 and 31 were positive statements about astronomy in the science curriculum. Questions 7, 8, 9, 11, 17, 18, 19, 20 and 27 were negative statements. Each response type was given a score on a scale of one to five as shown in table 4 below.

STATEMENT SCORE SCALE

RESPONSE TYPE	STRONG AGREEMENT	AGREEMENT	UNSURE	DISAGREEMENT	STRONG DISAGREEMENT
SCORE	5	4	3	2	1

Table 4

The scores were totalled for each set of statement types, thus giving a profile of H.O.Ds' opinions about astronomy in the science curriculum. See tables 5(a) and 5(b).

H.O.DS' OPINION PROFILE ABOUT
ASTRONOMY IN THE SCIENCE
CURRICULUM

POSITIVE STATEMENTS

Agreement Type	No. of Responses	Relative Frequency	Score
Strong Agreement	171	0.145	855
Agreement	648	0.549	2592
Undecided	216	0.183	648
Disagreement	45	0.038	90
Strong Disagreement	99	0.083	99
TOTAL	1179	0.998	4284
		MEAN	32.70
		MAXIMUM MEAN	45

n = 131

Table 5 (a)

NEGATIVE STATEMENTS

Agreement Type	No. of Responses	Relative Frequency	Score
Strong Agreement	36	0.030	180
Agreement	180	0.153	720
Undecided	198	0.167	594
Disagreement	207	0.175	414
Strong Disagreement	558	0.473	558
TOTAL	1179	0.998	2466
		MEAN	18.82
		MAXIMUM MEAN	45

n = 131

Table 5 (b)

All of the positive statements about astronomy in the science curriculum received a higher number of responses on the agreement side of the scale, apart from statements No. 8 (difficult to teach astronomy because of a lack of day time practicals) and No. 27 (astronomy is low in priority for time on the timetable). All other negative statements about astronomy education received a higher number of responses on the disagreement side of the scale.

This part of the survey suggests that H.O.Ds have a positive opinion towards the inclusion of astronomy in the science curriculum. Again, this supports Gold's claim of teachers' enthusiasm for the subject, but this is not related to how much astronomy is actually taught. We will see later on in this Chapter that any perceived enthusiasm of teachers for the subject does not reflect provision within their school, or their opinion of their current provision.

2.08 Years Where Astronomy is Taught

Of the sixty two schools which include astronomy in their science syllabus it is most prominent during the second year courses. Only three schools feature astronomy during the fourth and fifth years. This confirms the opinion of most teachers interviewed at the York A.S.E. meeting, that the examinations are dictating where, in the five years of secondary science, astronomy is taught.

YEARS WHERE ASTRONOMY IS TAUGHT

School Type	Year 1	Year 2	Year 3	Year 4	Year 5
Mixed Comprehensive	64.9%=====>	29.8%=====>			
Girls Comprehensive	5.2%=====>	<100%>			
Boys Comprehensive	100%=====>				
Girls Grammar	<100%>				
Mixed Sec. Modern	100%=====>				

n = 62

Table 6

2.09 Topics Covered by Schools which Include Astronomy in their Science Curriculum

The coverage of astronomy by the sixty two schools teaching astronomy appears to be rather superficial. The most commonly featured topics being day and night, the solar system and the seasons. Only four schools include work on stars and only one includes aspects about the history of astronomy. See table 7 below.

TOPICS COVERED BY SCHOOLS WHICH INCLUDE ASTRONOMY IN THEIR SCIENCE CURRICULUM

TOPIC	NO.	%
Day and Night	62	100.00
Phases of the Moon	53	85.50
Solar System	62	100.00
Seasons	62	100.00
History of astronomy	1	1.60
The Sun	12	10.35
Space Travel	6	9.70
Stars	4	6.45

n = 62

Table 7

2.10 Time Allocation for Astronomy

The time allowed for astronomy by those schools which include it in their science curriculum varied from just slotted in to their existing timetable, to a maximum of 4 to 6 periods; the most common time allocation being 1 - 2 periods.

TIME ALLOCATION FOR ASTRONOMY

TIME	SLOTTED IN	1-2 PERIODS	2-4 PERIODS	4-6 PERIODS	MORE THAN 6 PERIODS
NO.	21	29	11	1	0

n = 62

Table 8

The relatively small amount of time and limited depth of coverage given to astronomy education elucidated by this survey explains the discrepancy between the findings of this research and that carried out by Lintern-Ball (1972). His survey only identified timetabled astronomy and would not have gathered any information on incidental astronomy education.

2.11 Sexist Opinions and Astronomy Education

There appears to be no evidence of sexism in regard to those schools covering astronomy, but the data is too limited to come to any firm conclusions. However, H.O.Ds' responses to statement 14 - Astronomy is more likely to appeal to boys - does not identify any significant notions of gender preference. H.O.Ds' responses to this statement gives a Chi sq. value (see Appendix VI) greater than the 13.28 required for significance at the 0.01 level.

Statement 14

Astronomy is more likely to appeal to boys.

Opinion	Strong Agreement	Agreement	Unsure	Disagreement	Strong Disagreement
Number	2	20	27	30	52
%	1.5	15.3	20.6	22.9	39.7

Chi. sq. = 49.79 n = 131
p = 0.01

Table 9

These findings suggest that H.O.Ds consider it a subject which will have equal appeal to both girls and boys. This corresponds with the views of a number of educationalists (see Watts (1725) p27) of the eighteenth century, who considered woman should study astronomy, and indicates that the sexist view epitomised in the B.A.A.S. annual report of 1867 and the report of the School Board Chronicle, 1884, (see p35) towards girls in science does not feature in most H.O.Ds' opinions.

This result is not surprising and confirms Smail, Whyte and Kelly's (1986) observation that:

".... as professionals, most teachers are genuinely interested in fostering the development of all their pupils and so resent any suggestion that they treat either sex unfairly."

2.12 H.O.Ds' Opinions of Their Provision for Astronomy

At first sight the impression of school astronomy gained from this survey is quite encouraging, however, the picture becomes less promising when the H.O.Ds' responses to question (3) - Are you

satisfied with your present provision for astronomy education? - is taken into consideration.

Of all the returning H.O.Ds, only twenty one percent registered satisfaction with their present provision. Over two thirds of those from schools covering some aspects of astronomy claimed that they are dissatisfied with the way it is covered, and eighty nine percent from schools where astronomy is not taught registered dissatisfaction with their present lack of provision.

H.O.DS SATISFACTION WITH THEIR PRESENT
PROVISION FOR ASTRONOMY EDUCATION

School Type	Astronomy Covered	Number Satisfied	No Astronomy	Number Satisfied
Comprehensive mixed	57	19	49	4
girls	2	0	4	0
boys	1	0	2	0
Secondary Mod mixed	1	1	6	1
Grammar mixed	0	0	4	0
girls	1	1	2	2
boys	0	0	2	0
Totals	62	21	69	7
%	47.3	33.9	52.7	10.1

n = 131

Table No. 10

While the number of state schools covering aspects of astronomy is higher than Lintern-Ball's (1972) survey implied, H.O.Ds' opinion of their present provision confirms the depressing picture he painted of state school astronomy education.

2.13 H.O.Ds' Opinions of Pupils' Knowledge of Basic Astronomy

H.O.Ds' opinions of their school leavers' knowledge of basic astronomy is further evidence that there is a shortfall in astronomy education. See table 11 below.

Statement 24

In general, pupils leaving the fifth year have a satisfactory knowledge of basic astronomy.

Opinion	Strong Agreement	Agreement	Unsure	Disagreement	Strong Disagreement
Number	2	8	25	22	74
% of sample	1.5	6.1	19.0	16.8	56.5

Chi. sq. = 123.88 n = 131
p < 0.001

Table 11

Of the sixty two schools covering some aspects of astronomy, 96.7% registered dissatisfaction with their fifth year's knowledge of basic astronomy.

Responses to Statement 23 suggests that this apparent shortfall starts in the junior schools.

Statement 23

In general, pupils entering our first year have a satisfactory knowledge of basic astronomy.

Opinion	Strong Agreement	Agreement	Unsure	Disagreement	Strong Disagreement
Number	2	4	34	25	66
% of sample	1.5	3.0	25.9	19.0	50.4

Chi. sq. = 104.81 n = 131
p < 0.001

Table 12

Like the teaching of astronomy at secondary level, any astronomy taught to pupils during their junior school years appears to have little effect on the H.O.Ds' opinion of childrens' understanding of the subject. Only fifteen of the one hundred and thirty one H.O.Ds (11.4%) were able to say if their junior feeder schools covered any aspects of astronomy, and of that fifteen, only five were served by junior schools where the subject is taught. All five of these H.O.Ds disagreed strongly with Statement 23.

The survey of pupils' understanding of the easily observed astronomical events reported in Chapter III (and conversations with teachers attending Inset sessions at Leeds and Bath Universities) supports the opinions of the great majority of H.O.Ds responding to the questionnaire, that there is a shortfall in pupils understanding of basic astronomy. If pupils are to be literate with regard to basic astronomy when they leave school, astronomy must feature in the science curriculum of all pupils, and ways must be found which present astronomy in a more exciting and relevant way than that which Lintern-

Ball (1972) suggests was the case for the astronomy section of Nuffield 'O' level physics (see page 45).

2.14 Influences on the Inclusion of Astronomy into the Science Curriculum

Statements 29 (i) to (viii) of the H.O.Ds survey were the most recurrent opinions collected at York on factors which may encourage the introduction of astronomy into the curriculum. The analysis of this part of the survey was confined to the responses of the sixty nine H.O.Ds from schools where astronomy does not feature. The factors were ranked by giving each response type a score on a scale of five to one - five for the most positive agreement. This gives some measure of the factors and influences which H.O.Ds consider may influence the introduction of astronomy into their curriculum. Table no. 13 shows how the H.O.Ds from the sixty nine schools not covering astronomy rated these opinions.

Statement 29

We would introduce astronomy into the science curriculum if:

	Score	Rank Order
(i) We had a telescope	173	8
(ii) There were suitable daytime practicals	208	6
(iii) There was suitable INSET	225	5
(iv) There was a planetarium nearby	185	7
(v) Finance was made available	243	1
(vi) There was time on the timetable	240	2
(vii) We had the necessary apparatus	238	3
(viii) If astronomy topics were included in the examination questions of the three sciences	228	4

n = 69

Table 13

These results suggest that the three major constraints on the introduction of astronomy are those of finance, time and apparatus. However, although the data gives a chi squared value of 205.37 (see Appendix VI), which is well above the 50.89 required for significance at the 1% level, an analysis of the first three in rank order (finance, time and apparatus) gives a chi squared value of 6.17. This is not significant at the 10% level, suggesting that H.O.Ds' difference in choice between these three factors was due to chance and that all three factors have an equal influence on the inclusion of astronomy into the curriculum.

It is considered that this part of the survey only served to identify a range of reasons which H.O.Ds commonly use to justify the fact that astronomy is not included in their science curriculum, and that the

possession of a telescope or the close proximity of a planetarium are less frequently given than the others on the list.

In retrospect, the author considers that this section of the questionnaire would have yielded more useful information if it had been left as an open question for respondents to give their own reasons for not including astronomy in the science curriculum of their school.

2.15 Astronomy Apparatus in Schools

The high rank order of apparatus elucidated by H.O.Ds' responses to statement 29 above is not supported by their replies to the section of the survey asking about astronomy apparatus in their school. Considering that less than fifty percent of the schools teach astronomy, they seem surprisingly well equipped with resources for teaching the subject. Ninety eight - 74.8% - of the science departments possess some apparatus for teaching astronomy. Twenty six (37%) of the schools where astronomy does not feature have two or more different pieces of astronomy teaching equipment, and twenty nine schools have a telescope of which none teach astronomy and only two have an astronomy club. See Appendix VIII for details.

The high rank order of astronomical apparatus in Table 7 above is inconsistent with this part of this survey, and does not appear to be a deciding factor for the introduction of astronomy into the curriculum. Reasons for the purchase of equipment on the scale suggested by this survey is not clear. However, what is not made clear from the responses to the questionnaire is how H.O.Ds have interpreted the term "necessary apparatus". Recently (1989)

discussions with teachers taking part in the C.L.I.S. Attainment Target 16 - The Earth in Space - Inset programme held at the University of Leeds have identified a need for unconventional pieces of apparatus which can be purchased as class sets, or ideas for models giving pupils hands on experience (like the seasons model in the teaching units developed for this thesis, see Chapter IV). Possibly this was the respondents interpretation of "necessary apparatus". I will return to this topic in later chapters.

2.16 Astronomy Day Time Practicals

Sixty one of the H.O.Ds (46.6%) agreed that it is difficult to teach astronomy because there are few daytime practicals. Of this 46.6%, 57.4% came from schools where astronomy is covered; thus over half (57.4%) of those H.O.Ds with experience of teaching astronomy consider that there is a shortage of activities.

The view that there is a shortage of daytime practicals is allied to the perceived shortfall in pupil-centred apparatus. Reasons for which Westways (1923) and the Science Masters' Association Report (1950) eliminated astronomy from the main science syllabus (see page 40).

It is clear from H.O.Ds' responses to this section of the questionnaire that astronomy teaching material, which includes pupil centred practical activities suitable for use during the daytime, must be produced if astronomy is to be taught in a style which brings it into the mainstream of science teaching. It is also clear that some method of drawing H.O.Ds' and teachers attention to the astronomy teaching material available needs to be developed. One hundred and three (78%)

of the H.O.Ds consider astronomy is poorly represented in the literature they receive, and one hundred and fourteen agreed that they would like to see more material on astronomy suitable for use in secondary school science.

As this data was collected before the Education Reform Act (1988) and the introduction of astronomy into the National Curriculum, it is highly probable that demand for this type of material has increased. I will return to this topic in Chapter IV when discussing the development of teaching materials, and again in Chapter V when discussing the role astronomical societies may play in ensuring that available teaching material reaches a whole audience.

A number of teachers appear to equate school astronomy with telescopes and night time observation. Although a telescope ranks eighth in Table 13 above, seventeen (24.6%) of those teachers from schools where astronomy does not feature registered strong agreement with the statement that if they had a telescope they would introduce astronomy into the curriculum. Thirteen of this group agreed that it is not worth teaching astronomy because pupils would not return in the evenings for observation sessions. Clearly, these teachers see astronomy as a night time activity and are unaware of the potential of daylight astronomy activities, which make few demands on the science department's capitulation.

To some degree it is this attitude towards astronomy which has levelled against it as a subject suitable for schools. As stated in Chapter I, p.39, astronomy education has not adapted to the change in teaching

strategy from a didactic to pupil-centred approach. This has played an important part in the failure of astronomy to find a place in the science curriculum. Those wishing to promote astronomy as a school subject have to demonstrate that there are a good number of pupil-centred daytime activities which allow astronomy to take its place in the mainstream of school science.

2.17 Extracurricular Astronomy

Only four of the schools taking part in the survey have an astronomy club. The presence of a school astronomy club, therefore, an enthusiast on the staff, does not appear to encourage the inclusion of astronomy in the science curriculum as none of these schools teach astronomy; a situation with which three of the H.O.Ds registered their dissatisfaction.

The presence of an astronomy club appears to have no overall impact on pupils' knowledge of basic astronomy as all of the H.O.Ds from schools with an astronomy club considered their pupils' knowledge at sixteen years of age to be unsatisfactory.

These findings suggest that those, like Moore (1976), who consider that the astronomy education of children can take place through astronomy clubs are mistaken. A school astronomy club (in the experience of the author) will attract six to ten pupils in a school of eight to nine hundred pupils. If the only astronomy available is via the school astronomy club, there is a danger that the members will be seen (and possible see themselves) and an elite, thereby creating a priesthood image similar to those identified in Chapter I.

2.18 Effect of Planetaria and Astronomy Exhibitions

Fifty seven - 43.5% - of the schools are situated within reasonable travelling distance from either a planetarium, permanent astronomy exhibition, or both. However, the close proximity of these facilities does not appear to favourably influence the introduction of astronomy into the science curriculum as none of these schools cover any aspects of astronomy or use these facilities on a regular basis. This fact is supported by the data given in Table 13 above where close proximity of a planetarium is ranked seventh.

2.19 Staff Membership of Astronomy Associations

Only twenty six - 19.8% - of the H.O.Ds were aware of the Association for Astronomy Education (A.A.E.) and only four schools have a member of the A.A.E. on their staff. This statistic confirms the comments in Chapter I regarding the need for more publicity by the A.A.E. of their existence and the services they can provide the science teachers.

Having a member of the A.A.E. on the staff does not appear to favourably influence the introduction of astronomy; three of these schools run an astronomy club, but only one features it in the science curriculum, thus suggesting that other factors like timetable time and finance (see p80) predominate over teachers enthusiasm for the subject.

Six H.O.Ds, or one of their staff, are members of an astronomical association other than the A.A.E. Three of these schools cover astronomy in their science curriculum, but none run an astronomy club. This data suggests that - apart from the A.A.E. - membership of an astronomical association is associated with personal development and

has no influence on the promotion of astronomy as an extracurricular activity. However, the data is very limited and further research is required so that the A.A.E. and other astronomical societies can monitor (and possibly develop) the effect their members have on the promotion of school astronomy both as a subject within the science curriculum and as an extracurricular activity.

One hundred and seventeen - 89.3% - do not know if there is anyone within their Local Education Authority who can advise them on school astronomy. This may well have serious implications for the successful introduction of the astronomy content of the National Curriculum. I will return to this in later chapters after considering teachers' concerns on teaching basic astronomy.

2.20 Astronomy at Examination Level

Forty (30.5%) of the H.O.Ds were unaware of the G.C.E. astronomy 'O' level examination and the number of pupils entered for the examination by the schools is low. Three schools - each with an astronomy club - enter pupils for this examination, but none on a regular basis. This is consistent with the chief examiner's comments (see Note XIV, Chapter I, p60) at the A.A.E. A.G.M. 1988, that nationally, entries run quite consistently at about four hundred candidates each year and that he did not expect this figure to change over the next few years.

2.21 Astronomy for an Elite

In Chapter I it was shown that throughout the greater part of its history astronomy has been studied by an elite; priests, navigators, the landed gentry, rich amateur or academics. A number of comments made by teachers during the interviews at York suggest that some of these attitudes towards astronomy may have filtered into present day opinions about the subject. Moore (1976) appears to be promoting this 'priesthood' attitude when he claimed that astronomy should be kept out of schools because:

".... they will kill the subject...." [i]

As it was intended within this thesis to state a case for the inclusion of astronomy in the science curriculum of all pupils, it was considered necessary to discover if any notions of exclusivism still persist in H.O.Ds opinions about astronomy education. Any such notions identified would have to be targeted by those promoting the more widespread teaching of astronomy to demonstrate that they are ill-founded.

Questions 7, 9, 11, 17, 20 of the H.O.D's questionnaire were intended to discover if notions of exclusivism are a common feature of H.O.Ds' opinions about astronomy.

H.O.Ds from the sixty two schools where astronomy is taught consider it a subject suitable for teaching across the ability range. None agreed - at any level - with Statement no. 7 that astronomy is only suitable for able and motivated pupils.

The opinions of those from schools where astronomy does not feature are very similar. Only seven agreed with Statement no. 7 and only twelve were unsure about its suitability for pupils other than those labelled 'able'.

One hundred and twelve (85.5%) of the H.O.Ds disagreed with Statement 9, that if astronomy were introduced into the science curriculum, it would spoil it as a leisure time pursuit.

The fact that astronomy does not directly relate to the world of work (Statement 11) was not generally seen as a reason for not including it in the curriculum. Only four of the H.O.Ds agreed with this statement. An almost identical trend in response to Statement 20 was obtained with only seven (5.3%) agreeing that astronomy should not feature in the science curriculum because it has such little practical value.

In order to gain a full profile of H.O.Ds' opinions towards the secular study of astronomy, a total score of statements 7, 9, 11, 17 and 20 was made. Each response type was given a score from one to five; the highest score is allocated to the side of the agreement scale gaining the most responses. Tables 14 to 18 give the statements and scores.

Statement No. 7

Astronomy is only suitable as a subject for able and motivated pupils.

Level of Agreement	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
Numbers	1	12	25	24	69
Score	1	24	75	96	345

Table 14

Statement No. 9

If astronomy were introduced into the science curriculum it would spoil it as a leisure time pursuit.

Level of Agreement	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
Numbers	1	6	12	32	80
Score	1	12	36	128	400

Table 15

Statement No. 11

Astronomy should not be included in the science curriculum because it does not relate to the world of work.

Level of Agreement	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
Numbers	3	1	6	36	85
Score	3	2	18	144	425

Table 16

Statement No. 17

Astronomy is now such an advanced subject that the average person cannot identify with the work astronomers do. For this reason, astronomy should not be part of the science curriculum.

Level of Agreement	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
Numbers	1	5	17	32	76
Score	1	10	51	128	380

Table 17

Statement No. 20

Astronomy has such little practical application in the lives of most people, it should not be included in the science curriculum.

Level of Agreement	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
Numbers	3	4	11	28	85
Score	3	8	33	112	425

Table 18

The totals of these scores are given in Table 19 below and give a profile of H.O.D's opinion about an elitist view of astronomy education.

Statement No.	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
7	1	12	25	24	69
9	1	6	12	32	80
11	3	1	6	36	85
17	1	5	17	32	76
20	3	4	11	28	85
Totals	9	56	213	608	1975

<-----
 Increasingly elitist

Table 19

The results suggest that the elitist attitude (which reached its peak in the eighteenth century) and utilitarian view towards astronomy education, epitomised by Vives (c. 1520), patent in Gresham's (c. 1578) outline of his plans for his college, and often perpetuated by governments since the Revised Code of 1862 (see Chapter I), does not generally feature as an opinion of H.O.Ds, and the consensus opinion is that astronomy should feature in the science curriculum of all pupils.

2.22 H.O.Ds' Opinion of Their Own and Their Staff's Knowledge Of Basic Astronomy

Forty nine (37.4%) of the H.O.Ds from schools where astronomy does not feature agreed with Statement 21, that they would like to introduce some basic astronomy into their lessons but do not feel confident in their own knowledge of the subject. Of this, forty five (91.8%) consider that both they and their staff will require Inset [ii] before introducing basic astronomy (Statements 4 and 21). Therefore, of the 131 H.O.Ds taking part in this survey, 34.3% come from schools where there is no science teacher with the necessary background to

teach basic astronomy until they undertake some form of Inset. (Results of the teachers' survey given later in this chapter suggest that this figure is higher than shown by the H.O.Ds' survey).

Of the forty nine H.O.Ds who consider they need Inset, twenty six (53%) agreed that they would be more likely to introduce astronomy if peripatetic astronomy teachers visited their school (Statement 22) [iii]. Thirteen of this group of forty nine think that the astronomy education of their pupils will be best served if their L.E.A. provides short residential courses for pupils interested in the subject. I will return to this topic in Chapter III which reports about pupils' understanding of basic astronomy, as the L.E.A. from which the pupils' knowledge data was collected run an annual course of this type.

STAGE 5

2.23 Survey of the Science Teachers

Two hundred and sixteen (18%) of the science teachers returned completed questionnaires. A low level of returns was expected as replies depended on H.O.Ds giving out the questionnaires to teachers and collecting them back after they had been filled in. However, despite this obvious shortfall, the method gave a maximum coverage while keeping within budget limitations.

The returning teachers divided into four subject specialisms.

DIVISION OF RETURNEES INTO SUBJECT DIVISIONS

Subject	Number	%
Physics	102	47.22
Chemistry	47	21.75
Biology	57	26.40
General Science	10	4.63
Total	216	100

Table 20

2.24 Teacher Concerns

It was considered important to establish a teachers' concerns order of priority because the concerns were to act as a focus for the development of the Inset material reported in Chapter V of this thesis.

A priority order was established by giving each teachers' response to six concerns based statements (Statements 2, 3, 5, 7, 14 and 15) a score which related to their response type, as shown in Table 21 below.

METHOD OF SCORING TEACHERS RESPONSES

Response Type	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
Score	5	4	3	2	1

Table 21

Tables 22 to 27 below give the concern specific statements and their scores.

Statements 2 and 3 were directed towards teachers' personal knowledge concerns.

Statement 2

I will require some form of In service training before teaching basic astronomy.

Response Type	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
No.	52	96	23	21	24
Score	260	384	69	42	24

n = 216

Table 22

Statement 3

I do not think my teacher training has prepared me to teach basic astronomy.

Response Type	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
No.	84	80	12	24	16
Score	420	320	36	48	16

n = 216

Table 23

Only 20% of the teachers consider that they do not require Inset before teaching basic astronomy. This gives some indication of the Inset need for the successful introduction of A.T. 16, and demonstrates that the Inset must contain an element of subject matter. This conclusion is confirmed by teachers' responses to statement 3; 75.9% do not

consider that their teacher training prepared them to teach basic astronomy. This result is not surprising and confirms both Butt's (1985) and Gold's (1985) comments (see page 63) about the lack of astronomy taught to trainee teachers.

Statements 5 and 8 directed teachers towards organisational concerns.

Statement 5

I would be concerned about teaching astronomy because of the shortage of available practical material.

Response Type	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
No.	41	118	12	31	14
Score	205	472	36	62	14

n = 216

Table 24

Statement 8

It would be difficult to teach astronomy in our school because we do not have the necessary apparatus.

Response Type	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
No.	34	51	3	72	56
Score	170	204	9	144	56

n = 216

Table 25

Concern amongst the teachers about the shortage of daytime activities is even higher than the H.O.Ds. 73% of the teachers registered concern about teaching basic astronomy because of the shortage of practical material, compared to 46.6% of the H.O.Ds (see p.72). The responses of H.O.Ds and teachers to this statement demonstrates that over the past 60 years virtually no progress has been made towards redressing Westway's (1923) observation about the shortage of practical material for school astronomy (see Chapter 1.11, p.40).

Teachers appear to be far less concerned about apparatus than teaching material; only 39.4% agree that it will be difficult to teach astronomy in their schools because they do not have the necessary apparatus. There appears to be some difference of opinion between teachers and H.O.Ds regarding the importance of apparatus. The H.O.Ds placed apparatus third in order of importance in influencing the introduction of astronomy in the curriculum (see p.80). Perhaps teachers are more aware than H.O.Ds of the considerable amounts of astronomy teaching apparatus already in schools (see Appendix VIII). However, more probably, there is a difference in the way teachers and H.O.Ds have interpreted 'apparatus' (see p.82). I will return to this again in Chapter IV.

Statements 14 and 15 addressed peer group concerns.

Statement 14

Astronomy should not feature in the science curriculum because it does not relate to the world of work.

Response Type	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
No.	31	23	24	86	52
Score	155	92	72	172	52

n = 216

Table 26

Statement 15

If I use topics from astronomy to develop concepts in my subject specialisms, my colleagues would consider it wasting valuable time.

Response Type	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
No.	12	19	16	92	77
Score	60	76	48	184	77

n = 216

Table 27

Peer group concerns do not appear to be a concern for a majority of teachers; only 25% consider that astronomy should not feature in the curriculum because it does not relate to the world of work. This suggests that a majority of teachers see the science curriculum as providing more than employment related experiences.

Although only 14.3% of the returning teachers believe that their colleagues would consider the use of astronomy to develop concepts in their subject specialism a waste of time, this statistic is disturbing as it suggests that well over 10% of science teachers do not feel free to present the subject being taught to pupils in the context they feel most suitable.

2.25 Producing a Concerns Priority Profile

The teacher's responses to the concerns based questions were then combined to obtain a concerns based profile.

This was obtained by totalling the six concern specific scores. See Table 28 below.

CONCERN PRIORITY PROFILE

Concern	Score	% of maximum score possible
Personal	1619	74.95
Organisational	1372	63.52
Peer group pressure	988	45.74
Maximum score possible for each concern type	2160	

Table 28

These results show that when faced with the prospect of teaching basic astronomy the order of teachers' concerns is the same as Gardner and Dorset (1979) found for other subjects.

Confirmation of teachers' concerns priorities was gained from questions 4, 11 and 18 which gave space for respondents to write on their own concerns. Replies to these sections were not given by all teachers,

but the number of responses for each concern parallels the trend given in Table 28 above. The most common concerns were personal, followed by organisational concerns; peer group pressure concerns only featured in twenty respondents replies to this part of the questionnaire. This information is summarised in Table 29 below.

TEACHERS WRITTEN CONCERNS

Concern	Number responding	Most Common Concern and %
Personal	122	Lack of personal knowledge. (91%)
Organisational	110	Shortage of practical work. (79%)
Peer group pressure	20	Parents objecting to night time observation. (80%)

Table 29

This order of concerns priority is of importance to those designing Inset activities for astronomy education as it demonstrates that the planned Inset sessions must address both teachers' knowledge of subject matter and practical activities for pupils, if confident teachers of astronomy are to be the end product. I will return to this topic later when discussing the importance of this part of the research to the production of Inset material delivered at the University of Leeds and produced in conjunction with the University of Bath Programmes for School-based Inset.

2.26 Personal Concerns of Subject Specialists

Forty seven percent of the returnees were from teachers of physics. This is similar to Lintern-Ball's survey (50%) and suggests that physics teachers identify with astronomy more than teachers of other sciences. This goes some way to support those, which Butt (1985) has observed:

".... claim ipso facto, that every physicist is an astronomer"

However, an analysis of physics teachers' confidence throws doubt on this assumption. Forty five percent of the physics teachers registered a lack of confidence about teaching basic astronomy. Teachers of other sciences were even less confident.

SUBJECT TEACHER CONFIDENCE AT TEACHING
BASIC ASTRONOMY

Subject	% Not Confident to Teach Basic Astronomy
Physics	45
Chemistry	49
Biology	65
General Science	50

n = 216

Table 30

Teachers' lack of confidence concern is reflected in their opinion of Inset needs - Statement 2. Sixty eight percent consider they require some form of In service provision before they can teach basic astronomy with confidence. This is a higher figure than that identified by the

H.O.D. survey reported earlier in this chapter and suggests that the need for astronomy Inset is greater than H.O.Ds estimate.

2.27 Inset Needs of Subject Specialists

Dividing this sixty eight percent into subject divisions shows that there is very little difference between the percentage of physics, chemistry and general science teachers stating a need for Inset. However, teachers of biology appear to form a subgroup with a twenty percent increase over other science teachers in their need for In service provision, table 31. This has implications for science departments who intend presenting the science content of the National Curriculum in an integrated style because there will be a greater demand from biology teachers for Inset.

However, one approach is to deliver the astronomy content of the National Curriculum within the context of teachers' subject disciplines, an approach which teachers of biology showed the most positive interest, see p.91.

PERCENTAGE OF SUBJECT SPECIALISTS STATING
A NEED FOR Inset

Subject Specialism	% Stating Need
Physics	58.8
Chemistry	63.8
Biology	86.0
General Science	60.0

n = 216

Table 31

2.28 Teachers' Academic Background and Their Inset Needs

Of the fifty two teachers who disagreed with Statement No. 2 (I will require some form of In service training before teaching basic astronomy), only twenty three considered that their training prepared them to teach basic astronomy. While this group of twenty three only represents 10.6% of the survey sample, it was considered worthwhile to look closer at this subgroup to discover if there are any factors in their subject specialism or training background which leads to a greater confidence in teaching basic astronomy.

For clarity, the fifty two teachers disagreeing with Statement 2 are referred to as SG1 and the twenty three from SG1 who consider their training prepared them to teach astronomy as SG2.

SUBJECT DIVISION OF TEACHERS SATISFIED WITH THEIR TEACHER TRAINING

Subject	No.	As a % of SG1
Physics	12	11.76
Chemistry	4	8.50
Biology	5	8.77
General Science	2	20.00 *

n = 23

Table 32

Apart from the general science teachers (* one general science teacher has a higher degree in astronomy and elevates the percentage of this small group) there is very little difference in the percentage of each group of subject specialists claiming confidence and not requiring Inset. However, when SG2 are divided into training background groups and stated as a percentage of SG1 with the same training background, it

appears that the B.Ed. course leads to a greater confidence than other training methods. Table 33.

ACADEMIC BACKGROUND AND PREPAREDNESS
FOR TEACHING ASTRONOMY

Qualification	No.	As a % of SG1
B.Sc.	7	5.01
B.Ed.	11	37.93
Cert. Ed.	3	7.14
Higher degree	2	33.30 *

n = 23

Table 33

Further research is required to discover if this trend in confidence is a common feature of B.Ed. trained teachers, and if so, what factors (characteristics of course and applicants) give rise to this confidence. Those responsible for teacher training (including P.G.C.Es) would find the results beneficial in helping them to reorganise their courses in the light of the National Curriculum.

2.29 Organisational Concerns

A perceived shortage of practical material for astronomy is teachers' major organisational concern, and if suitable practical material is available there is an increase in teachers' confidence. Of those one hundred and thirty seven teachers claiming that they will require Inset, forty nine - 35.8% - registered confidence if given suitable practical work.

EFFECT OF PRACTICAL MATERIAL AVAILABILITY
ON TEACHERS' CONFIDENCE TO TEACH
BASIC ASTRONOMY

	No.
In need of Inset before teaching basic astronomy	137
Confident to teach basic astronomy if provided with suitable practical material	49
Still not confident even when provided with suitable practical material	88

n = 137

Table 34

These findings suggest that if practical material is available there is a 22.7% increase in teachers' confidence to teach basic astronomy. This will reduce the percentage of teachers lacking confidence from 63.4% down to 40.7%. Thus by following a national advertising campaign which draws teachers' attention to available practical material, it is reasonable to expect a reduction in the demand for Inset in the order of 20%. But teachers' responses to Statement No. 7 suggests that they are unsure about the availability of such material. One hundred and four - 48% - were undecided whether there are too few daytime practicals.

Statement 7

There are far too few suitable daytime practicals for astronomy to be taught in normal school hours.

Response Type	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
Score	10	14	104	52	36

n = 216

Table 35

This statement gained the highest undecided score of the whole questionnaire, and reflects the H.Q.Ds' opinion that of the literature they receive, astronomy is poorly represented. Teachers do not appear to know what is, or is not, available. I will return to the need for wider publicity of teaching material and suggest a mechanism through which this can take place in a later chapter.

Teachers appear to place less importance on apparatus than their H.O.Ds. A majority (59.3%) disagreed that it will be difficult to teach astronomy in their schools because they do not have the necessary apparatus - Statement 8. However, as stated earlier in this chapter, there appears to be some confusion about what is meant about the term 'apparatus', and I will return to this in a later chapter.

Teachers, like their H.O.Ds, do not see the lack of sophisticated apparatus in school astronomy lessons a problem.

APPARATUS CONCERNS

<u>Statement No. 9</u>	Strong agree-ment	Agree-ment	Unsure	Dis-agree-ment	Strong disagree-ment
Astronomers use such specialised equipment pupils will soon become disillusioned with basic school equipment	5	13	37	6	95

n = 216

Table 36

Like their H.O.Ds, teachers interest in material which use topics from astronomy to enhance their own subject specialisms is high; only eighteen percent registered any level of disagreement with this statement. This lends support to the claim in 'Science 5-16 A Statement of Policy' (1985) that astronomy can act as a vehicle for the development of important concepts in other sciences.

Interest in this type of material is spread relatively equally across the subject specialisms. Table 37.

PERCENTAGE SUBJECT SPECIALISTS INTERESTED
IN ENHANCEMENT MATERIAL

Subject	Strong agree-ment	Agree-ment	Unsure	Dis-agree-ment	Strong disagree-ment
-----	-----	-----	-----	-----	-----
-----	---%---	---%---	---%---	---%---	---%---
Physics	46.1	17.6	25.0	8.8	2.0
Chemistry	38.3	4.2	38.3	4.4	12.8
Biology	50.0	7.2	12.3	14.3	15.8
General Science	40.0	10.0	30.0	20.0	0.0

n = 216

Table 37

The high percentage of biology teachers (57.2%) interested in astronomy enhancement material is surprising as they registered the greatest Inset need. It may be that starting from a familiar footing is the best way of introducing astronomy as teachers will be more confident if they are able to present topics from astronomy within the context of their own subject specialism. I will return to this point in Chapters IV and V when discussing the development of teaching and cross curricular material.

2.30 Peer Group Concerns

Teachers are in agreement (63.9%) with their H.O.Ds that astronomy should not be excluded from the curriculum because it does not relate to the world of work. They also consider (68.5%) that parents would not claim it a waste of time if they introduced astronomy into their teaching.

Of the fifty eight teachers who strongly agreed that astronomy should not feature in the curriculum, fifty two claimed that parents would consider the introduction of astronomy a waste of time and fifty three claimed that their colleagues would be of the same opinion.

Forty one of the fifty eight who strongly agreed that astronomy should not feature, expressed an interest in astronomy enhancement material for their own subject specialism. These results suggest that peer group pressures may well be influencing some teachers' opinions, and that teacher opinions on the worth of astronomy elicited by the survey does not necessarily reflect their own beliefs about the worth of the

subject as a vehicle for developing concepts in their own subject specialism.

2.31 Teachers' Opinion of Sex Bias and Elitism in Astronomy Education

Teachers responses to Statement 10 - that astronomy will be more likely to appeal to boys - showed an even stronger disagreement than their H.O.Ds - Statement 14 H.O.D. survey.

H.O.DS AND TEACHERS OPINION ON A SEX BIAS FOR ASTRONOMY

	Teachers	H.O.Ds
% Disagreeing with statement	91.2	62.6
Mean	4.55	3.84
Maximum mean	5.0	5.0

Table 38

The view of equal appeal of astronomy is upheld by Belserene (1988) but Bishop (1980) and (1988) - suggests that females have more difficulties with the spatial concepts.

Sex bias and the ability to cope with the spatially demanding aspects of astronomy was not a subject of this research. However, during the process of collecting the data no obvious sex difference manifested itself. It is recommended that further research is carried out in this area. If there is a sex difference, it is essential that ways are found to present the spatially demanding aspects of Attainment Target 16 (most of which occur at K.S. 2 and 3) in styles which will not disadvantage either sex.

One hundred and seventy five (81.0%) disagree that astronomy should only feature as an extracurricular activity - Statement 17. Of this one hundred and seventy five, one hundred and twenty five - 57.9% - registered a strong disagreement with this statement. This corresponds with their H.O.Ds' rejection of elitism in astronomy, and while the value of a school astronomy club is clear, most H.O.Ds and teachers do not consider this should be the only source of astronomy education.

STAGE 6

2.32 Summary Statement About the Position of Astronomy Education in English State Secondary Schools

The results of the surveys reported in this chapter provide a picture of the state of English Secondary school astronomy prior to the introduction of the National Curriculum, and identifies the base line from which the introduction of astronomy into the science curriculum of all pupils commences.

The amount of taught astronomy is higher than suggested by Lintern-Ball (1972), and one suspects that the level of taught astronomy has increased since the launching of Sputnik in 1957, although there are no surveys to substantiate this claim. At present (1986) more pupils are exposed to some form of education in astronomy than at any other time in history, but the surveys suggest that there is a considerable shortfall in both teachers' and pupils' understanding of the subject.

Typically, around half of secondary schools teach some aspects of astronomy in their second year curriculum to pupils who are unlikely to have experienced any exposure to the subject during their junior years.

Very few schools teach any aspects of astronomy in their fourth and fifth year courses.

Almost all of the astronomy taught falls short of what H.O.Ds consider satisfactory, and most pupils leave school with a poor understanding of the subject.

Commonly, H.O.Ds and teachers are concerned about their own knowledge of astronomy and consider that they need Inset if they are to introduce astronomy into the curriculum with confidence.

Teachers' confidence is increased if they are provided with suitable teaching material, but there is a concensus opinion that practical astronomy activities suitable for use in schools are not available.

The great majority of respondents registered a positive opinion towards the inclusion of astronomy into the science curriculum of all pupils, and expressed a strong interest in teaching materials which use topics from astronomy to support important concepts in their own subject specialism.

Although the findings of both surveys support the decision of the D.E.S. to include astronomy in the National Curriculum, they demonstrate very clearly that there is a need for considerable investment into Inset programmes, and the development and publicity of pupil-active daytime astronomy teaching material. The results of the teacher survey suggests that if astronomy teaching material is developed which uses astronomy as a vehicle to develop important

concepts in the three main sciences (or set within the context of one of the main sciences), teachers will be more confident and there may well be a 20% reduction in demand for Inset.

The results of the surveys reported in this chapter focused the remainder of the research on three main areas which needed to be addressed if the introduction of astronomy into the science curriculum is to be successful, and the worst fear of Moore (1976) - schools killing the subject - is not to become a reality:

- (i) To discover the state of pupils' knowledge of basic astronomy when the present provision for astronomy education is so poor.
- (ii) To develop pupil-active teaching materials which start with the pupils' untutored understanding, and explanations for, the basic astronomical events.
- (iii) To develop Inset material which develops both teachers own understanding of basic astronomy, and ways which they can present school astronomy in a relevant and interesting way.

NOTES ON CHAPTER II

- [i] Recently Moore (1988) has advocated that astronomy be part of school science, not a subject in its own right.

- [ii] At this stage of the survey no attempt was made to identify the type of Inset provision required. However, the results of the survey of teachers demonstrated that the Inset provision needs to cover both content and methodology. This was the focus for the production of the Inset material produced for this thesis.

- [iii] The author considers that the employment of peripatetic astronomy teachers by L.E.As should be discouraged. Such action will reduce the possibility of developing the extra curricular potential of astronomy and of using it as a vehicle for developing important concepts in other sciences. See for instance the Moon and Seeds teaching material reported in Chapter IV of this thesis.

CHAPTER III

Pupils' Understanding of the Easily Observed Astronomical Events

3.00 Introduction

In Chapter I it was shown that throughout its history astronomy has never been a well-established feature of the ordinary person's education. Results of the H.O.Ds' survey reported in Chapter II of this thesis shows that its present status is little different from the past, and reveals that where it does feature in the science curriculum of the sample schools, it is generally considered by the H.O.Ds to be unsatisfactory and they consider pupils leave school at sixteen years of age with a shortfall in their astronomical knowledge.

The results of both the H.O.D. and science teachers' surveys suggest that there is a demand for astronomy teaching materials which fit into the main stream of science teaching. However, before embarking on the production of materials intended to go some way towards satisfying this need, it was necessary to gain an insight into pupils' current knowledge of basic astronomy, and to identify the theory of scientific methodology, and of childrens' learning, which were to be implicit in the units.

3.01 Scientific Knowledge

It is now commonly thought that the growth of scientific knowledge does not follow the logical inductivism of Baconian scientific methodology, where observation and facts precede theory. Medawar (1984) (showing the influence of Whewell (1840), Popper (1959) and Kuhn (1979) on his thinking) claims that a hypothesis is 'inspirational in character'.

If this is the case, then theories and expectations precede and guide observations; scientific knowledge is seen as a human construct, not just confined to scientists. (Driver and Erickson (1983)).

".... Students possess invented ideas based upon their interpretation of sensory impressions"

The recognition of this fact has given rise to the 'Constructivist' theory of learning, central to which is the notion of the student as a scientist (Driver 1983). This shifts the emphasis of teaching away from activities designed to support the consensus view, and towards those which encourage pupils to identify their own thoughts and design 'fair tests' which challenge their ideas.

This approach places a different interpretation on those pupils' ideas which are at variance with the accepted view. To the empiricist, they are simply 'wrong ideas' or 'misconceptions', because they were arrived at through faulty observation or logic. The constructivists propose the term 'alternative framework' (Driver and Easley (1978)) in place of the negative term 'misconception'. This affords pupils' ideas a greater respect; they are 'inspired guesses', and as such, worthy of testing. Thus providing a focus for practical activities, which become much more than mere demonstration of other peoples' thinking about the topic; in the pupils' eyes they become true experiments which challenge their own notions.

Nussbaum (1989) points out that the constructivist movement is not monolithic, and draws a distinction between the constructivism of

Popper, Lakatos, Toulmin and Kuhn. He argues that any research rationale within the constructivist approach must specify:

".... an inclination to one or two related variations."

While no inclination was specified in the original research proposal to this thesis, it will be suggested in Chapter IV that pupils' responses to the astronomy conceptual survey instrument (see p126) can be used to support Toulmin's (1972) model.

3.02 Piaget and the Constructivists

An understanding of cognitive development is contingent on a knowledge of how children structure their concepts and the changes these structures undergo as the concept develops towards the accepted view.

Precise studies aimed at finding out what children think about the natural world originate from the work of Piaget (1923) and (1929) who proposed that these structures develop in age related stages. This theory has received support from many researchers (Ginsburg and Opper (1969), Bruner, Goodfellow and Austin (1956)) and is central to the Piagetian view of cognitive development which has dominated research into childrens' learning for over half a century.

Recently the inviolate nature of Piaget's chronological stages of development have been questioned. Ross (1980) and Sugarman (1983) have shown that contrary to the classical Piagetian view, pre-school children are able to form consistent and exhaustive classes from an early age. Keil (1986) has proposed that the stage-like changes in structure are peculiar to domains, not global shifts, and that the

foundation of a particular stage may differ from one domain to another. Shifts from stage to stage being related to domain, not age.

In this thesis attention is focused on childrens' own theory of explanation and its influence on the way they make sense of new experiences, Driver and Erickson (1983) Osborne and Whittrock (1983) Pope and Gilbert (1983). However, it is recognised that the Piagetian and Constructivist theories of learning do not necessarily lay at opposite poles, and that not all researchers see the constructivists approach as being greatly distanced from the work of Piaget. Lawson (1982) has attempted to find domain independent forms of thought and Archenhold (1980) has investigated the relationship between the constructivist and Piagetian approaches.

While there are acknowledged overlaps between the two views of learning (Gilbert and Swift (1981), fundamental differences do exist.

FUNDAMENTAL DIFFERENCES BETWEEN PIAGET'S COGNITIVE
DEVELOPMENT AND THE CONSTRUCTIVIST'S APPROACH

Piagetian	Constructivist
Learning independent of content and context.	Learning dependant of content and context.
Learning stage related and associated to maturity.	Learning largely independent of age and no pre-ordained direction.
Conceptual development associated with progress through stages.	Conceptual development means developing one's conception of a phenomenon.

Adapted from Gilbert (1986)

Table 39

While I do not intend to pursue the 'Piagetian' versus 'constructivist' debate in this thesis, the conceptual maps developed from the results of the survey of twenty pupils over a period of four years (see pp 138-142) appear to support the constructivist view that learning is largely independent of age, with no pre-ordained direction.

3.03 A Background to Pupils' Alternative Frameworks

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 about the topic, and that these untutored notions are often at variance with the accepted view. See for instance, Driver and Erickson (1983) Driver, Guesne and Tiberghien (1985) Brook, Driver and Johnston (1988).

A knowledge of these alternative ideas is not new, Galileo's (1613) letter to the Grand Duchess Christina suggests that he was aware of the

untutored view of the ordinary man when he claimed that certain passages of 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.

The German educator Diesterweg (1790-1866) was aware of the importance of childrens' ideas to the process of teaching and emphasised the value of starting instruction from the students' point of view. Clearly Nunn (see Chapter I, p2) was aware of pupils' untutored ideas and their implications for teachers. However, it is only relatively recently that pupils' ideas have become a major focus for educationalists, forming a basis for the design of teaching materials.

3.04 Historical Trends in Pupils' Ideas

Parallels have been drawn between the ideas that children (and scientifically naive adults) use to account for a range of physical phenomena and those which have appeared in the history of science. Strauss (1981) argues that individuals' commonsense knowledge about qualitative physical concepts has not changed since the time of Aristotle. This view is supported by Watts and Zylbersztajn (1981), Clements (1982), and McCloskey (1982 and 1983), who have demonstrated that untutored ideas in mechanics resemble the pre-Newtonian impetus theory.

Research into childrens' concept of the Earth as an astronomical object demonstrates that pupils' ideas show a progression through a series of phases towards the accepted view. Nussbaum and Novak (1976), Nussbaum

(1979), Mali and Howe (1979), and Sneider and Pulos (1983) have all shown that childrens' ideas on the Earth in space and the gravitational field develop from a naive flat Earth notion through a series of phases to our present round Earth view. Nussbaum's (1979) Earth Notions Classification Scheme bears a resemblance to the historical development of man's Earth in space and gravitational field concept. Some observed phases reflect the notions supported by Cosmas and Lactanticus in their defence of the biblical world view. (See Chapt. I, p7). These parallels between the trends in childrens' developing concept of the Earth in space and the history of man's developing knowledge of astronomy lend support to the claim (McCloskey (1983)) that children recapitulate the major ideas in the history of science as they develop their own understanding of different topics. This parallelism has considerable potential for teaching astronomy and as a focus for cross curricular work. I will develop this further in Chapters IV and V.

3.05 Cultural Influences

Cross cultural studies of Mali and Howe (1979) and Klein (1982) have shown that similar notions about the Earth in space are present in different cultures and that they generally exhibit the same phases during their development towards the accepted view.

Othman (1988) has shown that cultural influences can result in pupils restructuring taught facts to reconcile with deep-rooted beliefs, and claims that in order to teach astronomy well, "one must first break some cultural bonds".

His phrase "break cultural bonds" implies that the cultural idea should be totally discarded. Perhaps a better approach would be to develop an ability in pupils to function in both a cultural domain and a scientific domain, and to be able to recognise each domain and its limitations. Then children will not lose contact with the way their own, and other, cultures have explained and used astronomy in the past (see Hinckley Allen (1963), Larue (1988) and McCrickard (1990), while at the same time appreciating the limitations of these cultural notions in the light of scientific advancement.

It is in passing on cultural notions rather than imparting a knowledge of astronomy (see p124) that parents probably play their greatest role in the astronomical education of their children, and while cross cultural studies were not carried out in this study, Othman's (1988) claim has implications for those teachers presenting the astronomy content of the National Curriculum to multicultural classes. This is an area which requires further research. [i].

3.06 Implications for Teaching

Over twenty years ago Ausubel (1968) drew attention to the tenacious nature of pupils' ideas (in Ausubel's terminology 'childrens' preconceptions) claiming that unlearning of preconceptions may be the:

".... most determinative single factor in the acquisition and retention of subject matter knowledge."

Gilbert et al. (1982) and Solomon (1983) have shown that pupils frequently hybridize their view with science instruction, resulting in a mix of teachers' science and the child's original framework; or they

may retain both ideas as separate domains, the life world domain and the science world domain.

Viennot (1979) has indicated that these "alternative frameworks" (Driver's (1983) terminology and one which will be used throughout this thesis) persist into adulthood. This view is supported by the findings of Durant et al. (1989) who have shown that 66% of adult Britons do not know that the Earth goes around the Sun once a year.

The situation is little different in other parts of the world; Miller's (1988) survey showed that only 46% of Americans appeared to know that the Earth goes around the Sun once a year, and in France, Acker and Pecker (1988) claim that about one third of the people still believe that the Sun orbits around the Earth.

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 they provide 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 experience.

An understanding of pupils' successive alternative frameworks provides 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.

Therefore, a knowledge of pupils' alternative frameworks becomes more than a mere inventory of 'wrong ideas'; they serve as a guide to the teacher for seeing the child's point of view (see Nunn Chapt.1, p2) and form a starting point from which pupils can clarify their ideas and put them to the test. Such a process is now considered to be closer to the way scientists really work and reflects the influence of Popper (1959) and Kuhn (1962) on our view of the scientific process (Ingle and Jennings (1981), Medawar (1981), Nussbaum (1989)).

3.07 Pupils' Ideas: Methods of Investigation

Most research into pupils' notions involve variations of a clinical interview technique developed by Piaget (1928).

Pupils are interviewed individually and their responses to questions or situations recorded. Some interviews are highly structured (Mali and Howe (1979)), others open ended (Tasker (1980)). Sometimes props or drawings are provided to help pupils explain their ideas (Sneider and Pulos (1983)).

Researchers have used a variety of methods to record pupils' responses: audio taping individual interviews (Gilbert, Watts and Osborne (1981)), asking pupils to make additions to diagrams provided by the interviewer (Nussbaum and Novak (1976)), or analysing responses to multiple choice questions (Watts and Zylbersztajn (1981)).

3.08 Data Framing of Data Collection Techniques

Driver and Erickson (1983) have written at length on the framing of data collection techniques, and point out that pupils' responses may

differ significantly depending on whether the investigational technique is framed in a conceptual or phenomenological mode. (A conceptual frame eliciting propositional knowledge, while a phenomenological frame elicits knowledge in action). Their summary of techniques for framing data collection provides a conceptual-phenomenological continuum. At the conceptual end of this continuum are the word association techniques used by Shavelson (1974) and Preece (1976), and at the phenomenological end, the observational studies of students theories in action used by Karmiloff-Smith and Inhelder (1976). Laying in the middle are the interview about instances/phenomena frames used by Osborne and Gilbert (1980), Nussbaum and Novak (1976), Erickson (1979) and Engel (1982). It is at this point along the continuum that data collection of pupils' ideas about astronomy are usually framed, and the way in which the data was framed for this study.

3.09 Domains Investigated

In this study childrens' theories about four domains were investigated to discover the influence of informal education on their knowledge of astronomy, thus giving some measure of a suitable starting point for the development of the teaching units.

The four domains investigated were:

- (i) Planet Earth in space and the gravitational field.
- (ii) Day and night.
- (iii) Phases of the Moon.
- (iv) The seasons.

These domains were selected because it was agreed at a meeting between myself and the curriculum committee of the A.A.E. that they form the minimal level of astronomical understanding of all pupils when they

leave school. They also form a firm foundation upon which those with a particular interest can build on their knowledge of astronomy.

3.10 The Sample

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 primary schools. Apart from planet Earth topics typical of secondary school geography, astronomy does not feature in the curriculum of the secondary school.

Interviews were carried out with the head teachers of the four feeder primary schools in an endeavour to discover areas from astronomy which feature in their curriculum. No aspects of astronomy, other than the thematic treatment of seasonal changes in the weather, featured in any of the primary schools; therefore, most notions pupils hold represent personal constructs, or are the product of informal education.

Two of the primary head teachers considered astronomical topics like day and night and phases of the moon are 'learnt at mother's knee' or from television programmes, and need not feature in the school curriculum. This opinion is open to doubt in the light of the research of Durant, Evans, and Thomas (1989), who have shown that the British public's understanding of science (including astronomy) is poor. If their sample is representative of the population as a whole, it is highly probable that a good percentage of any scientific learning which may take place 'at mother's knee' will be the passing on of misconceptions (or cultural notions, see p117) from one generation to another.

3.11 Survey Methods

One of the problems facing researchers using in depth interview techniques to probe childrens' understanding is the time factor and subsequent disruption of the normal school day. In order to keep this disruption to a minimum, while maintaining a high sample number, a two stage process of data collection was used.

First a sample of twenty pupils aged between nine and sixteen were interviewed individually about their theories concerning the four domains. The interviews were open-ended and lasted about ten minutes each. Props were available, but were not put out on open view so as not to influence pupil's responses.

These pupils interviewed covered the full range of abilities based on their teachers' subjective judgement.

PUPILS INTERVIEWED

Age group in years	9 to 10	11 to 12	13 to 14	15 to 16
Girls	3	2	2	3
Boys	2	3	3	2

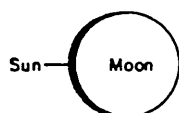
Table No. 40

The interviews were audiotaped and records of pupils' drawings were kept (see Appendix VIII). 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 (Appendix X). This comprised a series of statements with supporting diagrams. Pupils responded to the statements (which were also read to them) and their accompanying diagrams by placing a tick on the face which represented their view (Harty and Beall (1984)). (Figure 1).

Spoken statement

'It gets dark at night because the Moon covers the Sun.'

Supporting diagram



Pupils' answer sheet

I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

Figure 1. Example of question in the survey instrument.

By using this method of recording pupils' responses it was considered that variations between pupils' reading and writing skills would have a minimal effect on their final scores. It also provided a research tool which was both quick to administer and to mark.

During the second stage of the survey the instrument was administered to a representative sample of forty-eight boys and fifty-two girls in groups with an upper limit of ten pupils. Group size was restricted to a maximum of ten so that the researcher could ensure that pupils were giving responses to the statements which represented their own thinking.

PUPILS IN STAGE TWO OF SURVEY

Age range	9 to 10	11 to 12	13 to 14	15 to 16	
Male	12	10	15	15	
Female	9	17	11	11	
Totals	21	27	26	26	100

Table No. 41

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 think. The survey was then conducted in silence.

3.12 Results of the Survey

For clarity of presentation results from the interview for a particular domain are followed by the results gained by using the astronomy conceptual survey instrument for that particular domain. The prevalence of a particular notion in each of the four age groups is represented diagrammatically. 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 'I think it is True' box in response to each notion. It will be noticed that the percentage frequency from the survey instrument sometimes exceeds one hundred. This is due to some pupils believing in more than one notion.

3.13 Planet Earth and Gravity

Pupils were asked to imagine that they have taken off from Earth in a space rocket. They have been travelling away from Earth for a day and look out of the window towards Earth. They were given one minute to draw how they think the Earth will look. After completing their drawing they were given one minute to draw in some people to show where they could live, and then one more minute to draw some clouds and finally rain falling from the clouds.

Time for each response was limited to reduce the chance of pupils embellishing their drawings thus making them allegorical representations of their notions.

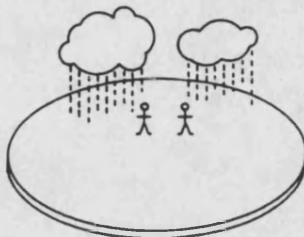
Pupils' drawings fell into four distinct notions. (see figure 2). The prevalence of each notion is shown in figure 3.

Notion

Drawing

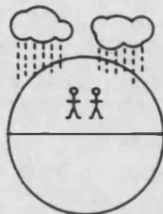
Notion 1

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.

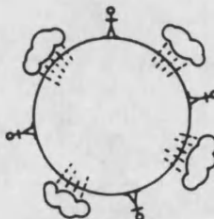


Figure 2. Pupils' notions about planet Earth and gravity.

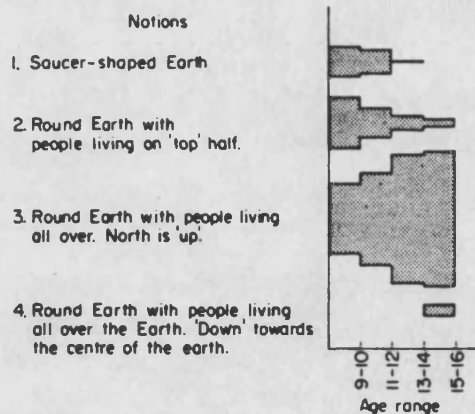


Figure 3. The prevalence of pupils' notions about planet Earth and gravity.

The four notions uncovered were similar to those first proposed by Nussbaum (1979). The most popular notion, and one which gains support with age, is that of the round Earth but with notions of vertical up and down still persisting. Support for the notions 1 and 2 decline with age. It is notable how few pupils even in the older age group use 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 (1986)).

3.14 Day and Night

Interviewees were asked to explain, with a diagram or by using the 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.



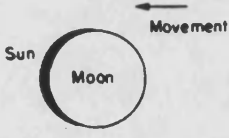

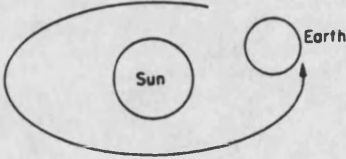
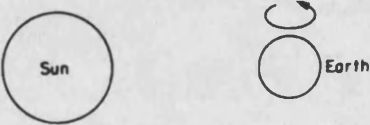
Notion	Drawing
<p><u>Notion 1</u> Sun goes behind hill.</p>	
<p><u>Notion 2</u> Clouds cover the Sun.</p>	
<p><u>Notion 3</u> Moon covers the Sun.</p>	
<p><u>Notion 4</u> Sun goes around the Earth once a day.</p>	
<p><u>Notion 5</u> Earth goes around the Sun once a day.</p>	
<p><u>Notion 6</u> Earth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

Figure 4. Pupils' notions about day and night.

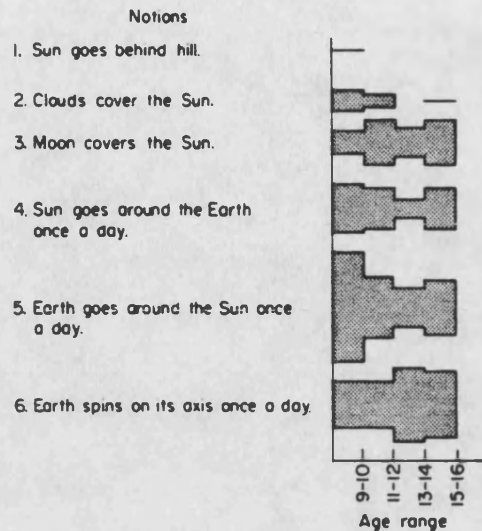


Figure 5. The prevalence of pupils' notions about day and night.

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

3.15 Phases of the Moon

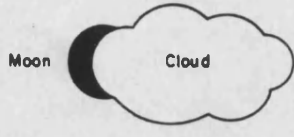
Pupils were asked in interview to draw some of the Moon shapes they have seen and asked to say if there is any regularity to its changes from shape to shape. After making their drawings they were asked to explain - using the polystyrene spheres or by drawing - how the Moon is able to change its shape.

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 obscuring part of the Moon or casting a shadow on its surface. There appears 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, which entails the Earth's shadow being cast on the Moon.

Notion	Drawing
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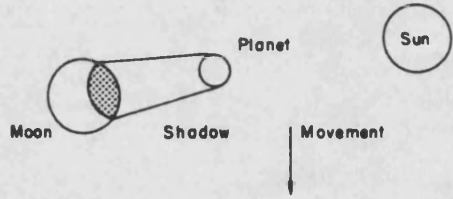
Notion 1

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



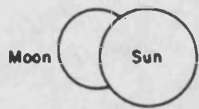
Notion 2

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.

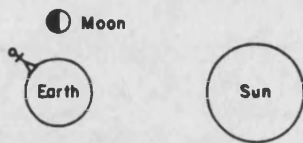


Figure 6. Pupils' notions about the phases of the Moon.

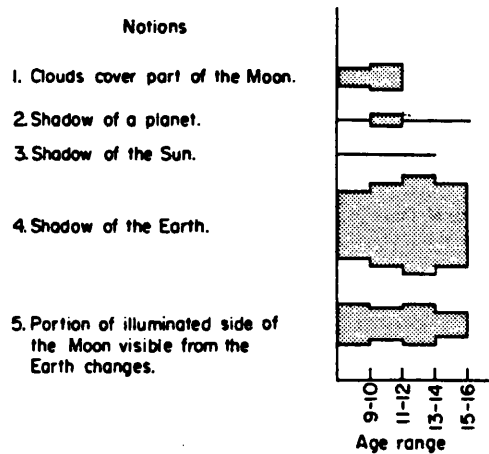


Figure 7. The prevalence of pupils' notions about the phases of the Moon.

3.16 The Seasons

Pupils were asked if they could name the four seasons. Three - age range 9-13 - were only able to name three and a further four - age range 9-14 - were unable to place them in order. They were then asked to explain what causes 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.

Notion	Drawing
<p><u>Notion 1</u> Cold planets take heat from the Sun.</p>	<p>Planet</p>
<p><u>Notion 2</u> Heavy winter clouds stop heat from the Sun.</p>	<p>Cloud</p>
<p><u>Notion 3</u> Sun further away from the Earth in the winter.</p>	
<p><u>Notion 4</u> Sun moves to the other side of the Earth to give them their summer.</p>	<p>Movement</p>
<p><u>Notion 5</u> Changes in plants cause the season</p>	<p>No diagram</p>
<p><u>Notion 6</u> Seasons explained in terms of the Earth's axis being set at an angle to the Sun's axis.</p>	<p>Angle of Earth</p>

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

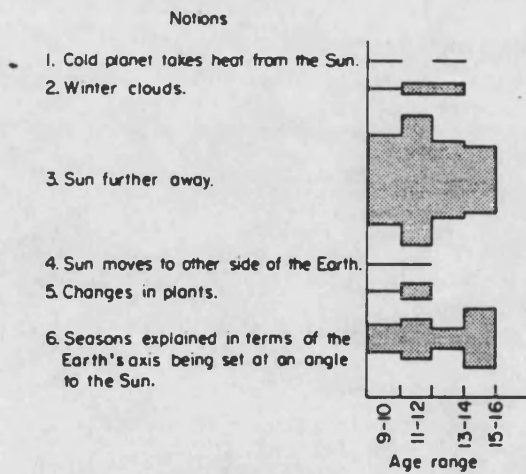


Figure 9. The prevalence of pupils' notions about the reason for the seasons.

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 involve the astral bodies moving their position. At first this motion was 'up' and '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 childrens' experience of altering their distance from a heat source).

3.17 The Effect of Age on Pupils' Score

If informal learning plays a part in the development of pupils' understanding of the easily observed astronomical events, there should be a significant increase in the older pupils' score on the astronomy conceptual instrument.

The prevalence of a particular notion diagram shows how children change their notions as they get older but do not give an overall picture of the relationship between age and score.

The total number of pupils in each of the age groups ticking the correct answer of each of the four domains investigated was noted and converted to a mean percentage score for each age group.

PERCENTAGE GAINED BY EACH AGE RANGE USING THE
ASTRONOMY CONCEPTUAL INSTRUMENT

Age range	9 to 10	11 to 12	13 to 14	15 to 16
Mean %	19.04	20.40	24.00	28.80

Table 42

n = 100
X² = 1.3

The mean percentage gained by each age group show a gradual improvement with age, but this only amounts to 9.76% over six years. The data gives a Chi square value of only 2.47 which is not significant (see Appendix VII) even at the 10% level.

In order to gain a better understanding of what happens to childrens' concepts about the four astronomical domains investigated as they become older, a sample of twenty pupils completed the astronomy conceptual instrument twice, with a four year gap between surveys; once when they fell into the 9 to 10 year old age group, and again when they came into the 13 to 14 year old group. The sample comprised equal numbers of boys and girls and covered the full range of abilities based on their teachers subjective judgment.

PERCENTAGE OF PUPILS GIVING THE
CORRECT ANSWER TO THE DAY AND
NIGHT STATEMENTS

9 to 10 age range	13 to 14 age range
45%	50%

Table 43

Although the results show a slight improvement in pupils' understanding of the cause of day and night as they become older, a closer look at the changes each individual's answer has undergone shows that the situation is more complex than table 43 suggests. Some pupils who gave the correct answer when they were between 9 to 10 years old have changed their ideas for an alternative model, others have exchanged one alternative framework for another.

These conceptual changes are shown in the conceptual change map below. The arrows show the direction that changes have taken, and the number by each arrow represents the number of children who have made that particular change.

CONCEPTUAL CHANGE MAP FOR THE CAUSE
OF DAY AND NIGHT

Age Range and Notion 9 to 10 Years	Age Range and Notion 13 to 14 Years
Earth around Sun	Earth around Sun
Sun around Earth	Sun around Earth
Clouds cover Sun	Clouds cover Sun
Moon covers Sun	Moon covers Sun
Earth spins	Earth spins
Unsure	Unsure

Table 44

Fifty percent of the pupils have not changed their notion on the cause of day and night. Only three pupils changed from an alternative notion to the accepted view. None of the pupils were unsure about their idea when they were in the 9 to 10 year age range, but two became less confident in their idea as they got older. Five children held the correct notion at 9 to 10 years of age, but had changed their ideas for an alternative notion by the time they fell into the 13 to 14 year old age range.

This trend of increasing uncertainty was observed in the conceptual development maps produced from the sample responses to questions about

the other domains investigated, and was first observed when carrying out the interviews with children (see p125). The primary school children were less hesitant in selecting their notion and did not use terms like "I think it's like this" or "maybe" as frequently. (See Appendix VIII). It is probable that as children grow older they become less confident in their original notions. This may be brought about by experiencing the need for conceptual change in other areas of knowledge, or by their increasing exposure to science education, which gives them a greater number of alternatives to select from.

No attempt was made during the course of this research to identify the cause of this uncertainty, but it is considered that this evidence supports the claim, made in later chapters of this thesis, that topics which call for a paradigm shift should not be introduced into the curriculum until the pupils are beyond twelve years of age when they will probably be more prepared for conceptual change. As will be shown in Chapter V of this thesis, this has implications for the sequencing of attainment levels of the National Curriculum.

Like childrens' ideas on the cause of day and night, their ideas on the cause of the seasons appear to change from notion to notion. These changes are invariably for another alternative framework, not the accepted view.

CONCEPTUAL CHANGE MAP FOR THE CAUSE
OF THE SEASONS

Age Range and Notion 9 to 10 Years	Age Range and Notion 13 to 14 Years
Sun further away	Sun further away
Tilt of Earth's axis	Tilt of Earth's axis
Unsure	Unsure
Clouds	Clouds

Table 45

More pupils were unsure about the cause of the seasons than were unsure about the cause of day and night. This lack of an explanation was maintained into age range 13 to 14 years by thirty percent of the pupils. Only one pupil changed from an alternative notion to the accepted view. As with day and night, there was an increase in the number of 13 to 14 age range pupils unsure about the cause.

Childrens' ideas about the phases of the Moon showed the same trend in conceptual change as the other domains investigated.

CONCEPTUAL CHANGE MAP FOR THE CAUSE
OF THE MOON'S PHASES

Age Range and Notion 9 to 10 Years	Age Range and Notion 13 to 14 Years
Earth's shadow	Earth's shadow
Clouds	Clouds
Sun's shadow	Sun's shadow
Unsure	Unsure
Correct idea	Correct idea

Table 46

Like the other surveys, the most common notion on the cause of the Moon's phases was the Earth's shadow being cast on the Moon. This idea was held by eight pupils (40%), and was maintained into the 13 to 14 age range by seven pupils (35%). Only one pupil changed notion from an alternative idea to the accepted view. Again there is an increase in the number of pupils who are unsure about the cause in the 13 to 14 age range.

Pupils' responses to the Earth in space and gravity section of the survey were almost identical to those obtained during the survey of one hundred pupils. The trend elucidated was to move from a naive view to one which more nearly represented the present view. However, only one pupil changed from an alternative notion to the accepted view.

CONCEPTUAL CHANGE MAP FOR THE EARTH
IN SPACE AND GRAVITY

Age Range and Notion 9 to 10 Years	Age Range and Notion 13 to 14 Years
Earth saucer shape	Earth saucer shape
Round Earth people on top half	Round Earth people on top half
Round Earth people all over	Round Earth people all over
Correct idea	Correct idea

Table 47

3.18 Discussion

The data from the survey show how childrens' 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 motions of astronomical bodies are most frequently used; these are later exchanged for the accepted view, but only in the case of some pupils.

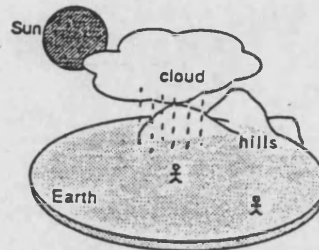
Although the surface features of the ideas that children use to explain the easily observed astronomical events vary from one context to another, a number of phases in the underlying conceptual representations which tend to underpin the responses can be identified.

(See figure 10.)

COMMON CONCEPTUAL FRAMEWORKS

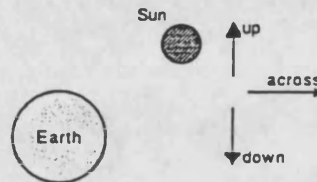
Phase 1

Earth static, frequently drawn as saucer shaped. Phenomenon explained in terms of near and familiar objects casting shadows or blocking the light



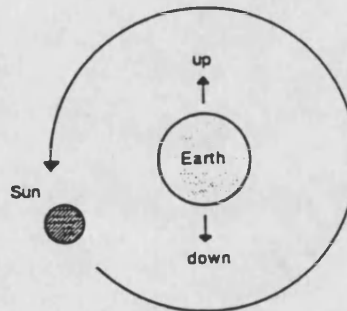
Phase 2

Earth drawn as a sphere, up towards the North. Notion that astral bodies can move but movement is explained as up, down or across



Phase 3

Astral bodies moving in orbits but frequently shown as Earth centred. Notion of gravity as Phase 2



Phase 4

Present heliocentric view and its associated gravitational ideas.

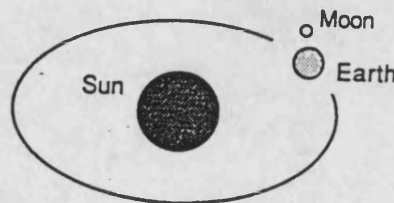


Fig.10 _

The first phase is characterised 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 characterised 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; their movement is represented as 'up', 'down', 'right' or 'left'.

In the third phase the same notions about 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 childrens' 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 childrens' concept of gravity. The saucer shaped Earth drawn by some 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. (See Chapter I p7).

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 daily orbit around the Sun; a view which is a mix of the old geocentric view and the heliocentrism of Copernicus.

3.19 Implications of the Results of the Pupils' Knowledge Survey for Teaching Astronomy

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. Conceptual change appears to take place as pupils become older, but this invariably involves exchanging one alternative notion for another.

The findings of the survey are particularly relevant 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 education 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 for introducing 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. Later on, these ideas are replaced by notions which embrace the idea of orbital motion. Thus it appears that while younger children may be encouraged to observe many of the astronomical events as possible, it is recognised 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 recognise that pupils may construct intermediate notions before moving to a heliocentric view, and that intermediate notions deserve some level of credit in any assessment scheme which may be linked to the National Curriculum for science. The conceptual change maps (tables 44 to 47) show that pupils' conceptual development often regresses, or that they become unsure about their notion at 13 to 14 years of age. These findings throw doubt on the long-term validity of any A.T. 16 assessment scores pupils may achieve during their primary or early secondary schooling. Any observed notion - alternative or agreeing with the accepted view - may be a transient notion, and bear little resemblance to the notion the pupils will subscribe to twelve months later. I will return to this topic again in Chapter V.

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 the 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.

The fact that many pupils' notions have historical parallels forms a useful teaching point. Presentation of ideas held in the past can be used to demonstrate the tentative nature of science. Making reference to historical ideas may possibly make pupils feel more comfortable when they realise that their notions, although incorrect in the light of scientific advancement, were once the popular view. They can also give pupils insights into the kinds of evidence that has encouraged scientists over the years to change their theories; thus offering a rich resource for the realisation of aspects of Attainment Target 17 of the National Curriculum. I will return to this topic again in Chapter V.

The results of the survey have shown that pupils come into their lessons holding a wide range of alternative frameworks about the easily observed astronomical events, and that the underlying conceptual structure frequently parallels those ideas held in the past. These findings - along with a constructivist view of learning - were the fundamental influences shaping the production of the teaching material produced as a part of this thesis.

These findings support the claim that childrens' naive concepts frequently pass on into adulthood; a fact which has been demonstrated by the results of a survey (Durant et al. (1989)), showing that a large proportion of the general public in the U.K. are confused about many scientific notions, including the motions of the Earth and Sun.

Despite more than four hundred years having elapsed since the publication of 'De Revolutionibus' (Chapt.1.03), and over three hundred since Newton's 'Principia' (Chapt. 1.07), these seminal concepts on planet Earth in space do not appear to be common features of pupils' (or adults') conceptual frameworks.

NOTES ON CHAPTER III

- [i] The author has begun research into this aspect of astronomy and while the research is in a very early stage, it appears that adults frequently subscribe to ideas which have their roots in their cultural heritage.

CHAPTER IV

Development and Evaluation of the Teaching Materials

4.00 Introduction

The survey of pupils' ideas about basic astronomy reported in Chapter III demonstrates that there is a need to cover these topics in the science curriculum. However, the results of the H.O.Ds' and Teachers' surveys reported in Chapter II of this thesis, testified to a shortage of practically based teaching materials for school astronomy. The situation appears to have undergone little change since the observations of Westways (1921) and the publication of the Science Masters' Association Report of 1950 (see Chapt. 1.11); both of which drew attention to the unsuitability of astronomy as a school science because of a shortage of appropriate practical work.

4.01 A Brief History of Practical Work in School Science

The development of the teaching material produced for this thesis is set against the historical background of the expansion of practical work in science to identify reasons why astronomy failed to establish itself within the mainstream of this change in methodology.

The experimental method as a means of studying science became increasingly popular towards the end of the nineteenth century, and has now been encapsulated in most educationalists' view of science teaching. This approach developed from the activities of the scientific societies (Kerr (1963),) and the subsequent development of the heuristic movement during the second half of the nineteenth century (Uzzell (1986)).

Although the notion of science education and experiments had become synonymous by the latter part of the nineteenth century, it appears that this approach was not widely adopted in schools (principally because of the high cost of necessary equipment). The Devonshire Commission (1871-75) reported that little progress had been made towards the use of methods of observation and direct experimentation. This opinion was confirmed by examiners of the Science and Art Departments who made repeated complaints about the neglect of practical work (Kerr 1963). However, by the early part of the twentieth century The Devonshire Commission's report, complaints from the Science and Arts Department examiners and growth of the heuristic movement, had a combined effect with a subsequent increase of practical work in school science. This (especially the continued growth of the heuristic movement, Curtis 1915) sounded the death knell of the old object lesson, and led to the notion that science education is an activity which goes on in a laboratory or work shop rather than a classroom.

The subsequent increase in practical work did not entirely satisfy all early expectations. The Thompson Committee's Report of 1918 was critical of laboratory exercises, claiming that they are considered to be too much of an end in themselves and that:

".... such an exercise loses the educational value of a real experiment when it becomes a piece of drill."

Kerr (1961) considers that the widespread introduction of general science in the 1930's [i] led to the discarding of a great deal of arid, repetitive practical work, but claims that full advantage has not been taken of the opportunity for introducing:

".... scientific investigation which has its roots in the common experiences of the children."

Since Kerr wrote on practical work in science, there has been an increase in the amount of practical work which, in most cases, Driver (1986) claims, is introduced to be illustrative or provide confirmatory evidence for the presented theories. This strategy assumes that children will change their ideas after being presented with the accepted view; a fact which Gilbert et al. (1982) and Solomon (1983) suggest does not necessarily happen.

The constructivist's approach (Chapt. 3 p114) offers an attractive alternative, whereby many of the traditional illustrative or confirmatory practicals are replaced by activities which encourage the pupils to put forward their viewpoint (Osborne, Bell and Gilbert (1983)), and enable them to test alternative theories (Driver (1983)). However, no astronomy teaching material has been published which reflects this view of childrens' learning, and although there is a growing body of literature cataloguing collections of pupils' notions about astronomy, the literature is short of ideas and examples which use pupils' alternative frameworks, in a practical setting, as a springboard for introducing the accepted view. In the same way that astronomy failed to accommodate the heuristic movement, it is failing to respond to the constructivist view of childrens learning, even though there is ample evidence to show that children do construct their own theories for many of the astronomical events.

4.02 Astronomy as a Practically Based School Science

In Chapter I it has been demonstrated that in the past the study of astronomy followed two different routes.

- (i) As a tool for predicting dates and for navigation. When used for this purpose the ideas of Copernicus or Newton are not necessary as the calculations will yield useable results even if the operator is geocentric in his world view.
- (ii) As a descriptive subject which was, by and large, studied by the gentry and used to demonstrate their status in society. The only requirement was a good book and perhaps a telescope through which the observations of Galileo (and the guided observations of Charles II) could be repeated.

At the same time as these two common uses of astronomy were being pursued, an elite of theoretical astronomers were becoming established. Copernicus, Newton and, during the second half of this century, the almost totally theoretical astronomy of Hawking [ii], are the giants in this field. This has influenced the common perception about the potential of school astronomy which, in comparison to biology with its dearth of detailed experimental results, is considered to be short on practical exercises and heavily laden with theoretical activity. (Lyttleton (1986)).

Apparatus which allow astronomical observations to be made which support theories is beyond the scope of schools' capititation, and probably outside members of the science department experience. Therefore, when the experimental method of study became established the

tendency was to neglect astronomy, and opinions of its worth as a school subject fell into decline.

There have been very few attempts to tease out suitable school-time practicals from the growing body of theoretical knowledge. There are notable exceptions; Clish (1976) who gives a range of practicals which can be carried out during the day, the LAMP scheme (mentioned in Chapt. 1.13) and Seymour (1984) whose book is probably better suited for use with a school astronomy club.

Publishers are wary about attempting to market school astronomy teaching material (see letter in Appendix X) due to a concern about the return potential on their original investment. Therefore, teachers and astronomers have almost no way of obtaining a wider publicity for any school based material they have written. Those astronomy books which do get published are of the 'look and wonder' type, and apart from demonstrating advances which have taken place in astronomy and the graphics and printing trade over the past two hundred years, are little different in style from Fontaneles 'Plurality of Worlds' (see Chapt. 1 p29). While these books form a valuable resource in which all school libraries should invest, they have little use in a pupil centred astronomy lesson.

4.03 The Unique Characteristics Which Astronomy Offers Science Education

The primary reason for developing the teaching material included in this thesis was to demonstrate that astronomy can be taught in a style which brings it into the mainstream of science teaching. However, this demonstration was not enough in itself to justify its inclusion in

the curriculum. A common response of the H.O.Ds returning questionnaires was that there are many subjects equally able to justify a place in the curriculum, but there is just not enough time on the timetable to include them all.

Even though astronomy has now secured a place in the National Curriculum, it has been common for teachers attending Attainment Target 16 Inset sessions to question its worth. Therefore, it is still necessary to demonstrate to teachers that astronomy has distinctive characteristics essential to the notion of balanced science, and which cannot be realised by any other branch of science. The six characteristics given below are intended to illustrate the unique aspects of science astronomy education can offer.

(i) The Measure of Things

Through a knowledge of the vastness of space and the smallness of the world they see under the microscope, pupils will gain some insight into these prodigiously large and small worlds which surround them. Pascall (1623-62) makes a convincing case for introducing pupils to these extremes:

"....show him (man) another prodigy equally astonishing, let him examine the most delicate things he knows Let him lose himself in wonders as amazing in their littleness as others in their vastness For in fact what is man in nature? A nothing in comparison with the infinite, an All in comparison with

Nothings, a mean between nothing and everything.

(ii) Dispelling the Most Enduring Aspect of Magic

Of all the magical rites and beliefs left over from medieval times, a belief in astrology has been the most enduring (see Chapt. 4 p158). An astronomy course makes a suitable context against which pupils can test their ideas about astrology. By recognising the rigour demanded by astronomers before they accept their observations and conclusions as significant, pupils are more likely to challenge their original belief in astrology.

(iii) Leisure Time Potential

Of all the branches of science pupils will meet during their school days, astronomy offers the greatest potential as a leisure time pursuit; one which can be continued throughout their lives and one in which they can make major contributions to research (see Iwaniszewska (1988)).

(iv) The Unification of Nature

Pupils will study the elements but unless they learn something about stellar evolution they will have no notion of their origin. As Eddington (1920) wrote:

"The stars are the crucibles in which the lighter atoms which abound in the nebulae are compounded into more complex elements."

Through astronomy, pupils can develop an awareness about the origin of the elements, and come to realise that all they

observe, including themselves, is composed of elements which were compounded in stars; they are in fact, 'star dust'.

(v) The Tentative Nature of Science

Astronomy offers particularly illuminating examples of the tentative nature of science as many of the early theories on the solar system and universe formed tenets central to cultural beliefs. Each of these ideas was considered 'true' at the time, becoming updated when new evidence challenged the consensus view. Thus, astronomy affords a fine illustration of the scientific process (but over a much greater time scale than other examples) and can begin to lead pupils into discussions about what is meant by the word truth in science.

(vi) Understanding our Living Planet

The growing concern about humankind's affect on the fragile balance of nature can only be fully appreciated from a 'spaceship Earth' perspective. An understanding of the unique position of our planet in the solar system, and conditions on other planets, leads to a whole Earth view of our environmental problems. (See Mitton 1990).

4.04 Teaching Materials Criteria

Prior to writing the teaching units the following criteria were identified as being essential aims if the material is to make a contribution to pupils' knowledge of basic astronomy and are not to be sectarian in their appeal. These criteria were derived from the author's personal experience of teaching astronomy, from opinions

collected at the A.S.E. 1986 York A.G.M., and the A.A.E. Curriculum Committee.

- (i) Activities should be pupil centred and give time and credit for testing alternative frameworks, be they historical, personal or those arrived at through group discussion.
- (ii) Suitable for use during the course of a normal school day.
- (iii) They should not require equipment other than that normally found in a school science department.
- (iv) They should be suitable for use by teachers of any of the sciences with a minimum of background knowledge.

4.05 Selection of Topics and Rationale of Teaching Units

The meeting with the A.A.E. curriculum committee and interviews at York (see Chapt. II) identified areas from astronomy which both astronomers and teachers consider should feature in the science curriculum of all pupils. This list comprised the easily observed astronomical events (see Appendix XI).

The survey of pupils' understanding of the easily observed astronomical events demonstrated that these topics are poorly understood if they do not feature in the curriculum (see Chapter III). Therefore, it was decided that they should act as the central focus of the teaching units.

Black holes and supernovae, commonly used by authors to attract young readers, were not included in this list as it was felt that these awe-inspiring events are frequently included before the readers have developed the accepted concept of planet Earth in space.

In addition to these topics it was decided to include an activity on astrology. Surveys carried out at Court Fields School on an ad hoc basis (at the end of lessons) had demonstrated that eighty four percent of pupils read their stars regularly, and of this eighty four percent, thirty six percent believe there is some truth in the predictions. These results are similar to those obtained by Kruglak (1978) who demonstrated that thirty eight percent of Americans in the 18 to 24 year age group believe in astrology. He claims that:

".... mere exposure to science courses will not automatically result in attitude changes."

Therefore, it was considered worthwhile to include an activity within the main body of the astronomy units which challenged the claims of popular astrology. With so many pupils having faith in the predictions of astrologers, a valuable opportunity for pupils to design an experiment to test their ideas presented itself.

In Chapter III it was demonstrated that children frequently construct their own alternative frameworks for many of the easily observed astronomical events. This observation influenced the rationale underpinning the teaching strategy of the astronomy units. The activities were designed to give pupils the opportunity to first clarify their own explanation for the particular event. Once established the alternative framework acts as a springboard, enabling them to challenge their notion in the light of new information or experiences.

4.06 Product Evaluation

For clarity the complete astronomy package is given in Appendix XII and reference will be made to specific topics only in this chapter. The S.S.C.R. evaluation of product procedure (1984) was used to evaluate the astronomy teaching pack. (See Appendix XXII). Criterion for evaluation were identified, and evaluation at levels 'A' (intrinsic evaluation within working party), 'B' (intrinsic evaluation at regional level) and 'E' (evaluation at national level) was undertaken. See Appendix XIII for evaluation criterion and responses. Evaluation at level 'A' could not take place within the working group as it comprised one member only. In order to overcome this difficulty, three members from the science department of Court Fields School who were to use the materials as one module of the third year modular science course, were included in this evaluation phase. This evaluation took place in the form of 'intrinsic' or 'armchair' evaluation and classroom trials.

The criterion for evaluation at level 'A' were extended to include test retest results, and two levels of pupils' evaluation, (i) Enjoyment, (ii) Pupils' view of the units importance to future employment.

4.07 Level 'A' Evaluation

First drafts of the teaching materials were given to each teacher for the intrinsic evaluation. Recommendations for changes were then received at a group meeting. No content alterations were made but the original draft was considered to be too 'wordy'. This was reduced in the light of the teachers' comments.

Discussion took place on the teaching sequence to be followed, and it was decided to use results from the pupils' knowledge test (presented to each group at the start of the module) to determine the starting point for each pupil or group of pupils. Therefore, the material was seen as a resource, not a course in itself.

4.08 Classroom Trials

The astronomy module was timetabled for two periods of thirty five minutes each once a week for eight weeks.

A progress meeting was arranged to take place during week four, but informal discussion was always possible at coffee and lunch breaks. These informal discussions did not result in any alterations to the product, but appeared to play an important role in giving each teacher support as none had received any training in astronomy, or had ever taught the subject. The main topic of conversation during these informal meetings concerned teachers surprise that they exhibited the same alternative frameworks as their pupils (a recurring feature of teachers attending the Inset courses (see Chapt. V.)

The reason for the Moon's phases caused the greatest difficulty and all teachers needed instruction before they could introduce this topic. It was interesting to note that teachers, as well as pupils, changed from a geocentric to a heliocentric view depending on which astronomical phenomenon they were trying to explain. (These shortfalls in the teachers' knowledge were later used as a focus for the design of Inset material (see Chapt. V)).

During the week four meeting the only recommended change was to reduce the printed material on the gravity section to a small booklet which could be given to pupils as a homework exercise. This was later eliminated from the published version of the teaching material because of printing costs and the editor's view on its limited use. A smaller version of this booklet has been included in the astronomy/English cross curricular pack (see Appendix XXII).

4.09 Problems with Astrology

During week six an emergency meeting had to be convened to discuss three phone calls received by the headmaster from parents regarding the content of the astronomy course. The three sets of complaining parents belong to a Born Again Christian group, and their concern had been raised by the 'Astrology Connection' and 'Sun Worship and Death' parts of the course.

The parents were invited to come to the school and discuss their concerns with the teachers and for us to explain why it had been decided to include this topic in the course.

One parent came to the school representing the other complainants. The meeting was amicable, but we were unable to convince the parent that we were using the scientific process to test an idea, and that in all probability, the results of astrological predictions from the popular newspapers would show them to be unreliable. This, we claimed, was arriving at a conclusion that born again Christians would approve. The parent considered that the outcome of the analysis is unimportant, it is reading the predictions in the first place that

causes the damage. Sun Worship and Death, he claimed, is encouraging pagan worship.

All three children were withdrawn from the following lesson and continued with the module after the offending topics had been completed by the rest of the groups.

During the meeting which followed discussions with the representing parent, all teachers agreed that the topics in question should appear during next year's modular science course as they had been well received by the pupils (most of whom read their stars more than twice a week), but that we should give a 'product warning' before asking children to make a collection of astrological predictions. No complaints have been received since adopting this approach.

4.10 Seasons Model Modification

The seasons model used in the first pupil trial posed more problems in use than any of the other models. Using stiff pre-cut card and pieces of wire already shaped resolved the difficulties many children experienced cutting the stiff card and bending the wire. But the original design appeared to be confirming the most common alternative framework on the cause of the seasons, namely that the Sun is further away during the winter.

The original model gave the Earth a circular orbit around the Sun. This resulted in the angle of the Earth's axis bringing the Northern hemisphere closer to the Sun during the summer (see figure 11a), thus confirming many pupils' original idea. It was common for pupils to

measure the distance on the model as further evidence in support of their view [iii]. Pupils did not realise the importance of the changes in the angle of incidence of light from the Sun over a period of one year.

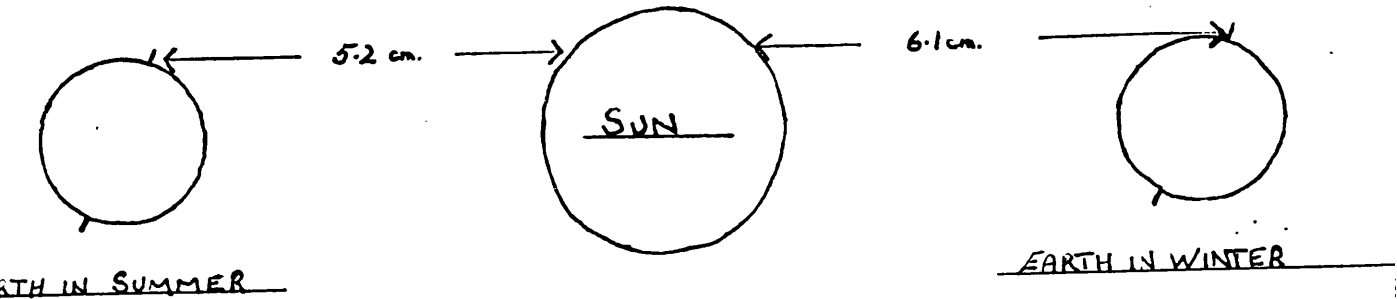


Figure 11a

In order to overcome this problem the model was redesigned so that the Earth's orbit is elliptical in shape, and that during the Northern hemisphere's winter the Earth becomes closer to the Sun [iv].

It was decided that teachers wishing to use a diagram to consolidate the accepted view after the pupil activity, should construct the diagram as shown in figure 11 below.

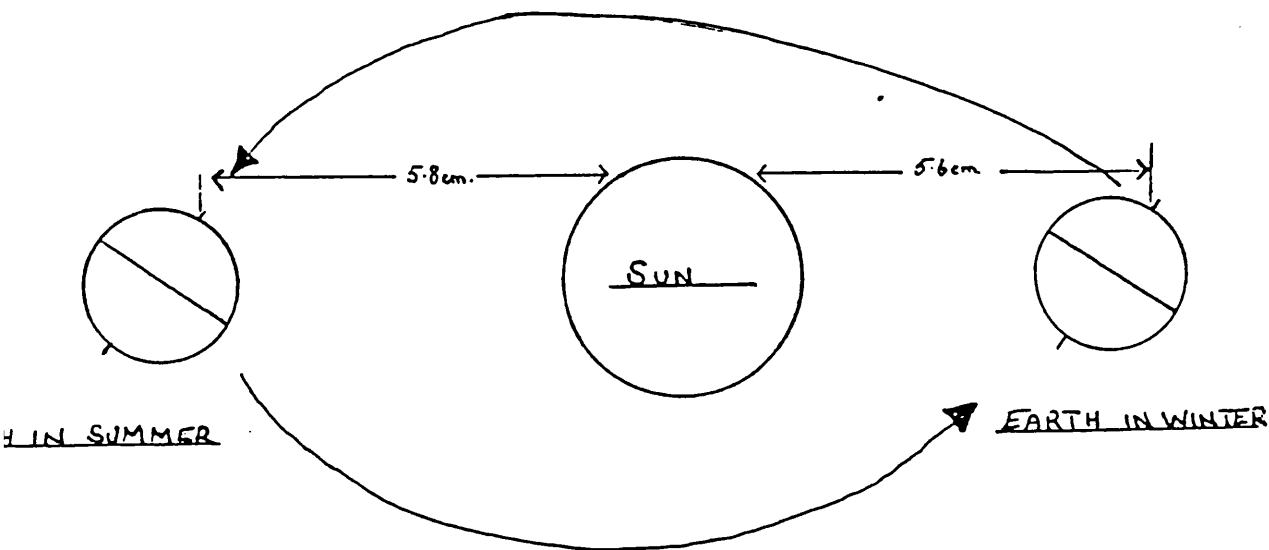


Fig.11b

After these modifications were made, no further problems were experienced with this model. However, all the teachers felt that the use of a large model after the activity was beneficial, and that an activity which demonstrates that the light from a source is spread over a greater surface area as the angle of incidence is decreased, should be experienced by the pupils before carrying out the seasons activity. (See Appendix XIV for example activity).

4.11 Pupils' Progress Evaluation

Test retest evaluation using the astronomy conceptual survey instrument (Appendix IX) was carried out on twenty-eight third year pupils before and after completing the twelve week course. Another parallel group of twenty-seven third years who did not follow the course were used as the control. (This group completed the module the following term.) Both groups were considered to be of equal ability based on the results of their end of second year science examinations. The results are shown in table 48 below.

TEST/RETEST RESULTS

	Pre test mean	Post test mean	P
Experiment group n=28	11.74	22.28	>2.771
Control group n=28	10.62	11.92	<1.07
	Maximum mean	34.0	

Table 48

The data for the experimental group gives a 'Student t' (see Appendix XV) greater than 2.771. Their improvement in score on the astronomical conceptual instrument is highly significant at the 0.1% level, and suggests that completing the units results in a significant improvement in pupils' knowledge of astronomy.

The control group's data gave a Student t value less than 1.70 and shows that completing the astronomical conceptual instrument without completing the units does not result in a significant improvement in score at the 5% level. It is, therefore, concluded that the experimental groups improvement in astronomical knowledge was due to experiencing the teaching units and not influenced by completing the conceptual survey instrument.

4.12 Pupils' Evaluation

Pupil evaluation was carried out at the personal subjective level. After completion of all the third year science modules (Physics, Chemistry, Biology, Astronomy and Technology), pupils completed a questionnaire (see Appendix XVI) which asked them to rank (in decreasing order) each of the science modules they had studied; first based on enjoyment, and secondly, on their view of its importance to their future employment. Subjects were scored on a five point scale, 5 for the most enjoyed/important and 1 for the least enjoyed/important. The responses of the one hundred and thirty one third year pupils completing this survey are shown in tables 49 and 50 below.

Pupil Enjoyment

Subject	Score	Rank Order of Enjoyment
Physics	329	4
Chemistry	480	3
Biology	534	1
Astronomy	532	2
Technology	281	5

Table 49

Importance to Employment

Subject	Score	Rank Order of Importance
Physics	540	1
Chemistry	538	2
Biology	484	3
Astronomy	189	5
Technology	344	4

Table 50

The results show that for pupils enjoyment, astronomy compares well along with biology. However, when it comes to pupils' opinion of the importance of each subject to their employment prospects, a very traditional pattern emerges with astronomy coming at the bottom of the list. It is clear from this survey that a considerable amount of work has to be done before pupils see astronomy as a part of a balanced science course.

4.13 Level 'B' and 'E' Evaluation

A first draft copy was sent to Miss C. Ditchfield (S.S.C.R. South West Co-ordinator) for level 'B' evaluation. She passed on the copy to a Head of science from Avon county for completion of the evaluation at this level (see Appendix XIII).

After making alterations to the draft based on the comments from level 'B' evaluation, the modified draft was submitted for level 'E' evaluation (see Appendix XIII for results of evaluation at this level).

R.L.D.U. Avon county, used level 'E' evaluation to measure the worth of the package and decided to go ahead with publication. With the aid of editor J. Sage and a graphic arts department, we were able to address the recommendations made at level 'E' evaluation and produce a final copy which satisfied the original criterion and was a marketable product (see Appendix XII for copy of final draft).

4.14 Discussion on Teaching Strategy Adopted

The module on astronomy was started by presenting the class with the astronomy conceptual survey instrument to identify individual pupils' strengths and weaknesses. It was originally intended to use the instrument to decide the starting point for each pupil, or groups of pupils, and they would then progress through the material at their own pace. This strategy was not adopted during the trials, partly due to the fact that almost all pupils presented the same weaknesses, and also that the teachers were not comfortable with a resource based learning situation.

The survey generated considerable interest and pupils appeared to enjoy completing the questions. It also set the tone for the other lessons, drawing pupils' attention to their own notions on astronomical phenomena and laying the foundations for them to challenge their views.

The notion underpinning the teaching strategy of the units is that pupils construct their own theories on the easily observed astronomical events and that if they do not hold good when challenged, pupils will discard them for the correct idea. The classroom trials demonstrated that this view of childrens' learning was itself naive, and that conceptual change is not a linear progression from alternative framework to the accepted view, but frequently involves intermediate stages. A fact confirmed by the conceptual change maps, tables 44-46, pp138-142. Some children resisted change, and attempted to interpret their results in a way which gave support to their original notion.

This aspect of the research is in its early stages, the conclusions drawn are provisional and require further research to be substantiated.

4.15 Pupils Challenging their Ideas on the Cause of the Seasons

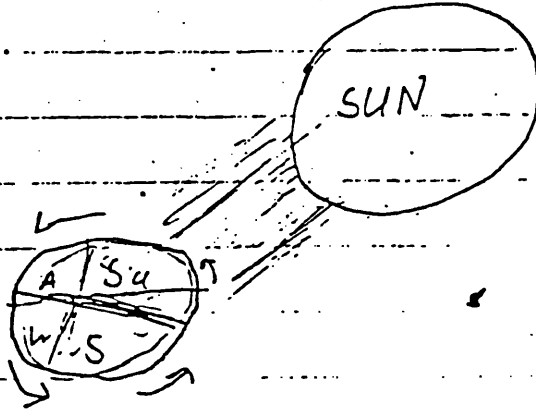
The results given below were obtained during a normal lesson. The discussions are brief and more closely represent the discussions which would take place between a teacher and pupils during the course of a normal day.

Pupils were first asked to draw and write about what they think causes the seasonal changes. They did this in silence and then discussed their idea with the members of their group. Each pupil then constructed the seasons model and used it to challenge their idea. If their idea did not hold good they then were asked to write on how they had to change their thinking.

As expected, most pupils thought that the Earth moves away from the Sun during the winter (although most of the other alternative frameworks identified during the pupil survey (Chapt. III) appeared). For most pupils the idea that the Earth is farther away from the Sun during the summer was such a contradiction of their every day sensory experience that it tended to dominate their thinking. It was common for pupils to give this as the cause of the seasons. The examples overleaf make this point:

Richard's Explanation for the Seasons

When ~~only~~ part of the Earth is facing the sun it is summer. The part of the Earth furthest away is the winter. The parts that are left are spring and Autumn. The parts are really quarters. Basically the Earth's movement AS the Earth moves ~~summer~~ becomes ^{Autumn} winter, Autumn, winter and so on.



A = Autumn

W = Winter

S = Spring

Su = Summer

Angle of the Earth to the sun. The nearer the sun the Earth is, it is winter and vice versa

- T. Richard, what did you say was the cause of the seasons, can you explain your drawing?
- R. Well, its this part of Earth facing the Sun. When this is it's Summer.
- T. O.K., what about winter then?
- R. Well, it's the same only this part (points to other side of Earth) that turns and they get summer.
- T. Why is it colder here? (points to part of Earth not facing Sun).

- R. That's cause it's further away from the Sun there.
- T. Did you have to change your idea after using the model?
- R. Yes. The nearer the Sun is to Earth its winter.
- T. But you have written something here about the angle of the Earth, does this make any difference?
- R. Yes, it turns us away in the winter when we are closer.

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

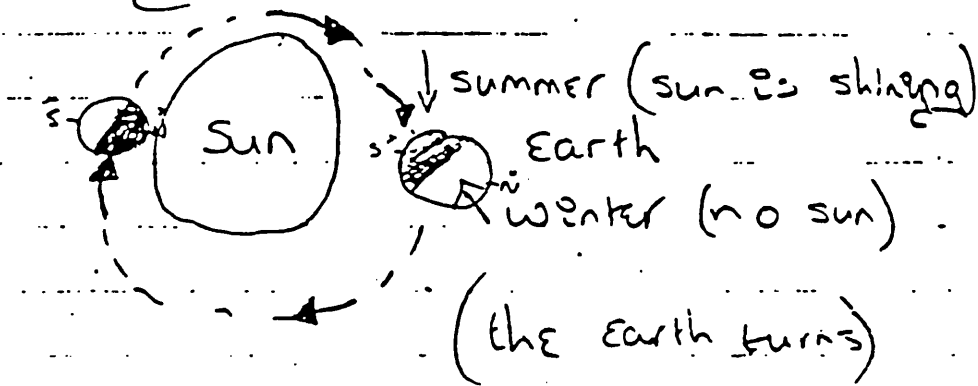
The other point which emerges from Richard's own explanation for the seasons is that he has chosen to forget about the cause of day and night (he had worked on this topic during the last lesson and was quite clear on this). His diagram shows the Earth taking one year to spin on its axis. This is a common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

Linda's Explanation for the Seasons

A similar trend is seen in Linda's explanation. There was no discussion with Linda.

What causes the seasons?
(Why is it cold in the winter and warm in the summer?)

We get seasons because the earth orbits around the sun. When the earth is orbiting the sun it turns. The seasons are caused because the earth at times is not facing the sun. (winter). Other times it is facing the sun, (summer).



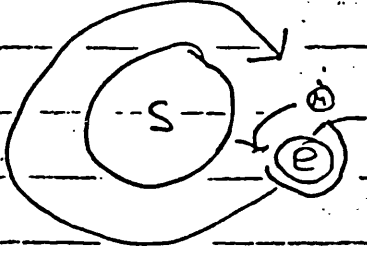
The seasons are caused by the angle of the sun. Summer is when the Earth is furthest from the sun. Winter is when the earth is closest to the sun but we are facing the opposite way to the sun.

Her explanation is very similar to Garry's and it is difficult to see how she can explain both the seasons and day and night.

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

Anthony's Explanation for the Seasons

The seasons change because we move around the sun, when that changes the weather from hot or to cold when we move round the sun. Or it probably gets colder if the moon gets in front of us as well.



My thinking was almost right, when I said the earth orbits the sun and the seasons change accordingly, but I think I was wrong about the moon getting in between the earth and sun.

Anthony is very protective about his original idea, claiming that it was 'almost right'. The part played by the moon in his first idea is clearly wrong, but he chooses the more amiable phrase 'I think I was wrong'. He has either not noticed (which is unlikely as the teacher circulated around the groups drawing pupils' attention to the angle) or refuses to acknowledge the importance of the angle of the Earth's axis to the plane of the ecliptic. His attempts to protect his original idea are noticeable in the short interview carried out just after he had written about how his idea had changed.

- T. Anthony, did you have to change your idea about the cause of the seasons?
- A. Well a bit, but not much, I got it almost right.
- T. What bit of your thinking did you have to change?
- A. Well it was just that bit about the Moon, but I didn't say it was the reason, just it may be.
- T. Use your model to show me how we get different seasons.
He picks up the model and orbits the Earth around the Sun.
- A. Well, its like I said, the Earth orbits the Sun and we get the seasons.
- T. Where will the Earth be when it's winter north of the equator?
He places the Earth in the correct position with the angle of inclination directed away from the Sun.
- A. It's winter now.
- T. What's special about this position, what makes it winter?
- A. Earth has gone around to here, and here is where is winter.
- T. O.K., but what makes it winter here (takes model and moves Earth to summer position) and not here?
- A. It can't be winter there 'cause we're facing the Sun.
- T. What makes us face the Sun?
- A. Well it's this angle here (points to the wire axis).
- T. Can you now tell how we get the seasons again, but this time mention the angle.
- A. We go around the Sun like I said and we get winter here cause we're angled away from the Sun. And when we get to here its summer and we're facing the Sun. This is where summer is and this is where winter is (he orbits the Earth around the Sun while saying this).

As stated in Chapter III p115), we can use these findings to decide the philosophical bias of the research. In order to achieve this it is helpful to refer to Nussbaum's (1989) diagram giving a comparison of sets of basic statements characteristic of various philosophical views (see Appendix XVII).

Those pupils who attempted to protect their original idea appear to be faced with a crisis (like scientists during the demise of Ptolemaic cosmology and, like scientists (Donnelly (1986)), appear to be actively hostile to changes in theoretical structure.

This is coming into line with the view of Kuhn (1979), but when pupils begin to change their view there is communication between the two paradigms. This, and the observation that there is no evidence to suggest that pupils have applied deductive logic, inclines from the views of both Kuhn and Popper and towards Lakatos and Toulmin (see Nussbaum (1989)).

The evidence is too sparse to differentiate between the views of Lakatos or Toulmin, but the fact that those pupils who did change their view, did so by completing the rational act of orbiting the Earth around the Sun, favours the view of Toulmin. This is in agreement with Novak (1977) who favours Toulmin's model, and Nussbaum (1989) who claims that his earlier studies seem to support Toulminian descriptions in classroom contexts.

The Toulminian model, like Lakatos, views conceptual change as evolutionary, but differs from Lakatos in that it sees progress as

similar to biological adaptation, not - as in the Lakatos model - driven by a more fruitful 'problem shift' proposed by a rival research programme (which in the classroom situation may take the form of a peer, or group of peers, working on the same problem).

The findings of the pupil survey (Chapt. III) support the Toulminian view. Pupils' ideas do not all move in the same direction (see especially the concept maps); they (like biological evolution) may take a number of forms. The one best adapted to survive in the light of the new evidence becomes the dominant view; but this process may take time and involve one, or more, intermediate stages.

4.16 Astronomy in a Supportive Role

In Chapter I (p43) it was suggested that astronomy has an important supportive role to play. The seasons model was used by some teachers to relate the position of the Earth on its annual orbit around the Sun to the growth plants and the behaviour of animals. Some pupils made 'signs of nature' calendars while others drew the way plants look at different points along the Earth's orbit around the Sun (see Appendix XVIII). This activity was considered by the teachers to be well received by the pupils and appeared to develop an integrated view of astronomy and biology.

The activity most directly aimed at using astronomy in a supportive role was the 'Moon and Seeds' (see Appendix XII). All three teachers presented this activity to their pupils after they had experimented with the cause of the Moon's phases model. Pupils were presented with the problem as a homework, and asked to design an experiment to

discover if there is any truth in the old country tale that seeds germinate better if planted at full moon.

This activity was highly successful, developing pupils' long-term organisational and group work skills. The moon phase predictors (see teaching material Appendix XII), which pupils had constructed during an earlier lesson, were used to calculate the dates seeds should be planted. They also needed to think back to their second year work on the conditions seeds need if they are to germinate. All groups worked hard on displaying their results, examples of which are given in Appendix XVIII.

This approach has considerable potential as all teachers felt comfortable dealing with an unfamiliar topic within a familiar setting. It also confirmed the findings of the teachers' survey reported in Chapter II concerning teachers' interest in material which supports concepts in other sciences. There are many other opportunities for a similar approach using topics in the other sciences, but it does demand a meeting of minds between astronomers and teachers of the three sciences. This topic will be raised again in Chapter V.

4.17 Discussion

The classroom trials suggest that the easily observed astronomical events can be taught in a style which is compatible to the other sciences, and that pupils' ideas can be used as a starting point. However, the evidence suggests that concept change is not the simple linear process imagined at the beginning of this research. Pupils frequently attempt to accommodate new information with their notion and

will resist paradigm shifts. The findings of this research suggest that concept change is not a unidirectional process from alternative framework to the accepted view. The evidence suggests that conceptual change is a multidirectional phase-like process similar to the evolutionary view given by both Lakatos and Toulmin, and that there seems to be a fear in pupils' minds about having a 'wrong' idea. Maybe, as teachers, we should pay more attention to the wrong ideas scientists have often pursued, and not just concentrate on those experiments which gave them the correct answer. Thereby demonstrating to pupils that updating ones ideas is an important part of the scientific process.

It is at this point that cross-curricular work with English departments can be of value as it provides both the time and a vehicle through which pupils can express their ideas and concerns. The most obvious focus from astronomy is the change from a geocentric to heliocentric planetary system. Piaget (1962) draws a parallel between the shift in egocentric perspective which scientists underwent during the Copernican Revolution with that process experienced by children today when he stated:

.... for science to shift from a geocentric to heliocentric perspective required a gigantic feat of decentration (overcoming egocentric perspective). But the same kind of process can be seen in the small child."

The results of this research show that when pupils do change their ideas they may well pass through one or more stages before believing in the accepted view. Perhaps we should (as Nussbaum (1989) suggests)

plan the instructional sequence so that pupils can gradually move towards a theory without requiring them to reach clear-cut conclusions. Such an approach more closely represents how science has progressed in the past. For example, Herakleides of Portus (4BC) proposed an intermediate model of our solar system whereby Mercury and Venus were in orbit around the Sun, the three of which were in orbit around the Earth. The Copernican system was an intermediate model as it failed to identify the elliptical nature of planetary orbits, and Einstein's universe was static. Progress in science is a stage like process, rather than the quantum leaps we expect our children to make.

Clearly, giving children credit for reaching a halfway point will pose problems for any tests which may be included within the National Curriculum package, but a system whereby teachers can give credit for the process pupils have followed when testing their ideas may alleviate pupils' fear of being wrong, provide the numbers the National Curriculum appears to be demanding, and more closely represent how science works.

NOTES ON CHAPTER IV

- [i] The general science movement grew out of the publication of 'Science for All' (1916) which advocated a broad generalized science, and a British Association survey (1917) which showed that there was an imbalance between the sciences taught to boys and that taught to girls. The Gregory Report (1917) encouraged the teaching of a wide selection of sciences and by 1936 the Science Masters' Association published 'The Teaching of General Science' which it claimed did not emphasize '.... the traditional divisions into specialized subjects....'.
- [ii] Hawking, in his book 'A Brief History of Time', makes the point that he has only looked through a telescope once and was disappointed with the view obtained.
- [iii] It is common for diagrams in astronomy books to present the same problem. 'Astronomy for 'O' Level' by P. Moore (1978) P31, shows the North pole 1.7 cm. away from the Sun during the Northern hemisphere's summer and 2.2 cm. away during the winter.
- [iv] This is closer to the true situation. The Earth is closer to the Sun during the northern hemisphere's winter by about three million miles.

CHAPTER V

5.00 Introduction

In this final chapter the principal findings of the research are first summarized and then each aspect is developed and reviewed against the statutory requirements of the National Curriculum for Science. The results of the pupils' knowledge survey are drawn on to support recommendations made about changes in the sequencing of some of the attainment levels of A.T. 16, potential roles are identified for the main astronomical agencies, and a model is proposed for an astronomy education infrastructure in an attempt to find the best way forward for astronomy education within the framework of the National Curriculum for Science.

5.01 The Principal Findings of the Research

The research has identified both negative opinions and shortfalls in provision concerning the development of astronomy as part of the science curriculum. Many of these issues have a history stretching back to the inception of compulsory education (see Chapter I).

Astronomy has frequently been perceived as a subject which has no place in the school science curriculum (see pp. 39, 40, 44) primarily because of concerns about its poor potential for suitable practical work.

However, the teaching material produced during the development of this thesis has demonstrated that astronomy can be part of the fabric of science education and offer a rich source of practical activities which

enable pupils to test their ideas using the scientific process implicit in Science 5 to 16 A Statement of Policy (1985) of:

IDEA → TEST → RESULT → CONCLUSION

see Chapter IV.

Furthermore, it has been shown that astronomy possesses distinctive characteristics not offered by any other branch of science which are essential to the notion of balanced science as laid down in Science 5 to 16 A Statement of Policy (1985) (see p155).

Evaluation of the pilot teaching materials (see Appendix XIII) carried out by the Secondary Science Curriculum Review (see Appendix XXII) and subsequent school based trials (see Chapter 4.08) has demonstrated that astronomy can be presented in a style that brings it into the mainstream of science teaching, thus refuting the concerns voiced by Westway (1929) and the Science Masters' Association (1950) (see pp 40, 43) about the lack of potential for suitable school science practical work.

Results obtained during the research demonstrate that astronomy can meet the principles set out in Science 5 to 16 A Statement of Policy (1985) and provide a suitable context for the development of important concepts in the three main sciences; for example, the Moon and Seeds teaching material (see Chapter 4.16) has demonstrated that aspects of biology and the Exploration of Science (Attainment Target 1) can be presented through astronomy.

These results build on Stoneman's (1972) work which utilized aspects from astronomy to introduce important ideas in human biology. Similar potential of using astronomy as a vehicle for developing important ideas in chemistry (where elements come from) has been demonstrated by Slater and Thompson (1987) and by Bolton (1974) for physics (velocity, time and waves).

Teachers responding to the concerns survey (see p110) registered a strong positive opinion towards introducing astronomy into the curriculum as a vehicle for developing important ideas in their subject specialism. The results of the teachers' concerns survey (see p107) demonstrate that teachers will be more confident about introducing astronomy into the curriculum if it can be presented within the context of their own subject specialism.

Although the research has demonstrated that astronomy can be a part of the fabric of school science, that it can be presented in a style compatible with teaching methods used for the other sciences, and that there is considerable interest in support material for the main sciences which feature astronomy, the survey of H.O.Ds (see Chapter II) revealed that there is a shortage of teaching material. This finding confirms Lintern-Ball's (1972) concern about the 'out of date' material for astronomy education, and demonstrates that little, if any, progress has been made towards the production and publication of astronomy teaching material during the intervening years between Lintern-Ball's survey and the collection of data for this thesis. This topic will be developed later in this chapter when outlining a way of encouraging the development and publication of astronomy teaching material.

The survey of pupils' growth of understanding of the "easily observed astronomical events" (see Chapter III) has confirmed the findings of Nussbaum and Novak (1976) that pupils' notion of planet Earth in space develops from a simple, flat Earth view, through a series of phases to the accepted notion. In addition, the survey demonstrated that children frequently construct Earth centred alternative frameworks for the easily observed astronomical events which are commonly pre Copernican in structure. The study of childrens' developing ideas about astronomy shows that conceptual change towards a post Copernican view frequently involves phases which parallel ideas held in the past, as humankind's understanding of astronomy developed (see Chapter 3.18). The conceptual change maps (see pp 38-42) suggest that pupils are probably more able to accommodate the shift in their egocentric view of the centre of the solar system (which is necessary when moving from a pre to post Copernican view of planet Earth in space) when they are beyond the age of 12 years. These findings throw doubt on the sequencing of a number of the attainment levels of Attainment Target 16, and are used to support the recommendations made for changes in the sequencing of some of the attainment levels suggested later in this chapter.

The survey of teachers' concerns about introducing astronomy into the science curriculum (see Chapter 2.24) shows that their main concern is the shortfall in their own understanding of astronomy. Subsequent Inset sessions with science teachers held at the University of Leeds have confirmed these findings and uncovered teachers' own alternative frameworks which are little different from those held by children (see Appendix XX).

Secondary Science Curriculum Review evaluation and classroom trials of the pilot teaching materials has vindicated the rationale underpinning the teaching style of the teaching material produced as a part of this thesis (see p158) and has demonstrated that pupils' alternative frameworks form a valuable focus for the teaching process. However, the case studies of pupils challenging their alternative frameworks about the cause of the seasons (see Chapter 4.15) has shown that they - like many scientists - will attempt to interpret their observations in a way that supports their original notion, and that a shift from alternative framework to accepted view may involve intermediate phases. This observation poses considerable difficulties for those working on assessment procedures for the National Curriculum, as giving credit for a shift from one alternative notion to another, even though the newly adopted notion may be closer to the accepted view, will be difficult to manage under the present National Curriculum model for assessment.

It was the introduction of the National Curriculum for science which, for the first time since the inception of compulsory education, placed astronomy into the science curriculum of all pupils. While the author was in support of this decision - and the survey of pupils' understanding of basic astronomy demonstrated that there is a shortfall in both present provision and pupils' understanding of basic astronomy - it did alter the focus of this thesis, in particular the content of the teaching material which now had to conform to Attainment Target 16 if the prototype was to make any contribution to astronomy education. Therefore, it was necessary to equate the topics of the teaching material produced for this thesis with the content of Attainment Target 16.

5.02 Equating the Topics in the Teaching Material with the Content of A.T. 16

Prior to the production of the teaching material the Association for Astronomy Education (A.A.E.) curriculum committee were consulted on what they consider constitutes essential knowledge of astronomy which should be a part of all pupils' education (see Chapter IV and Appendix XI). The topics covered by the teaching material produced for this thesis were based on the recommendations of the A.A.E., the results of the pupil survey and the author's own experience of teaching astronomy. However, if the product is to go any way towards redressing the shortage of practically based astronomy material identified by the surveys reported in Chapter II, and be a useful resource for presenting A.T. 16 of the National Curriculum for science - a criterion which did not feature in the original evaluation of the teaching material as the National Curriculum for science was not in place - there has to be a good correlation between the content of the astronomy units and Attainment Target 16.

Table 51 below shows that there is a good correlation between A.T. 16 and the astronomy covered in the teaching material up to and including level 7.

Level	Statement of Attainment	Section of the pilot teaching material where covered
	Pupils should:	
1.	be able to describe through talking, or other means, the seasonal changes that occur in the weather and in living things.	The Seasons
	know the danger of looking directly at the Sun	What do you know about the Sun?
	be able to describe, in relation to their home or school, the apparent daily motion of the Sun across the sky	What do you know about the Sun?
2.	be able to explain why night occurs	What do you know about the Earth in space?
	know that the day length changes	What do you know about the Sun?
	know that we live on a large, spherical, self-contained planet called Earth	What do you know about the Earth in space?
	know that the Earth, Moon and Sun are separate bodies	What do you know about: the Earth in space, the Moon, the Sun?
3.	know that the inclination of the Sun in the sky changes	What do you know about the Sun?
	be able to measure time with a sundial	Teacher's booklet
4.	know that the phases of the Moon change in a regular and predictable manner	What do you know about the Moon?
	know that the solar system is made up of the Sun and planets, and have an idea of scale	The planets, and in Teacher's booklet
	understand that the Sun is a star	What do you know about the Sun?

Table 51

Level	Statement of Attainment	Section of the pilot teaching material where covered
5.	be able to relate a simple model of the solar system to day/night and year length, changes of day length, seasonal changes and changes in the inclination of the Sun	The seasons
	be able to observe and record the shape and surface shading of the phases of the Moon over a period of time	What do you know about the Moon?
6.	be able to argue, using relevant scientific language how the Earth, Moon, Sun and planets move relative to one another	Ideas from various parts of the pack
	be able to explain that the solar system forms part of a galaxy which is part of a larger system called the universe, and that the position and nature of the component parts of the universe change over the long time scales	Partly covered in The Astrology Connection
7.	be able to argue with the aid of supporting evidence that the Earth is not flat	What do you know about the Earth in space?
	understand that gravity acts towards the centre of every astronomical body	Understanding gravity

Table 51 contd

Material following the same teaching strategy now needs to be produced for levels 8 to 10.

There is also a need for the production of teaching material suitable for primary school use. Although table 51 above shows that levels 1 to 3 are covered by the pilot teaching material, the style of

presentation (in particular the wording) is not suitable for primary school use.

The major concern about the production of material to support the teaching of A.T. 16 is that it only reflects the thinking of one or two writers. A system whereby authors of one-off activities can reach a wider audience needs to be put into place if teachers are to be given access to a comprehensive resource of astronomy teaching material. This aspect will be returned to later in this chapter when recommending roles for the main astronomical societies.

5.03 Attainment Target 16 Sequencing Changes

Results from the survey of pupils' understanding of basic astronomy (Chapter III) and the conceptual change maps (see pp. 38-42) suggest that the sequencing of the attainment levels needs rearranging if pupils are to be presented with topics which reflect and build on their current thinking. A number of attainment levels are mismatched against the prevailing notions held by the age group to which they will be presented, while others are sequenced in a way which fails to utilise their supportive potential both within A.T. 16 and with other Attainment Targets.

For example, at level two, pupils are to be able to explain why night occurs. The research and subsequent discussions with teachers on Inset courses shows that if this is presented to pupils as a level two topic (taught to pupils aged 7 to 9 years) they will be at a phase when they still hold a wide range of notions on the cause of day and night.

A majority of these notions will be self-centred. A point

illustrated by one primary teacher who recalled the results of a lesson with a group of eight year olds. She posed them the question, 'Why does it go dark at night?' Almost half of the class replied that it happens so that they know when to go to sleep. An identical self-centred view was observed by the author when collecting data for this research. During discussion with children about the cause of the seasons, three eleven year old pupils claimed that we get the seasons so that we can get Christmas and Easter.

By seeing themselves as the central focus of the universe, these children appear to be at a very early stage of recapitulating man's early cosmology (see Chapter I). If children do recapitulate the major features of the history of man's cosmology (Chapter III), (and the evidence suggests they do) then it will be unprofitable to present them with ideas which demand decentralisation when they still think that all the sensory stimuli of the heavens are focused on them alone.

The research has shown that pupils are less sure of their ideas at around 12 years of age. Therefore, topics which call for a paradigm shift (day and night notions) should be moved to higher attainment levels where they will be presented to pupils who have become less self-centred and are thus, more likely to be unsure about the alternative framework to which they subscribe.

As reported in earlier chapters, pupils experience difficulty with those astronomical events which demand the visualisation and manipulation of spinning and orbiting planets. An understanding of these events requires a well developed spatial awareness, and although

it is not intended to correlate childrens' spatial development with the attainment levels of A.T. 16 (this should be the subject of a separate study), it was observed that the sequencing of the attainment levels exhibit little, if any, regard for childrens' developing spatial awareness. Gardner (1983) writes:

".... children may know their way around many areas in their neighbourhood or town and, in fact, never fail to find what they are looking for. Yet they often will lack the capacity to provide a map, sketch or an overall verbal account of the relationship among several spots."

If these spots (the Sun, Earth, Moon and planets) are moving, then the task becomes increasingly difficult, and bears a resemblance to the problems concerning an understanding of atomic structure and the geometry of molecules (A.T. 8 levels 7 and 8), neither of which feature until Key Stage 4. And yet some of the most spatially difficult concepts of basic astronomy included in A.T. 16 appear as Key Stage 2 and Key Stage 3 topics. The Key Stage 2 programme of study states that:

"children should use a simple model of the solar system to attempt explanations of day and night, year length and changes in the aspect of the Moon and elevation of the Sun"

And that they:

.... should learn about the position and motion of the Earth, Moon and Sun relative to each other.

The latter 'relative motion' has proved difficult for many of the teachers attending Inset, little chance that primary school children will cope any better. It therefore seems appropriate to delay introducing these spatially taxing topics until Key Stage 4.

This will demand changes in the sequencing of the levels of attainment. Recommendations for changes in sequencing which follow from this research are given below, and take into account the developing spatial awareness of pupils and cross curricular potential astronomy offers.

PROPOSED A.T. 16 SEQUENCING CHANGES

Level	Statement of Attainment	Notes
1	No change	Pupils activities based on observations. Alternative frameworks not challenged
2	<ul style="list-style-type: none"> . Know that we live on a large, spherical, planet called earth . Know that the Sun and Moon are separate bodies . Know that the Sun is a star which is close to Earth . Observe and record shape and surface shading of the phases of the Moon over a period of time 	<p>Explanation of day and night and changes ie. day light hours removed from Level 2. All activities based on pupils' observations. Alternative frameworks not challenged</p>
3	<ul style="list-style-type: none"> . Be able to explain how night occurs and how our ideas differ from those of the past . Know that daylight hours change throughout the year . Know that the inclination of the Sun in the sky changes throughout the year . Be able to construct and use a simple sundial (not including the equation of time) 	<p>A.T. Level 3 pupils begin to challenge their own notions about day and night. Ideas held in past used to facilitate pupils' change in notion. Pupils' explanations for other phenomenon not challenged</p>
4	<ul style="list-style-type: none"> . Know that the solar system is made up of the Sun and planets and have an idea of its scale . Understand that gravity acts towards the centre of every astronomical body . Be able to argue with the aid of supporting scientific evidence, that the Earth is not flat 	<p>A basic understanding of gravity moved from Level 7 to Level 4. Pupils frequently believe that there is no gravity on other astral bodies. Videos used to describe the solar system often refer to gravity, therefore an elementary treatment should feature where the solar system is introduced</p>

Level	Statement of Attainment	Notes
5	<ul style="list-style-type: none"> . Be able to relate current theories of the Earth's position within the solar system with those of the past . Be able to relate a simple model of the solar system to day and night and year length . To be able to use data on the solar system to speculate on the conditions on other planets 	<p>Ideas from history used to help pupils challenge their notions.</p> <p>Idea of spinning and orbiting Earth introduced.</p> <p>Seasons, sun's inclination and daylight hours moved to Level 6</p>
6	<ul style="list-style-type: none"> . Be able to use simple model of the solar system to explain seasonal change, changes in inclination of the Sun and day length hours . Be able to tell time using sundial and the equation of time . Know that variations in solar power affect the Earth's climate 	<p>Children who have developed the concept of a spinning and orbiting Earth are now in a position to challenge their notion on the cause of the seasons.</p> <p>The sundial features again but this time making use of the equation of time; thus introducing the idea of changes in the Earth's velocity as it orbits the Sun</p>
7	<ul style="list-style-type: none"> . Be able to describe using relevant scientific language drawings and models how the Earth, Sun, Moon and planets move relative to one another . To know that the phases of the Moon change in a regular and predictable manner 	<p>The use of language alone is unrealistic; almost all astronomers use either diagrams or models and language to explain phenomena</p>
8	<ul style="list-style-type: none"> . Be able to explain that the solar system forms part of a galaxy which is part of a larger system called the Universe, and that the position and nature of the component parts change over long time-scales . To use data on stars other than the Sun to speculate on the of other planetary systems . To know that other planets may be geologically active and that their initial composition was determined by their distance from the Sun 	<p>This involves highly abstract ideas and is more suited to Level 8 than the present Level 6</p> <p>This has been separated from the original Level 8 statement as it implies that there definitely are planetary systems around other stars</p>

Level	Statement of Attainment	Notes
9	<ul style="list-style-type: none"> . To know that gravity acts between all masses and the magnitude of the force diminishes with distance . To be able to relate the idea of gravitational force to the behaviour of tides, the motion of planets and satellites, and the possibilities and limitations of space travel . Understand that the Sun is powered by nuclear fusion processes 	
10	No change	

Table 52

Level 1 remains unchanged, but at Level 2 explanation of night and annual changes in daylight hours (incorrectly stated as daylength changes in the National Curriculum) moved to Level 3. Recording the shape of the Moon's phases has been moved from Level 5 and a knowledge that the Sun is a star moved from Level 4 to Level 2. Shading moon shapes is well within the capabilities of primary school children, as too is the notion that near (our Sun is a nearby star) objects appear to be larger than those that are far away.

Sundials (Level 3) is restricted to simple shadow stick structures, a more indepth study is left until Level 6 when the equation of time can be explained in terms of changes in the Earth's velocity as it orbits the Sun.

An explanation of night is moved from Level 2 to Level 3. The historical development of ideas about day and night are included as a Level 3 topic because many children will subscribe to notions which

parallel those from history (see Chapter III). As stated earlier, this offers a valuable platform for easing pupils into a paradigm shift.

Level 4 features the solar system and the notion that gravity acts towards the centre of every astronomical body. This elementary treatment of gravity has been moved from Level 7 to Level 4. It was considered useful to include this treatment of gravity at the same time as introducing the solar system as many pupils think that there is no gravity on the Moon or planets.

Evidence that the Earth is not flat has been moved from Level 7 to Level 4. While studying the solar system pupils will note that all other planets are spheres, and will probably see videos showing a view of planet Earth from space. Other earthbound evidence can be given as in the teaching units included in this thesis.

Level 5 presents the opportunity to introduce the 'conflict thesis'. As pupils will frequently experience a paradigm shift themselves, it is a good place to make a cross link with A.T. 17 Level 5: "able to discuss clearly with others their way of thinking about some experiment which is new to them".

The use of a simple model of the solar system has been reduced to just demonstrating day and night and the period of one year. Thus introducing pupils to the spatially difficult concept of the Earth spinning on its axis while orbiting the Sun (see childrens' explanations for the seasons, Chapter IV).

Using data on the solar system (not stars) has been moved from Level 8 to Level 5 as it follows on naturally from pupils' studies of the solar systems; those planets nearest to the Sun being the hottest.

Level 6 develops the more spatially difficult topic of the seasons and annual changes in inclination of the Sun; both Level 5 in the National Curriculum document. Variations in solar power is moved from Level 9 to Level 6. No indication of the depth required regarding variations in solar power is given in the scheme of work, and it is assumed that the depth required can be achieved through a study of the seasons. Therefore, it sits well with the above Level 6 topic.

Sundials feature again in Level 6, this time introducing the equation of time. This is a fitting place; during pupils' study of the seasons they will learn about the elliptical nature of the Earth's orbit around the Sun. It is appropriate to introduce the idea that the Earth's velocity as it orbits the Sun is not constant.

Level 7 develops the relative motion of the Sun planets and their moons. Thus placing this spatially difficult concept more clearly in Key Stage 4, bringing this topic in line with A.T. 8 (chemistry), Level 8 where the structure of atoms and molecules is studied; both topics make similar demands on pupils' spatial awareness.

In this suggested reorganisation of A.T. 16 levels of attainment, the phases of the Moon have been moved from Level 5 to Level 7 and although there is no suggestion at Level 5 that pupils should understand the

cause of the Moon's phases, it is implicit in the Key Stage 3 programme of study which states:

"Compare such ideas and theories with their own emerging understanding and relate them to available evidence"

Details on galaxies and the changing universe is moved from Level 6 to Level 8, thus removing this conceptually difficult topic from Key Stage 3 into Key Stage 4.

Data on stars and speculation on the condition on other planets has been changed to speculation on the existence of other planetary systems. Evidence for the existence of other planetary systems is almost all theoretical, and there is not enough evidence to speculate about conditions on these, at present, hypothetical planets.

Levels 9 and 10 are unchanged apart from moving gravity mass and distance to Level 9 where it sits well with the original Level 9 topics of gravity tides and the motion of planets and satellites.

The rearrangement suggested moves the more difficult spatially conceptual topics from Key Stages 2 and 3 into Key Stage 4, and will, therefore, be introduced to pupils when they are more able to deal with the spatial imagery required for these topics. At this age they will be more likely to appreciate the relationship between ideas held in the past and their own notions, thus giving an opportunity to relate a current theory to ideas held in the past (presently A.T. 16 Level 10). This, as stated in Chapt. III p.146, may possibly make pupils feel more comfortable when they realise that their notion, although incorrect in

the light of scientific advancement, was once the popular view. This approach will develop the idea that scientists have often pursued wrong ideas. It also serves to utilise the history of astronomy to realise aspects of A.T. 17, for example level seven, which states to:

".... be able to give an historical account of a change in accepted theory or explanation, and demonstrate an understanding of its effects on peoples lives"

5.04 Cross Curricular Development

The development of cross-curricular and cross-attainment target potential for the National Curriculum receives attention in Circular No. 6/89 (1989), and it appears that it is intended to develop this aspect further. Although the mechanism through which this development will take place is not made clear.

"The N.C.C. is considering a framework for the whole curriculum and this may, in due course, lead to recommendations and guidance on a co-ordinated approach to cross-curricular themes."

There has been almost no astronomy cross-curricular material developed for use in English secondary schools and those considering developing material will be well advised to look at initiatives from other countries - see for example, Zelilik (1988), Nikolov (1988), Yorke (1988), Franknoi (1988) and Philips (1988).

5.05 Teachers' Preparedness to Deliver Attainment Target 16

The teachers' concerns survey, and H.O.Ds' opinion of their own and their staffs' knowledge, reported in Chapter II, has shown that they are aware of a shortfall in their understanding of basic astronomy. Subsequent discussions with those teachers taking part in the level 'A' evaluation and the Inset sessions (see Appendix XX) have shown that their knowledge of the easily observed astronomical events is little different from that of pupils. Many of the alternative frameworks proffered by children commonly feature in teachers' understanding of astronomical phenomena. As suggested in Chapter III, it appears that alternative frameworks are frequently carried into adulthood (including teachers') and if astronomy does not feature in their training these notions remain unchallenged and are possibly passed on to pupils. The research demonstrates that a majority of teachers do not have an adequate understanding of basic astronomy to deliver the astronomy content of the National Curriculum with confidence unless they receive some form of Inset provision. (See teachers' response to Inset Appendix XX). But at the time this research was carried out (1988/89) science advisors (and to some degree H.M.Is) were apparently not fully aware of the urgency of this need.

5.06 H.M.I. and Science Advisors' Responses Towards Teachers' Needs for Effective Delivery of A.T. 16

Originally it had been intended to include the opinions of science advisors towards astronomy education and Attainment Target 16. However, after three pre-interview discussions with a sample of science advisors, it was clear that the general consensus was that there is so much to be done in realising the demands of the National Curriculum,

and as A.T. 16 is only 1/17 of the whole, any special treatment which astronomy may receive could well result in an imbalance of emphasis.

None of the science advisors contacted considered that they are in possession of the necessary information to be able to comment on how well prepared the teachers in their local education authority are to introduce A.T. 16. None had any plans for Inset especially aimed at A.T. 16, and one claimed that to provide Inset just for A.T. 16 was like taking a "sledgehammer to crack a nut"!

The overall impression from these preliminary interviews was that science advisors hope that teachers will find their own way to cope with A.T. 16. However, these interviews were conducted during the early days of the National Curriculum when the full impact of teachers' needs had not been realised, but since then the surveys of H.O.Ds and teachers, reported in Chapter II of this thesis, has demonstrated that teachers are ill-prepared to find their own way to cope with Attainment Target 16, and that there is an urgent need for Inset.

5.07 Teachers' Astronomy Education

The need for teacher training institutions to include astronomy in their curriculum is clear from both the results of the teachers' concerns survey (Chapt.II) and discussions with teachers during Inset sessions held at Leeds and Bath Universities.

During informal discussions with retired H.M.I. Gold at the 1987 A.A.E. A.G.M., he voiced concern about teachers' lack of understanding and considered that some form of basic astronomy should feature in the curriculum of all science teachers during their training.

The A.A.E. can perform a valuable service to astronomy education if they reconsider their original proposal for input into the S.S.C.R. (see Chapt.1. p.49) and produce a student teacher astronomy module for use by teacher training institutions. However, any initiative aimed at student teachers will take a number of years before it makes any impact on the curriculum received by pupils. Therefore, the approach needs to be two pronged; one aimed at the student teacher and another at practising teachers. To some degree the Inset material being developed in conjunction with the Universities of Bath and Leeds will help to satisfy practising teachers' needs, but the material is primarily concerned with the presentation of A.T. 16, it is not a complete teachers' course in astronomy.

Possibly the quickest way to achieve an astronomically literate teaching profession is through open-learning institutions. Zeilik (1988), University of New Mexico, has run an undergraduates' astronomy correspondence course since 1976, and astronomy forms a significant part of the Open University (O.U.) science degree. It is through the O.U. that a practising teachers' course in astronomy could be presented to a wide audience. According to Jones (1988) there are plans for an O.U. In-service course for school teachers; however, at the time of writing (1990), this material is not yet available and a completion date has not been fixed. Thus, for the meantime, it appears as though the astronomy content of the National Curriculum will be taught by science teachers, the majority of whom have a considerable short-fall in their astronomical knowledge.

5.08 A Potential Role for Astronomical Societies

The full potential of the qualities astronomy offers school science can only be communicated to teachers through the publication of high quality, pupil active, teaching material. No amount of Inset will improve the standard of astronomy teaching unless it is backed up with good teaching schemes.

Until the Education Reform Act (1988) there was a 'chicken and egg' situation regarding the publication of astronomy teaching material; no material because there is no demand, and no demand because there is no material. The introduction of astronomy into the science curriculum offers an opportunity to break this circle, but the publishers need to be convinced that they will get a return on their investment (see Chapter IV and Appendix X). It is here that those astronomical

societies who stated a case for the inclusion of astronomy in the curriculum can follow up their endorsement of school astronomy by acting as a clearing house for a major publisher. Writers of school astronomy material are far more likely to be favourably received by publishers if their work has the endorsement of the major astronomical societies. This would require that the astronomical societies set up a schools' literature council to which potential authors can submit their manuscripts. These can then be subjected to the same rigour (using different criteria) as academic papers submitted for publication in their journals. If a proposed publication is regarded as satisfactory, it can be passed on to the publisher as an example of good astronomy and good teaching practice which they may like to consider for publication.

If the societies decide to set up a schools' literature council it can also function in a similar fashion to Sunal's (1985) Astronomy Resource Network. In this way authors of 'one off' lessons which would normally never get into print, can reach a wider public and teachers can be made aware of the considerable amount of good quality but, under our present system, unpublished astronomy material that exists. The net effect of this initiative would be to demonstrate to prospective authors of astronomy teaching material that there is an outlet for their material. This will serve to encourage them to go into print. In this way the available material will not just reflect one or two individuals' view of good practice (the present situation).

To initiate and maintain an astronomy teaching literature council requires a considerable effort on the part of the astronomical

societies, but it is worthless stating a case for the inclusion of astronomy into the science curriculum (as the British Astronomical Society, Association for Astronomy Education and the Royal Astronomical Society did) unless they are prepared to follow up this recommendation with some form of guidance, or monitoring, to ensure that their recommendations are being realised in an appropriate manner. The Royal Astronomical Society have shown an interest in the potential of this strategy and it is one of the subjects of a paper by the author to be published by the R.A.S. in June 1991. (See Appendix XXI).

5.09 Amateur Astronomers as a School Resource

In Chapter I mention is made of the important role amateur astronomical groups fulfil as agents of informal education for those with a special interest in astronomy. Retired H.M.I. Gold (1979) acknowledges the importance of the work some of these groups carry out when they visit schools to give talks and demonstrations. In an attempt to discover the level of amateur astronomical societies' commitment to education, questionnaires were sent to the first twenty five amateur groups to have details of their club's activities published in the first editions of the amateur astronomers' magazine 'Astronomy Now'. See Appendix XXIII for copy of questionnaire and covering letter.

There was a one hundred percent return of answered questionnaires. Membership ranged from six to several hundred. All of the societies carried out activities to "promote an awareness of astronomy" ranging from articles in local newspapers to full scale public awareness weekends with 'hands on' opportunities.

Seventy six percent of the groups claimed that they rarely have requests from schools for assistance, and that if they do, they mostly come from the primary sector. Their opinions on why they are not asked for assistance were mainly based on statements about astronomy not featuring in schools. However, three claimed that they felt teachers would not want to involve unqualified people in their lessons. Twenty four (96%) said that they would be willing to assist schools with astronomy education. Their offers ranged from organising nighttime viewing (including the provision of telescopes) to daytime talks, demonstrations and slide shows. A majority considered that astronomy should feature in the science curriculum, but four claimed that it should only feature if the teachers are competent to teach the subject. Six considered that astronomy should not feature in the science curriculum because teachers do not know enough about the subject to teach it properly.

This survey serves to demonstrate that the amateur astronomical groups form a willing but largely untapped resource which most schools can utilise. Amateur groups can be used for individual school based Inset specifically aimed at updating teachers' knowledge. Such an approach would probably meet approval under Local Management of Schools (L.M.S.), as most astronomical societies help schools on a voluntary basis. Thus, by working with local astronomical societies and purchasing Inset materials like those being produced by Leeds and Bath Universities, schools have an opportunity to redress the shortfall in teachers' knowledge of basic astronomy with a minimal effect on their capitation and within a relatively short period of time. However, there is a need to persuade schools that it is worthwhile.

5.10 The Role of the A.A.E.

In Chapter I it was suggested that the A.A.E. needs to improve its publicity. Footnote [xvi] (Chapter 1) quote their vice-chairperson who claimed that they are entering a "... new dynamic phase". This is yet to manifest itself, and apart from one letter in the Times Educational Supplement drawing attention to the existence of the A.A.E., they do not appear to have improved their publicity enough to make a significant improvement in the number of teachers who are aware of their existence (see Chapt.II, p.85). Based on their past form, failing to respond to the S.S.C.R. initiative and their slowness to respond to the National Curriculum, it is difficult to imagine, with their present structure, what role they may fulfil; one would hope that they can muster the depth of talent which exists within their membership and produce two teacher training packages. One along the lines of the American non-science major courses, (Fraknoi 1988) thus improving all teachers' understanding of basic astronomy and developing the full cross-curricular potential of astronomy, and another aimed at science teachers.

Another valuable contribution the A.A.E. may consider is the production of a Newsletter on the lines of that produced by the Astronomical Society of the Pacific (A.S.P.), who have sponsored a quarterly newsletter since 1984 on teaching astronomy in grades 3 to 12. As well as information on teaching resources it gives astronomical data of direct importance to teachers, such as Moon phases and the time they are visible. The A.S.P. newsletter is co-sponsored by the American Astronomical Society, the Canadian Astronomical Society and the International Planetarium Society and now reaches over 20,000 teachers. One can visualise a British equivalent co-sponsored by the Royal Astronomical Society (R.A.S.) and the British Astronomical Association (B.A.A.). Astronomy teaching in Britain needs an active teaching association to ensure that the full potential of the astronomy content of the National Curriculum is realised and to act as a go-between for the teachers, astronomy associations and the D.E.S. It is possible that the success of A.T. 16 stands or falls on the ability of the A.A.E. to fulfil its role in astronomy education.

5.11 Discussion

In this thesis it has been shown that the ordinary person's understanding of basic astronomy has undergone little change from the ideas held in medieval times. The increase in demand for navigators and the notion that astronomy should feature in the education of a gentleman (or woman) had almost no effect on the astronomy education of the ordinary person, and throughout the greater part of the twentieth century astronomy failed to find a place in the science curriculum.

After the launching of Sputnik there were calls for an increase in astronomy education, but apart from one or two initiatives by teachers with a particular interest in the subject, there has been a general inability to demonstrate that astronomy can be taught in a style which brings it into the mainstream of science teaching. The nett effect is that it is commonplace for pupils, adults and teachers to have made almost no progress in their astronomical understanding since their ancestors living at the time of Copernicus.

The inclusion of astronomy in the National Curriculum offers an opportunity for our pupils to emerge from their medieval world view, but this hinges upon having an astronomically literate teaching profession; something which this research suggests we do not yet have. However, the successful introduction of astronomy into the curriculum demands more than just Inset or teacher training. If astronomy's full potential in education (cross-curricular development as stated earlier in this thesis) is to be realised, then an infrastructure for astronomy education needs to be established. Table 53 is a model for such an

infrastructure which is based on the findings of this research; the stage numbers relate to the present order of priority.

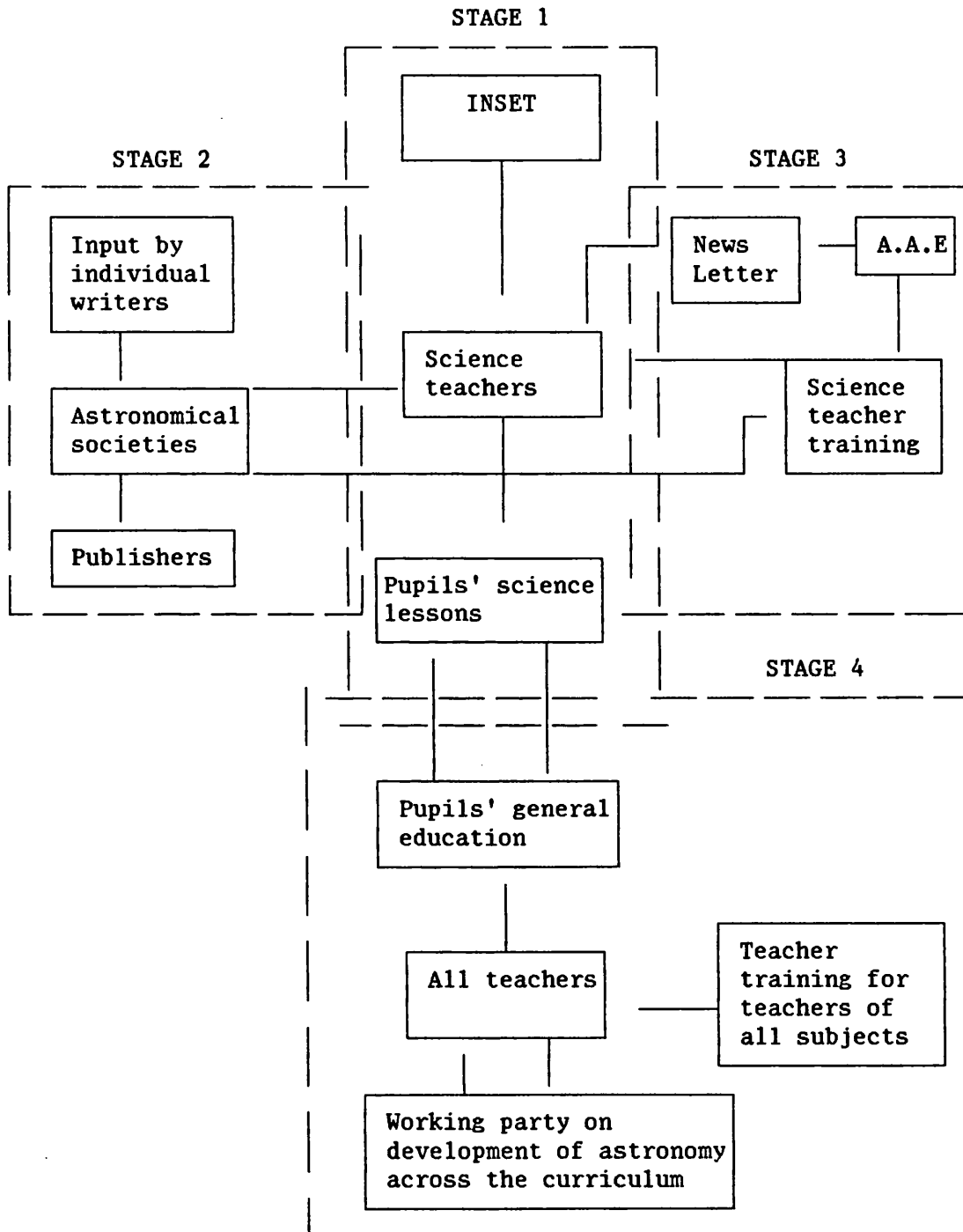


Table 53

As table 53 shows, the first priority is Inset. This can be realised almost immediately if L.E.As, individual schools or groups of schools use the Inset material already available and utilise the amateur astronomical groups who have shown themselves to be willing assistants in developing school astronomy. Stage Two depends on the astronomical societies setting up a teaching materials clearing house as mentioned earlier in this chapter. This recommendation has been favourably received by the R.A.S. (see Appendix XXI) and it is hoped that their education committee will work towards this aim. The A.A.E. play the key role for the successful development of Stage 3. They need to revive their original interest in developing an astronomy teacher training pack for delivery at all teacher training establishments. They will also need to develop an astronomy education newsletter similar to the A.S.P. mentioned earlier in this chapter; possibly funded by the astronomical societies. A newsletter, as well as bringing teachers up to date with important astronomical events, will be a medium through which to advertise the teaching material developed at Stage 2. This will help to make good schools' shortfall in information about astronomy which the H.O.Ds' survey uncovered (see Chapter II).

Stage 4 will demand a meeting of minds between the A.A.E., astronomical societies and teachers. This will probably be best first approached through the development of A.T. 17 material and then working on the wider issues. For example, developing the rich resource astronomy offers for narrative in English lessons, or how the development of astronavigation influenced the course of history.

Although table 53 shows the development of an astronomy education infrastructure as a series of stages, they are not seen as transient goals. Inset (stage 1) will always be required, as will the reviewing of new material (stage 2) the production of the newsletter (stage 3) and the development of up-to-date cross-curricular material (stage 4). However, once established, it is most likely that the arrows on the diagram will be redrawn going in both directions. A committee formed from this infrastructure will be the best voice through which to report to the National Curriculum Council (N.C.C.) regarding changes in the sequencing of the levels of attainment (see earlier on in this chapter), and any other changes that arise through teachers growing experience of teaching the astronomy content of the National Curriculum.

As the model shows, nothing of any worth can be achieved without a knowledgeable teaching profession, and the wider this knowledge is spread across subject teachers, the greater the potential for astronomy.

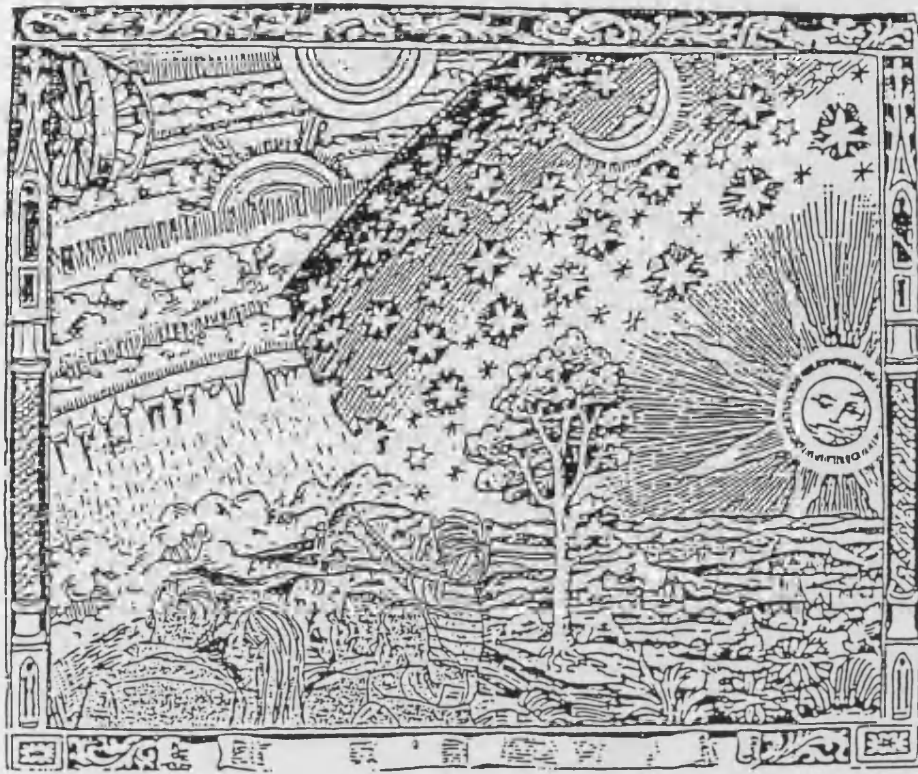
This then opens up a variety of cross-curricular opportunities which can both enhance our pupils' work in a variety of subjects and help them develop their knowledge of astronomy. In this way astronomy is acting as a vehicle, not just for developing important ideas in science (as recommended in the D.E.S. document 'Science 5 to 16: A Statement of Policy' (1985)), but for important ideas and skills across the curriculum. Perhaps the best way to present astronomy is to drop the name altogether, and along with it all the negative ideas about astronomy education which have accumulated over the years, and present

it as an important part of the subject we call science; a part which has had a considerable influence on all cultures since the beginning of time. This may be one way of changing the opinion held by many pupils that astronomy, while being an enjoyable subject, does not relate to their needs for employment (see Chapter IV).

The results of the survey of teachers reported in Chapter II of this theses suggests that teachers will feel more confident about teaching topics from astronomy if they are set within the context of their own subject specialism. These results also suggest that by presenting astronomy in this way there will be a 20% reduction in the number of teachers in need of Inset. Clearly, such an approach to the teaching of astronomy will demand a meeting of minds between subject teachers and astronomers, and this can only be realised on the scale required if an infrastructure is established along the lines given in table 54.

The inclusion of astronomy into the science curriculum can help to dispel the belief in myths and the medieval view which is still commonly held, but its inclusion in the National Curriculum must not be seen as a war won against astronomical ignorance. It is a small victory, and it is now incumbent on those institutions and individuals who stated a case for the inclusion of astronomy into the curriculum to see their recommendations through, by identifying the areas of need they are best suited to address; then, using their position, knowledge and enthusiasm, act to ensure that our childrens' education in astronomy brings them into a postCopernican world. Perhaps then we can recarve Flammarion's woodcut (see fig. 12), knowing that the gap

between astronomers and the ordinary person has not widened to such an extent that astronomy, once again, is held within a priesthood.



(with apologies to Camille Flammarion).

Fig.12

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APPENDIX I

TRANSLATION OF A FRENCH POEM

"Those clerks who think (think how absurd a jest)
Than neither heav'ns nor stars do turn at all,
Nor dance about this great round earthly ball;
But th'earth itself, this massy globe of ours,
Turns round-about once every twice twelve hours:
And we resemble land-bread novices
New brought aboard to venture on the seas;
Who, at first launching from the shore, suppose
The ship stands still, and that the ground it goes
So, never should an arrow, shot upright,
In the same place upon the shooter light;
But would do, rather, as, at sea, a stone
Aboard a ship upward thrown;
Which not within-board falls, but in the flood
Astern the ship, if so the wind be good.
So should the fowls that take their nimble flight
From western marches towards morning's light;
And bullets thundering from the cannon's throat
(Whose roaring drowns the heav'nly thunder's note)
Should seem recoil: since the quick career,
That our round earth should daily gallop here,
Must needs exceed a hundred-fold, for swift,
Birds, bullets, winds; their wings, their force, their drift.
Arm'd with these reasons of Copernicus;
Who, to save better of the stars th'appearance,
Unto the earth a three-fold motion warrants."

From: Johnston, F.R. (1937)

APPENDIX II

ASTRONOMY IN PUBLIC EXAMINATIONS

ASTRONOMY IN PUBLIC EXAMINATIONS (1982)

GCE Examining Boards:

University of London School Examinations Department

- O Astronomy - only national examination exclusively on astronomy.
- O Navigation - contains the necessary astronomy.

University of Cambridge Local Examinations Syndicate

- O Environmental Science - small section on astronomy.
- O Navigation & Astronomy - section on astronomy.

Southern Universities Joint Board for School Examinations

- O General Science - brief mention of astronomy.

Joint Matriculation Board

- O Navigation - section on nautical astronomy.
- A Physics - optional topic on physics of astronomy.

Oxford Delegacy of Local Examinations

- O Physics - optional topic on astronomy.
- AO Elementary Aeronautics - brief mention of cosmography.
- A Geology - brief mention of earth/moon system, meteorites.
- A General Studies - occasional mention of astronomical topics.

Oxford and Cambridge Schools Examinations Board

- AO Astronomy - available to only two schools.
- AO Navigation - contains the necessary astronomy.
- AO History of Science - contains a large amount on the history of astronomy and cosmology. (Joint with Cambridge Local Board).
- A History - optional topic on growth of the scientific world, c. 1500 - c. 1640: Copernicus, Kepler, Galileo.
- O Nuffield Physics - very small section on planetary astronomy. (Inter-board examination).

Associated Examining Board

- O Sea Navigation - brief mention of necessary astronomy.
- O Air Navigation - brief mention of necessary astronomy.

Welsh and Northern Ireland Examining Boards

No astronomy included in syllabuses.

SCOTTISH CERTIFICATE OF EDUCATION Examination Board:

- O Geology - nature and composition of solar system, origin of earth.
- O Nautical Studies - celestial sphere, hour angle, etc.
- H Navigation - celestial sphere, time, star recognition, etc. (Deeper than O level).

CSE Regional Examining Boards:

Associated Lancashire

Physics - optional topic on astronomy and space travel.

East Midland

Environmental Studies - brief mention of solar system and space.
(NB. Astronomy option in Physics has been withdrawn due to lack of demand).

West Midland

Physics - optional topic on the physics of astronomy and space.

North

Science - compulsory and optional topics on the universe.

North Western

Science - optional topic on astronomy.
Physics - optional topic on astronomy and space.

Yorkshire

General Science - very brief mention of solar system.

West Yorkshire and Lindsey

Physics - optional topic on astronomy.

In addition, a couple of Boards operate Mode 3 CSE examinations containing astronomy.

No Astronomy is included in the syllabuses of the South Western, London, East Anglian, Southern, South East, Welsh and Northern Ireland Boards.

* * * * *

Details of astronomy containing syllabuses may be obtained from the appropriate Examining Board.

* * * * *

A W Lintern Ball
(Loughborough Grammar School)

MEMBERS OF THE WORKING PARTY

Dr D McNally, University of London Observatory - Chairman
H Bloch, Federation of Astronomical Societies
Dr R A Booth, Royal Astronomical Society
Ms H Couper, Greenwich Planetarium
J M Harrison, The Schools Council
A Lintern Ball, Association for Science Education
Capt. P Richards-Jones, British Astronomical Association
P O Montgomery, Federation of Astronomical Societies
Mrs R Naylor, Junior Astronomical Society
I Nicholson, Junior Astronomical Society
Dr P Seymour, British Planetarium Association
F Tobin, Junior Astronomical Society
P D Dudley, HMI, Department of Education and Science
D J Gold, HMI retired - Secretary

The following served on the two Working Groups

Group 2 - Resources

Dr P Seymour - Chairman
H Bloch
Ms H Couper
T Murtagh, British Planetarium Association
J Ravest, British Planetarium Association

Group 1 - Curriculum

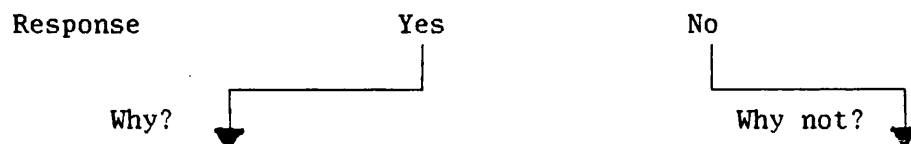
Dr R Booth - Chairman
A Lintern Ball
I Nicholson
P Montgomery
Capt. P Richards-Jones

APPENDIX IV

MOST RECURRENT STATEMENTS ABOUT
ASTRONOMY EDUCATION COLLECTED
AT THE A.S.E. YORK 1986

Although the interviews were open-ended, three leading questions were used to stimulate the discussion.

- (i) Do you think astronomy should be taught as part of the science curriculum?



- (ii) Who should teach it?

- (iii) What difficulties do you envisage if astronomy was included in the science curriculum?

	Most Common Responses	No subscribing to view or one which is similar
1	No time on the timetable to fit astronomy in	28
2	No practicals suitable for daytime use	16
3	It can only be taught at night	17
4	I have no knowledge of the subject	52
5	There is no one in our school who can teach it	21
6	It's got too much of a boffin image	19
7	Too much maths in it for the average person	7
8	Those interested can join an astronomy club	11
9	Other subjects are more important to pupils'	15
10	We've not got a telescope	24
11	It's o.k. to teach it at a boarding school when all the pupils will be there at night	6
12	It's such a sophisticated subject, schools just couldn't afford the equipment	14

	Most Common Response	No subscribing to view or one which is similar
14	Very few teachers know much about it, it's a bad situation we ought to teach more	23
15	It's the oldest science, pupils should know something about it	14
16	We hear so much about space missions and satellites on the news our pupils should know the basics	12
17	It should be taught, but someone should be brought in so that it is taught properly	13
18	The pupils would not be interested in it	6
19	Pupils know so little about astronomy they should learn the basics at school	19
20	It should be taught as part of physics	43
21	Astronomy should be taught because it dictates conditions on earth like seasons and tides which govern life on our planet	17
22	Astronomy should be taught, there is some very good chemistry going on in the stars	5
23	It should be taught, pupils find it interesting	11
24	All teachers should be able to teach basic astronomy	10
25	It is bad that hardly any astronomy is taught at teacher training colleges	14
26	I would like to see it taught at our school but we just don't have the money to set it up	28
27	Older pupils would not be bothered to work at the subject because it doesn't feature in the exams	12
28	What would you teach the girls because they would not be interested in astronomy	6
29	I don't think there are any suitable well-priced books for school astronomy	6

APPENDIX V

THE POSTAL SURVEYS

Survey strategy. Method of selecting the sample.
Copies of H.O.Ds' and Teachers' questionnaires and
covering letters.

The H.O.D. Questionnaire

Aim

The questionnaire was designed to discover the following about school astronomy:

- (i) Its present status.
- (ii) H.O.Ds' opinion of their provision.
- (iii) Factors which may encourage H.O.Ds to include astronomy in the science curriculum.
- (iv) Suitability of astronomy as a subject to be studied by all pupils.
- (v) Their science departments' preparedness to teach basic astronomy.

Design of the Questionnaire

The statements which made up the bulk of the questionnaire were based on the most commonly occurring statements about school astronomy collected at the York A.S.E. meeting (see Appendix V).

Questions asking for details on the astronomy provision within the school were based on a yes, no, unsure, response (questions 1 to 13). Those questions intended to elucidate H.O.Ds' opinions about aspects of astronomy gave respondents a five point scale along which to show their level of agreement or disagreement with a particular statement.

It was considered that H.O.Ds may give the response they think the researcher required concerning their attitude towards the inclusion of astronomy into the science curriculum, and its suitability as a subject for study by all pupils. In order to reduce the effect of this tendency on the conclusions reached from an analysis of the questionnaires, a number of questions to elucidate opinions about these

two areas were included in the questionnaire. These were then analysed to give a profile of teachers' opinions. See Chapter III.

Pilot Trial

A first draft of the H.O.D questionnaire was given a pilot trial by the curriculum committee of the A.A.E. and the science department staff at Court Fields School, Somerset.

Suggestions for improvements and removal of ambiguities were made and suggestions used for the production of the second, and final, draft.

Strategy for Maximising Returns

The recommendations made by Leedy (1985) were followed regarding the style of the covering letter (polite, quickly to the point and stating the importance of the respondent to the success of the research).

Good quality prepaid envelopes (Futrell and Lamb (1981)) were used to emphasise the importance of the survey, but lack of funding limited the use of follow-up letters to improve responses.

Coding and Analysis

Returned questionnaires were coded and entered on to Paramount punch cards. This data was later transferred to a Delta Plus data base for final analysis.

SELECTING THE SAMPLE

All schools were selected from the Education Authorities Directory and Annual 1985 edition.

Schools were divided into five categories.

<u>CATEGORY</u>	<u>NUMBER OF SCHOOLS</u>
Inner London and London Boroughs	493
Other Metropolitan Areas	953
Non Metropolitan Areas	2315
Wales	228
Northern Ireland	<u>257</u>
TOTAL	<u>4246</u>

Limited finances restricted the sample size to 395 to 400 schools.

The correct proportion of schools from each category to give a population of 399 was calculated as:

$$\frac{\text{No. of schools in category}}{\text{Total number of schools}} \times 400$$

NUMBER OF SCHOOLS SELECTED FROM EACH CATEGORY

<u>CATEGORY</u>	<u>NUMBER</u>
<u>ENGLAND</u>	
Inner London and London Boroughs	46
Other Metropolitan Areas	90
Non Metropolitan Areas	218
<u>WALES</u>	21
<u>NORTHERN IRELAND</u>	<u>24</u>
TOTAL	<u>399</u>

Schools were selected from the Annual by random numbers generated by a computer until the correct number of schools from each category was obtained.

One H.O.D. and three science teacher surveys were sent to each school selected.

University of Bath

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Claverton Down
Bath BA2 7AY

Tel: (0225) 826826
Telex 449097
Fax: 0225 62508 (Group 3)

Professor K Austwick
Professor J J Thompson

26th June 1986.

Dear Colleague,

At Bath University we are looking into the part of astronomy can play in the science curriculum of all pupils.

Both the Secondary Science Curriculum Review and the recently published Government Advisory Document have called for the inclusion of astronomy in school science. If astronomy is to find its way into the science curriculum of more pupils, the way forward can only be ascertained by taking into account the attitudes and perceptions of science teachers towards astronomy as a school subject.

We hope you will find time to complete the enclosed Head of Department Questionnaire, and that you will encourage members of your staff to fill out the Science Teachers' Questionnaire, as your comments are essential if we are to come to any worthwhile and workable conclusions.

Please collect your teachers' questionnaires and, along with your H.O.D. questionnaire, return them in the prepaid envelope provided.

Many thanks in anticipation of your time and help.

Yours sincerely,

JOHN H. BAXTER

Enc. 1 H.O.D. Questionnaire.
3 Science Teachers' Questionnaires and envelopes.
1 S.A.E. for return of Questionnaires.

DEFINITION OF SCHOOL ASTRONOMY

Those events which can be observed with the naked eye and which form a part of our everyday experience. eg. Day / night, the tides, gravity, phases of the Moon, seasons and the easily observed night sky.

ASTRONOMY IN SCHOOLS QUESTIONNAIRE
FOR HEAD OF SCIENCE

NAME OF SCHOOL:

NUMBER ON ROLÉ:

TYPE:

All information will be treated in confidence

QUESTIONS

RESPONSES

QUESTIONS	RESPONSES		
1. Is there an astronomy club in your school?	YES	NO	UNSURE
2. Does astronomy feature in the science curriculum of your school?	YES	NO	UNSURE
3. Are you satisfied with the way astronomy is covered in your school?	YES	NO	UNSURE
4. Is there a planetarium within reasonable travelling distance from your school?	YES	NO	UNSURE
5. Is there a permanent astronomy exhibition within reasonable travelling distance from your school?	YES	NO	UNSURE
6. Did you know there is an Association For Astronomy Education?	YES	NO	UNSURE
7. How many members of your staff are members of the above Association?			UNSURE
8. Are you or any other members of your staff members of any other astronomical association?	YES	NO	UNSURE
9. Did you know there is an astronomy 'O' Level examination?	YES	NO	UNSURE
10. On average, how many pupils do you enter for the above 'O' Level examination?			
11. Is there anyone within your L.E.A. who could advise you on school astronomy?	YES	NO	UNSURE
12. If you have answered YES to (11) above please give this persons status.			

QUESTIONS

RESPONSES

13a. How many junior schools feed into your school?		UNSURE
13b. How many of these schools teach some basic astronomy?		UNSURE

DOES YOUR SCHOOL POSSESS:-

- Slides about astronomy
- Astronomical Charts
- Star Globes
- Films on astronomy
- A Telescope
- Other astronomical apparatus
(Please give details)

YES	NO	UNSURE
YES	NO	UNSURE
YES	NO	UNSURE
YES	NO	UNSURE
YES	NO	UNSURE

Please indicate the extent of your agreement or otherwise to the following statements by ticking the accompanying five point scale.

RESPONSES

statements

	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
1. Astronomy should be taught as an independent subject					
2. All science teachers should receive instruction in basic astronomy during their training.					
3. Only physics teachers should receive instruction in basic astronomy during their training.					
4. Before we introduce basic astronomy into our science curriculum my staff will require in-service training.					
5. The only realistic way we could introduce astronomy into our science curriculum is in the form of support material for the three sciences.					
6. Many topics in physics, chemistry and biology can be enhanced by using examples from astronomy.					
7. Astronomy is only suitable as a subject for able and motivated pupils.					

statements

RESPONSES

	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
8. It is difficult to teach astronomy in schools because there are few daytime practicals.					
9. If astronomy were introduced into the science curriculum it would spoil it as a possible leisure time pursuit.					
10. Astronomy should be taught in schools because it has potential as a leisure time pursuit.					
11. Astronomy should not be included in the science curriculum because it does not relate to the world of work and industry.					
12. All pupils who leave school should have a basic understanding of our solar system.					
13. Advances in astronomy have gone hand in hand with advances in technology. We should use this fact in the teaching of technology and use examples from astronomy.					
14. Astronomy is more likely to appeal to boys.					

statements

RESPONSES

	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
15. Basic space science should be included in the science curriculum in order that pupils have an understanding of how space can be used for peaceful purposes.					
16. Basic space science should be included in the science curriculum in order that pupils have an understanding of how space can be used for military purposes.					
17. Astronomy is now such an advanced subject that the average person cannot identify with the work astronomers do. For this reason astronomy should not be part of the science curriculum.					
18. Modern astronomers use such specialised equipment, our pupils would quickly become disillusioned with the basic apparatus.					
19. It is not worth teaching astronomy in schools because most pupils would not return in the evening for observation sessions.					
20. As astronomy has such little practical application in the lives of most people it should not be included in the science curriculum.					

statements :

RESPONSES

	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
21. I would like to introduce some basic astronomy into my science lessons but do not feel confident in my own knowledge of the subject.					
22. We would be more likely to introduce basic astronomy if peripatetic astronomy teachers could visit our school to teach the subject.					
23. In general, pupils entering our first year have a satisfactory knowledge of basic astronomy.					
24. In general, pupils leaving the fifth year have a satisfactory knowledge of basic astronomy.					
25. Basic astronomy should form part of the junior school science curriculum.					
26. The astronomy education of our pupils would be best served if the L.E.A. ran short residential courses for those pupils interested in the subject.					
27. I consider astronomy to be low on the priority list for time in the science curriculum.					

statements

RESPONSES

	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
28. If astronomy was introduced into the science curriculum it should form part of the scheme studied by:					
i. 1st year pupils only.....					
ii. 2nd year pupils only.....					
ii. 1st and 2nd year pupils.....					
iv. 3rd year pupils only.....					
v. 4th year pupils only.....					
vi. 5th year pupils only.....					
vii. 4th and 5th year pupils.....					
29. We would introduce astronomy into the science curriculum if:					
i. We had a telescope.....					
ii. There were suitable daytime practicals					
iii. There was suitable in-service training					
iv. There was a planetarium near by.....					
v. Finance was made available.....					
vi. There was time on the timetable.....					
vii. We had the necessary apparatus.....					
viii. If astronomy questions were included in the examination questions of the three sciences.....					

statements

RESPONSES

	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
30. Of all the science literature I receive as H.O.D., material on astronomy is poorly represented.					
31. I would like to see more material on astronomy which is suitable for use in secondary school science lessons.					
32. Many of the books on astronomy are written by astronomers who are too far removed from the classroom situation.					
33. There are many topics in physics which can be enhanced by using topics from astronomy.					
34. There are many topics in chemistry which can be enhanced by using topics from astronomy.					
35. There are many topics in biology which can be enhanced by using topics from astronomy.					

Please complete this part of the Questionnaire if Astronomy features in the Science Curriculum of your school.

Where does astronomy feature in the science curriculum of your school?

YEAR	Please tick		How many teaching periods does it occupy?
	YES	NO	
Year 1			
Year 2			
Year 3			
Year 4			
Year 5			

Which topics from astronomy are covered in your school's science curriculum?

TOPIC	Please tick
Day and Night	_____
The Seasons	_____
Phases of the Moon	_____
The Solar System	_____
Space Travel	_____
The Sun	_____
History of Astronomy	_____
Any other	_____

Thank you for filling out this questionnaire. The next page has been left blank for any comments you may wish to make regarding this research.

If you wish to be notified of our findings please tick the box below.

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Fax: 0225 62508 (Group 3)

Professor K Austwick
Professor J J Thompson

Dear Colleague,

At Bath University we are looking into the part astronomy can play in the science curriculum of all pupils.

Both the Secondary Science Curriculum Review and the recently published Government Advisory Document have called for the inclusion of astronomy in school science. If astronomy is to find its way into the science curriculum of more pupils, the way forward can only be ascertained by taking into account the attitudes and perceptions of science teachers towards astronomy as a school subject.

We hope you will find time to complete the enclosed science teachers' questionnaire and that you will return it to your HOD in the sealed envelope.

Many thanks in anticipation of your time and help.

Yours sincerely,

John H. Baxter.

DEFINITION OF SCHOOL ASTRONOMY

Those events which can be observed with the naked eye and which form a part of our everyday experiences. eg. day /night, tides, gravity, phases of the Moon, seasons, and the easily observed night sky.

ASTRONOMY IN SCHOOLS QUESTIONNAIRE

All information will be treated in confidence

Name of School _____

Your position in the school _____

Please indicate the extent of your agreement or otherwise to the following statements by ticking the accompanying five point scale.

statements	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
1. I feel confident about teaching basic astronomy.					
2. I will require some form of in-service training before teaching basic astronomy.					
3. I do not think my teacher training has prepared me to teach basic astronomy.					
4. What other personal doubts would you have about teaching basic astronomy?					
5. I would be concerned about teaching astronomy because of the shortage of available practical material.					
6. If given suitable practical material I could teach basic astronomy with confidence.					
7. There are far too few suitable daytime practicals for astronomy to be taught in normal school hours.					

statements

RESPONSES

	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
8. It would be difficult to teach astronomy in our school because we do not have the necessary apparatus.					
9. Astronomers use such specialised apparatus pupils will soon become disillusioned with basic school equipment.					
10. Teaching basic astronomy to a class will be difficult because boys will be more interested than girls.					
11. What other organisational problems do you think will face the classroom teacher when teaching a basic astronomy course?					
12. I would like to have material which uses topics from astronomy to enhance the teaching of my subject specialisms.					
13. Astronomy should not feature in the science curriculum unless it appears in the examinations.					
14. Astronomy should not feature in the science curriculum because it does not relate to the world of work.					
15. If I used topics from astronomy to develop concepts in my subject specialisms, my colleagues would consider it wasting valuable time.					

statements :

RESPONSES

	Strong Agreement	Agreement	Undecided	Disagreement	Strong Disagreement
16. If I used topics from astronomy to develop concepts in my subject, specialisms, parents would consider it wasting valuable time.					
17. Astronomy should feature in schools as an extra-curricular activity only.					
18. What other problems from colleagues, parents or others do you think you will face if you teach basic astronomy?					

Training and Background Details

The following details will help us to ascertain changes in teacher training and in-service training provision necessary should astronomy feature in the science curriculum of more pupils.

Please tick the appropriate box in regard to your training.

B.Sc.	B.Ed.	Cert.Ed.	Higher Degree (State type)	Any other (Give details)

Subject specialisms _____

Many thanks for filling out this questionnaire. Please use the space below for any comments you may wish to make with regard to this research.

APPENDIX VI

THE CHI SQUARED TEST FOR GOODNESS OF FIT

The Chi Squared Test for Goodness of Fit

The Chi squared (x^2) test is perhaps the most commonly used non-parametric test where a comparison between observed and theoretical frequencies is required (Leedy 1985).

The x^2 test assess the probability that differences between opinions selected for a particular statement occurred by chance. It therefore, indicates whether there is a particular bias in choice of response type to a particular statement.

If there was no bias in choice of response type to a particular statement, each response type would have been selected an equal number of times. For example, with the H.O.D. survey $n = 131$, therefore, the theoretical distribution of responses to the five levels of agreement to a particular statement = $\frac{131}{5} = 26.2$ per response type.

The chi squared (x^2) test will indicate if any deviation from this theoretical distribution is due to chance or if the trend towards a particular response type is significant.

Method of Calculating X^2

$$X^2 = \frac{(O-E)^2}{E}$$

Where O = observed number selecting response type.

E = expected number selecting response type.

After finding the x^2 statistic the number of degrees of freedom (df) was calculated. The df relates to the number of response types that

are free to vary. Df = number of response types available (5) - 1;
df = 5 - 1 = 4.

The probability of obtaining the calculated x^2 value was looked up using x^2 distribution tables (Neave 1979). Following the recommendation of Heyes, Hardy Humphreys and Rookes (1986), p was not considered significant unless $p = 5\%$ (0.05) or smaller.

CHI SQ. ANALYSIS OF H.O.D. SURVEY

STATEMENT 29 (i) TO (viii)

STATEMENT 29	Score No x		Score No x		Score No x		Score No x		Score No x		Row Totals
	5	No	4	No	3	No	2	No	1	No	
(i)	5	1	76	19	33	11	42	21	17	17	173
(ii)	10	2	116	29	39	13	36	18	7	7	208
(iii)	40	8	112	28	39	13	28	14	6	6	225
(iv)	20	4	68	17	48	16	34	17	15	15	185
(v)	80	16	108	27	24	8	26	13	5	5	243
(vi)	60	12	128	32	21	7	26	13	5	5	240
(vii)	75	15	112	28	18	6	26	13	7	7	238
(viii)	55	11	112	28	24	8	30	15	7	7	228
Column Totals	345		832		246		248		69		1740

GRAND TOTAL

Table 55

Calculation of X²

O = observed, E = expected. Expected calculated from table n as row total x column total - grand total.

O	E	(O - E) ²	$\frac{(O - E)^2}{E}$
5	34.3	858.49	25.03
10	41.2	973.44	23.63
40	44.6	21.16	0.47
20	36.7	278.89	7.60
80	48.2	1011.24	21.00
60	47.6	153.76	3.23
75	47.2	772.84	16.40
55	45.2	96.04	2.12
76	82.7	44.89	0.54
116	99.4	275.56	2.80
112	107.6	19.36	0.18
68	88.4	416.16	4.70
108	116.2	67.24	0.60
128	114.7	176.90	1.54
112	113.8	3.24	0.03
112	109.0	9.00	0.08
33	24.4	73.96	3.03
39	29.4	92.16	3.13
39	31.8	51.84	1.63
48	26.1	479.61	18.40
24	34.3	106.09	3.09
21	33.9	166.41	4.90
18	33.6	243.36	7.24
24	32.3	67.24	2.09
42	24.6	302.76	12.31
36	29.6	40.96	1.38
28	32.0	16.00	0.50
34	26.4	57.76	2.20
26	34.6	73.96	2.14
26	34.2	67.24	1.96
26	33.9	62.41	1.84
30	32.5	6.25	0.19
17	6.9	102.01	14.78
7	8.2	1.44	0.17
6	8.9	8.41	0.94
15	7.3	59.29	8.12
5	9.6	21.16	2.20
5	9.5	20.25	2.13
7	9.4	5.76	0.61
7	9.0	4.00	0.44

$X^2 = 205.37$

Table 56

Number of degrees of freedom (df) = number of choices per statement - 1 x number of statements. Therefore for analysis of statement 29 df = 5 - 1 x 8 = 32.

From the X² distribution tables (Neave 1979) X² with 32 df at the 1% level = 50.89. Therefore, from table 56 above X² = 205 - 37 which is well above the 50 - 89 required for significance at the 1% level.

CHI. SQ. ANALYSIS OF H.O.D. SURVEY

STATEMENT (v), (vi) and (vii)

STATEMENT 29	Score No x		Score No x		Score No x		Score No x		Score No x		Row Totals
	5	No	4	No	3	No	2	No	1	No	
(v)	80	16	108	27	24	8	26	13	5	5	243
(vi)	60	12	128	32	21	7	26	13	5	5	240
(vii)	75	15	112	28	18	6	26	13	7	7	238
Column Totals	215		348		63		78		17		721

GRAND TOTAL

Table 57

O	E	(O - E) ²	$\frac{(O - E)^2}{E}$
80	72.46	56.85	0.78
60	71.56	133.63	1.86
75	70.97	16.24	0.23
108	117.28	86.11	0.73
128	115.84	147.86	1.28
112	114.87	8.23	0.07
24	21.23	7.67	0.36
21	20.97	0.0009	0.00004
18	20.79	7.78	0.37
26	26.28	0.08	0.002
26	25.96	0.002	0.00006
26	25.74	0.068	0.003
5	5.72	0.52	0.09
5	5.65	0.42	0.07
2	5.61	1.93	0.34
		X ²	6.71

Table 58

Df = number of choices per statement - 1 x number of statements.

Df = 5 - 1 x 3 = 12.

From the X² distribution tables (Neave 1979) with 12 df, the X² value calculated from table 58 is not significant at the 10% level, and it is concluded that the distribution of choices for statement 29 (v), (vi) and (vii) to be a chance distribution.

CHI. SQ. ANALYSIS OF EFFECT OF AGE
ON PUPILS SCORE

Calculation where observed (O) = mean percentage for each age range and expected (E) = mean score for all age ranges. Df = number of age ranges - 1 = 3.

O	E	(O - E) ²	$\frac{(O - E)^2}{E}$
19.04	23.06	16.16	0.70
20.40	23.06	7.07	0.31
24.00	23.06	0.88	0.04
28.80	23.06	5.74	0.25

$$X^2 = 1.3$$

Table 59

From the X² distribution tables (Neave 1979) with 3 df X² value from table 59 is not significant at the 10% level. Therefore there is no significant difference between the mean score of each age range.

APPENDIX VII

ASTRONOMY APPARATUS IN SCHOOLS

ASTRONOMY APPARATUS IN SCHOOLS

H.O.Ds' responses to question 14, p2 of the H.O.Ds' survey.

APPARATUS	NO. OF SCHOOLS POSSESSING APPARATUS	NO. OF SCHOOLS TEACHING ASTRONOMY	NO. OF SCHOOLS WITH ASTRONOMY CLUB
SLIDES ABOUT ASTRONOMY	43	26	2
ASTRONOMICAL CHARTS	34	28	1
STAR GLOBES	16	12	-
FILMS OR VIDEO TAPES ON ASTRONOMY	27	16	2
SMALL PLANETARIA	6	3	1
PLANISPHERES	2	-	2
TELESCOPE	34	0	2

Total number of schools with astronomy apparatus = 74.8%.

37% of the schools surveyed have two or more pieces of astronomy apparatus and do not feature astronomy in their curriculum.

APPENDIX VIII

EXAMPLES OF PUPILS' RESPONSES
TO THE INTERVIEWS

To prevent repeating pupils notions and supporting diagrams, a representative sample of the 20 pupils' responses to the interview are included in this appendix.

Interviews with the pupils about the four domains investigated involved the use of drawings, models and verbal descriptions.

Because teachers were concerned about their pupils missing time out of their normal lessons, the interviews were kept to about four minutes each.

Robert age 9 years

Rb=Robert R=researcher.

R. How do you know when it's night Robert ?

Rb. You've got to put lights on.....it gets dark.

R. Why does it get dark?

Rb. The Sun goes away.

R. Where does the Sun go at night then Robert ?

Rb.I don't know.....(thinks again)....I don't know.

R. What else do you know about the night?

Rb.well the Moon comes out..... and there's clouds.

R. Do the clouds make it go dark ?

Rb. Yeait's the clouds because it goes dark.

R (brings out globe, torch and Moon shape and explains to R. what each represents)

Can you use these to show me how it gets dark at night?

Rb.(looking for the switch on the torch) The Sun goes out.

R. How does the Sun switch out?

Rb.(thinks and moves each piece of apparatus)the clouds and Moon cover it.

Comment

Robert has no concept of orbital motion and does not appear to have put much thought into the cause of day and night prior to this interview. The researcher appears to have led him into an idea which, to Robert, worked.

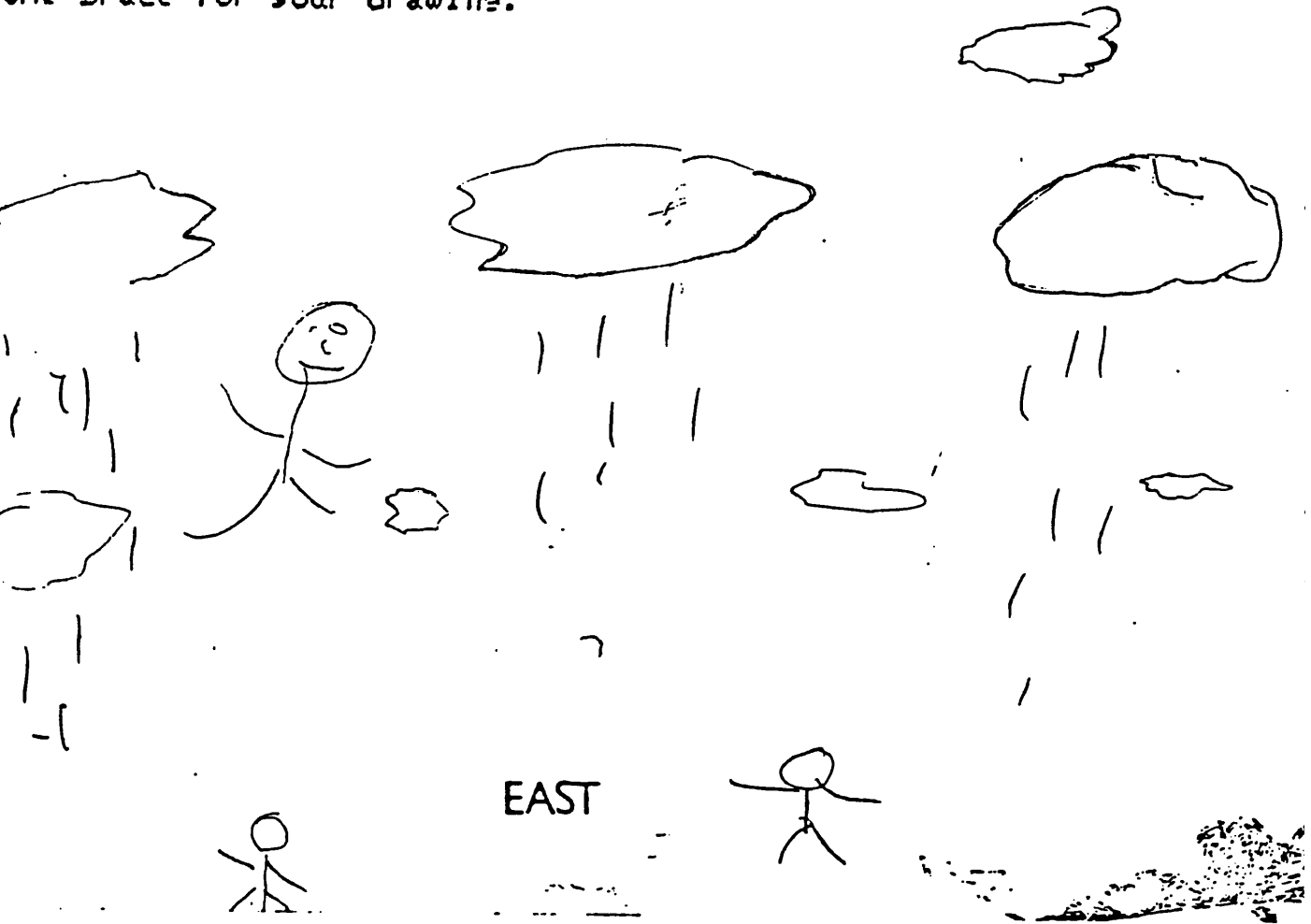
ASTRONOMY KNOWLEDGE

23

J. 10/11

is Doreen Lang age 10

the space for your drawing.

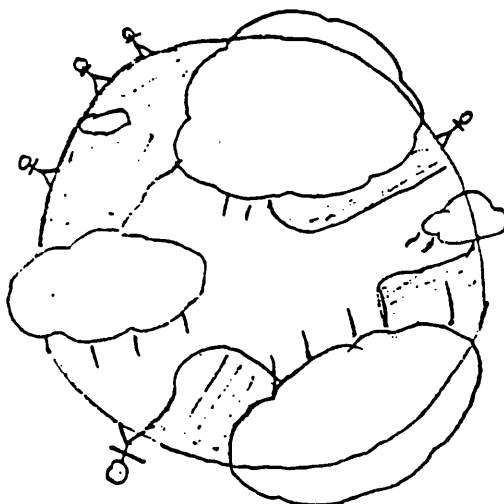


ASTRONOMY KNOWLEDGE

J. 10/11

is Catherine Whitfield (3B7) (3E) 14/6/11

the space for your drawing.



18
34

Darren age 10 years

D=Darren R=researcher

Interview after Darren had drawn his diagram of the Earth.

R. If this person travels a long way in this direction, where will he go? (points off the page).

D.thinks.....Another place.

R.And if he travels this way ? (points off the page in the opposite direction).

D. Anotherhot place.

R. Could he go on travelling for ever?

D.....(thinks for some time).....No.....its got desert.....and sea too.

R. If this person dug a hole in the ground, very deep, and then went down the hole, will he get to a country?

D.....(thinks).....No, there's rock.

R (Shows D. a satellite picture of Earth) What is this a picture of Darren?

D.(Without hesitation) Earth.

R. Can you point to where you and I are?

D.(Points to a position between the equator and the North pole)

R. Can people live here? (Points to Australia).

D.....(long wait).....I don't know.

Comments

Although Darren's notion of the Earth in space appeared to be at a very early stage of development, he was able to recognize a satellite image of the Earth. He appears to be functioning in two domains; that of his immediate sensory impressions , and that of the scientific world. The interview was not continued to investigate this because Darren was beginning to become agitated.

Catherine age 14 years

C=Catherine R=researcher.

After C. had produced her drawing of the Earth, the following interview took place.

R. If the person drawn in Australia threw a ball up a long way, show which way it will go?

C. It goes up like this. (uses the back of a pencil to trace the ball's path correctly).

R. Which way is down for this person?

C. This way. (points towards the centre of the Earth.).

Comments

This short interview and Catherine's diagram, demonstrated that she has a concept of the Earth in space and gravity which is in accord with the accepted view.

Steven age 11 years

S=Steven R=researcher.

R. If the person you have drawn throws a ball, which way will it go?

S. Up. (Traces path with his finger).

R. Could the person throw the ball up to this line? (points to the sky like arc).

S. No.

R. Why not?

S. It's the sky and it's too high up.

R. What is here? (Points to region beyond Steven's sky).

S....(thinks).....Well.....its.....its up in space.

R. What's here then Steven? (Points to area beneath the diagram)

S. It's earth.

R. Where is Australia?

S. Around here. (Points behind the central dome of his diagram.)

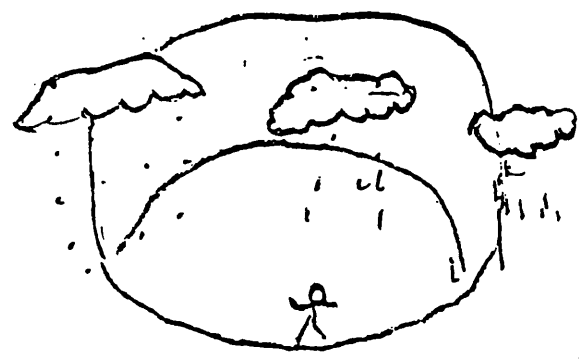
Comments

Steven appears to view the Earth as being a dome shape, with countries around this dome. His notion is similar to the ancient Egyptians who thought that the sky formed a dome shape which was spread over the Earth.

Ben age 10 years.

is steven Beckman Age 11

the space for your drawing.



ASTRONOMY KNOWLEDGE

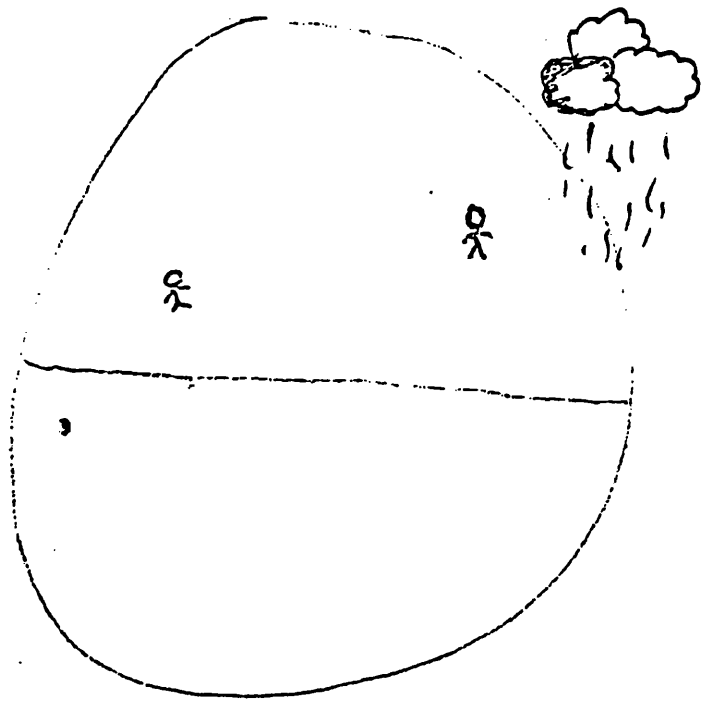
2 11

J, 10/11

is Ben Beale Age 10

the space for your drawing.

10



B=Ben R=researcher.

R. Do clouds ever form here Ben? (Points to Southern region of Ben's diagram).

B. No.....clouds are here. (Points to Northern hemisphere).

R.Can people live here. (Points to position below the equator).

B.....long wait.....I don't know.

R.(Showing a globe with a doll placed on Australia) Can people live here?

B.Nono..I don't think they can.

R. Why not Ben?

B. They would'nt be able to stand up.

Comments

Ben's world view appears to be like that of the early Church fathers (see chapt 1). He accepts that the Earth is round, but does not visualise people living on what he considers to be the bottom half.

Julie age 11 years

J=Julie R=researcher.

R. Julie, you have drawn two circles, which one is the Earth.

J. (Without talking she places an E on the left hand sphere)

R.(Drawing sketch of people on the South pole and the equator) Can people live here?

J. No.

R. Can you tell me Julie, why people can't live here?

J.They'll not stand up properly.

R.Can these clouds move from here to here? (Points from left sphere to right one).

J. Yes.

R. How do they get there?

J.....Well.....well its the weather that blows them.

R.Could I live here? (Points to the other sphere).

J.Yes.

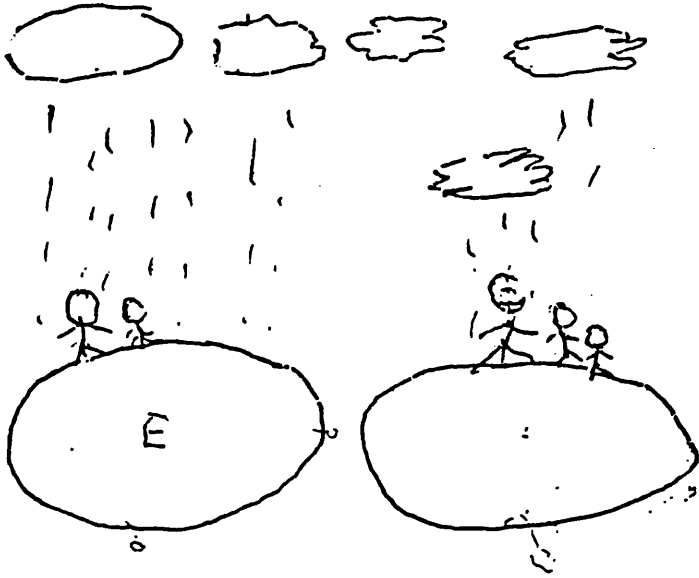
R.Have you ever been here? (Pointing to the right hand sphere).

J.No.

is Julie Skerm age 11

the space for your drawing.

8



R. How could I get there then Julie?

J. In a rocket.

Comments

Julie (in a similar way to that reported by Nussbaum (1979) visualises two worlds. However, unlike Ruth - same age as Julie- in Nussbaum's report, both of Julie's worlds are round.

Julie was the only pupil in the sample who exhibited this dual world view.

Stuart Age 12

3

If they did not change there would not be
many seasons like Christmas Easter, + it
be cold or hot ^{most of the} year.
(It might just be the way earth turn around).

Wendy Age 11½

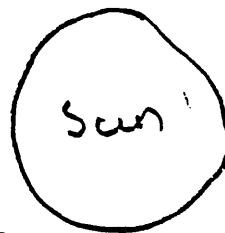
Wendy Age 11½

5 they say because in the summer
is a bit further away and
in the winter it is closer
because the sun is a
halfway away

CLIS:A2

WID AGE 10 YEARS

1. So we can sleep at night and do
things in the day.



The Seasons

Stuart age 12 years

S=Stuart R=researcher.

R. Stuart, in your explanation you say that the celebration causes the seasons.

S. That's what I thought.....it could be something else though.

R. Can you explain to me how christmas can make it winter?

S.....(thinks).....I can't.....I don't know.....that's what I wrote.....but it could be something different.

R. What else could it be ?

S Maybeperhaps the Earth turns andand a bit goes into winter.

R. (explains the Earth and Sun balls props) Stuart, can you use these to explain how we get different seasons?

S. (Handles the props).....I.....I don't knowis the Sun further away?

Comments

Stuart first explains the seasons in terms of the celebration he associates with the particular season. When asked to explain how his idea worked, he had to formulate a new idea as his original notion did not hold up when challenged.

Wendy age 11 .5 years

W=Wendy R=researcher.

R (Explains the props) Can you use these to tell me how we get the seasons?

W.(Handles props and thinks).....This.....well this is Earth (picks up green ball) and here is the Sun (picks up red ball). It's this one , the Sun , moves away in the winter.

R. What about the summer?

W. The Sun moves closer.....I thinklike this.

R. Does the Sun move in a straight line or does it move in a circle?

W.(thinks).....No.....like this (moves Sun straight towards the Earth).

Comments

Wendy's explanation is quite commonly held with children and adults. She has not yet taken on the idea of orbital motion to explain the motion of the astral bodies.

David age 10 years.

David=D. R= researcher.

R. David, you say that we get night so that we know when to go to bed, but why does it go dark?

D. (Pointing to the Moon in his diagram) This is it... theit's the Moon makes it dark.

R. How does it do this?

D. I thinkIts moving up (using back of pencil to trace the Moon's path straight up between the Earth and the Sun).

R. When the Moon is up here, (points to top of diagram) where does it go?

D. Goes back here.....like this (traces path back down to original position)

R. Does the Sun and Earth move?

D.....(thinks).....I don't know.....I don't think they can.

Comments

David first explained day and night in terms of indicating to him when to go to bed. The Moon was seen as the cause of darkness by casting its shadow on the surface of the Earth. From this interview it appears that David has no concept of orbital motion.

Philipa age 10 years

Philipa=P. R=researcher.

R. Is the Earth you have drawn, round like a ball or round like a saucer?

P.(thinks).....It's like an egg shape.....I wanted to draw it looking round.

R. (Showing P. a ball and a saucer) But is it round like this (pointing to the ball) or round like this (pointing to the saucer).

P. (without talking she points to the saucer).

R. Placing a small doll on one side of the saucer) Move the Earth to show me how this doll gets day and night.

P. Well...the Sun's here (pointing over the doll).....this moves(turns the saucer) and it's night.

R. In your drawing you have shown the Moon. Can you show me where this is?

P. This is at nighthere.

R. Does the Moon move?

P.(thinks).....No.....I don't think so.....I don't know.

Comments

Philipa has explained day and night from a flat Earth perspective. The Sun is fixed, and the Earth spins. The Moon is equated with night, but she is unsure about it moving.

Mary age 10 years

Mary=M. R=researcher.

R. (Explains the Earth and Sun ball props) Mary, you have drawn how we get day and night, now can you use these balls to show me how it happens?

M. I think it's this (Holds Sun in one hand and orbits Earth around the Sun).

R. (Places a pin in the Earth ball and explains to Mary that this represents a person).

Move the Earth to make the person be in the day.

M. (orbits the Earth until the pin faces the Sun) This is day....now.

R. Now show me night.

M. Thats here (moves Earth until pin faces away from the Sun).

R. How long does it take the Earth to go around the Sun.

M. A Day.

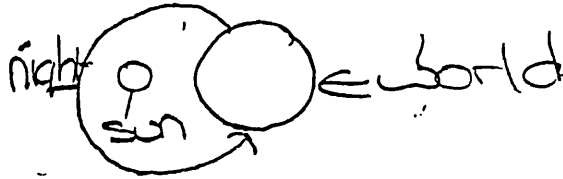
Comments

Mary manipulated the models in complete accordance with her diagram. She sees astral bodies as having orbital motion, but does not include any spin on the Earth's axis. For Mary, the Earth takes one day to orbit the Sun.

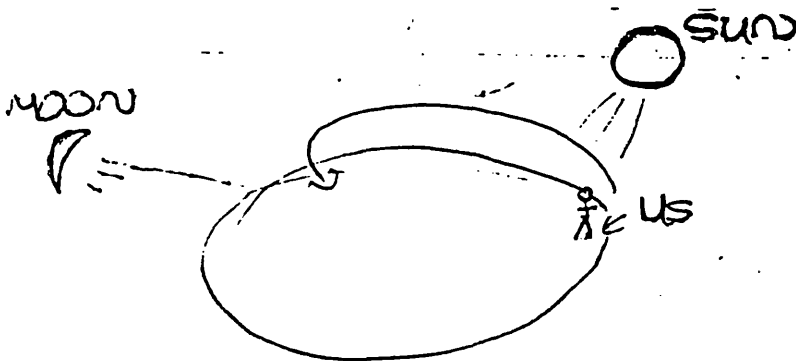
DAY 9 NIGHT

MARY Age 10

The world moves around to
get dark for the night
and light for the day

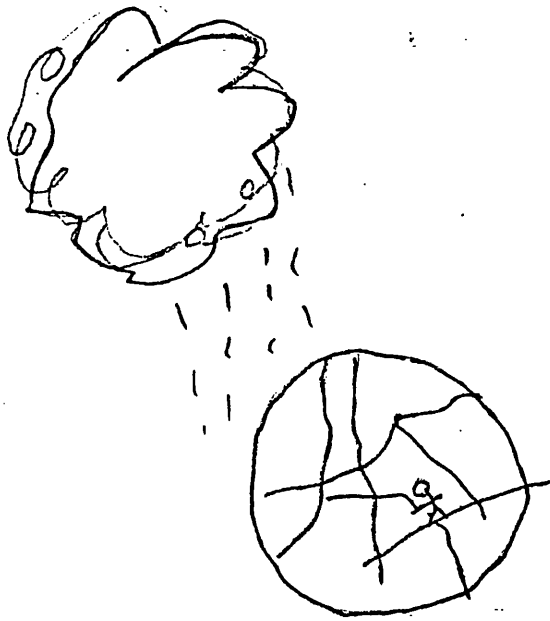


Philipa age 10 year



our world goes around and the sun
shines on us and then the moon
shines on us.

class
Note the
disc shaped Earth which spins like a saucer shape.



Claire Hawking
10 years

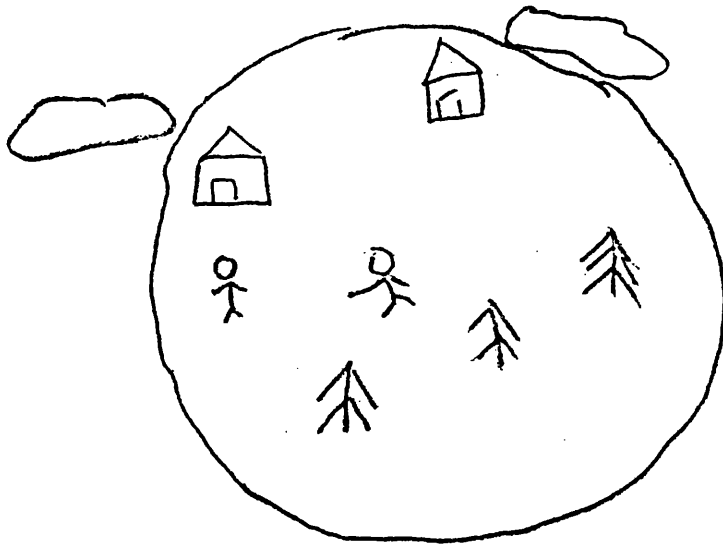


Jane Mulken
9 years

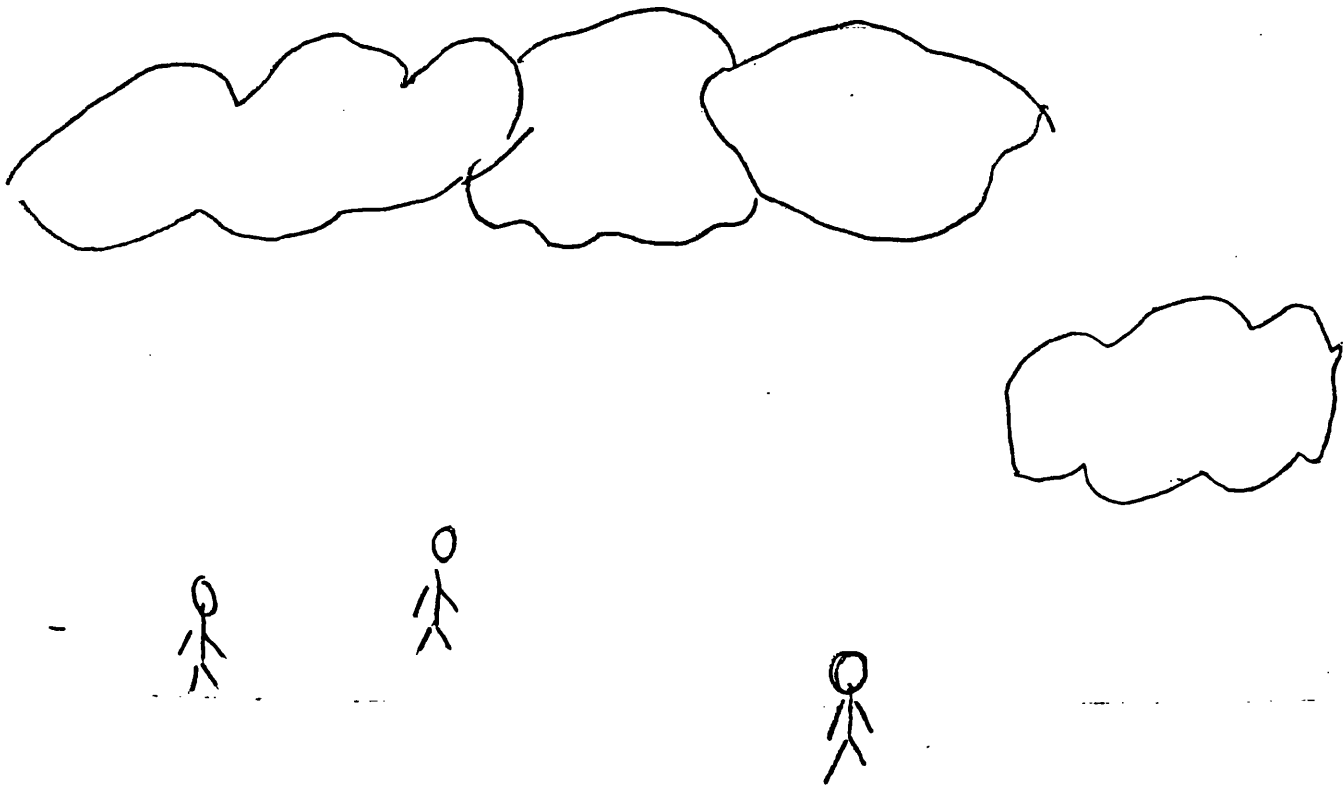


EARTH IN SPACE

Shelley Bill
10 years



Alex Opie
9 years



EARTH IN SPACE

9 I think the moon changes its shape because the planet next to it keeps on moving forwards and backwards covering and uncovering the moon.



and when there is no moon at all its because the other planet is covering it

10

The moon seems to change shape by where the earth is. If we are at an angle to the moon it may look curved if we see it straight on it may be rounded.



straight on.

11

The moon changes shape because the earth gets in the way of the suns rays.



ASTRONOMY KNOWLEDGE

10

J.10/11

name is Christina Smith Age 10

Use the space for your drawing.



ASTRONOMY KNOWLEDGE

8

J.10/11

name is Amelia Catchard Age 10

Use the space for your drawing.



West

North

SUN

ASTRONOMY KNOWLEDGE

J. 10/11

Name is Rachael Isaac (21/11/97)

14 YEARS

Use the space for your drawing.



ASTRONOMY KNOWLEDGE

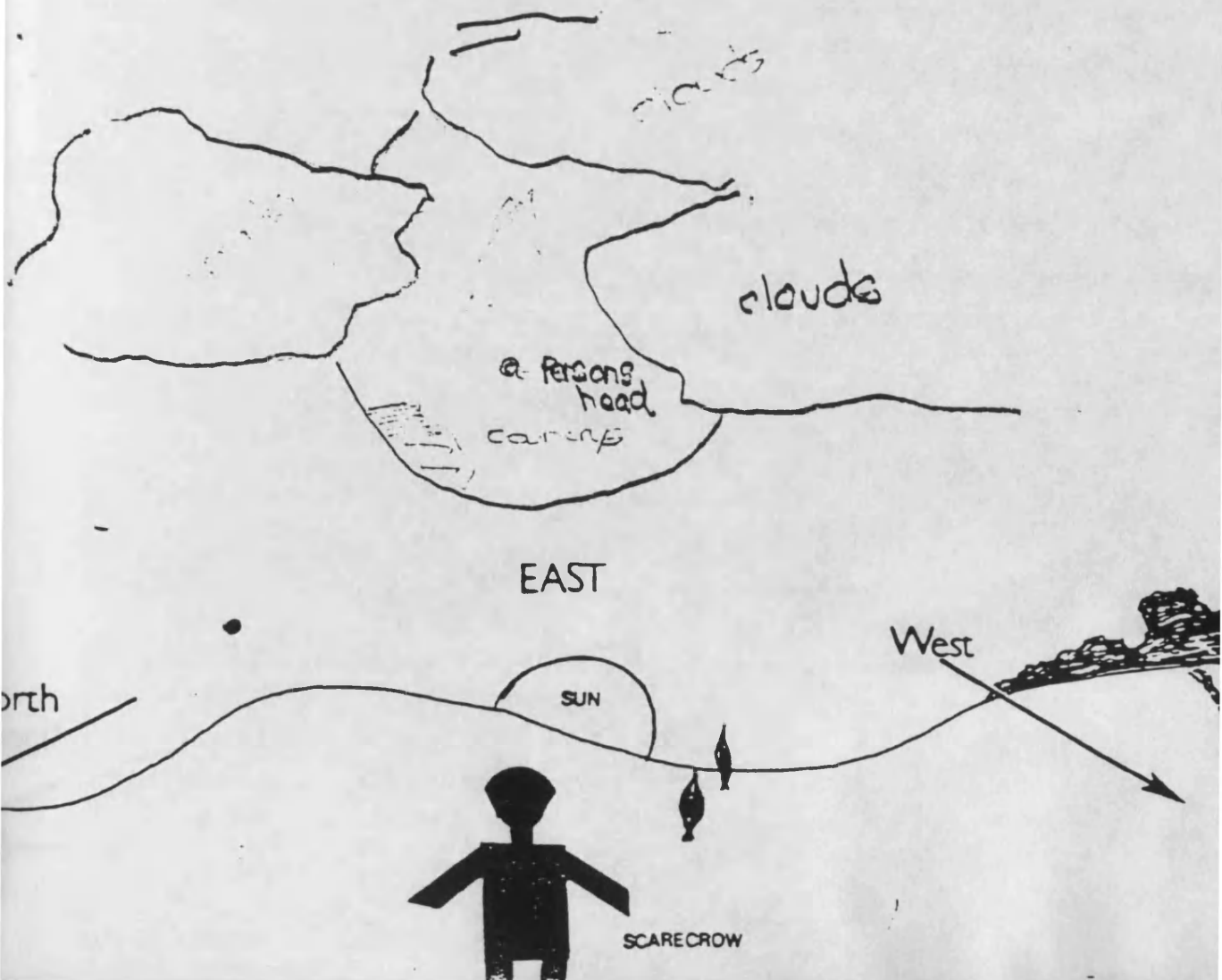
9

J. 10/11

Name is Rachael Isaac (21/11/97)

14 YEARS

Use the space for your drawing.



ASTRONOMY KNOWLEDGE

23.

J, 10/11

name is JEFF PREVOST (3CA) 3F Age 14

Use the space for your drawing.

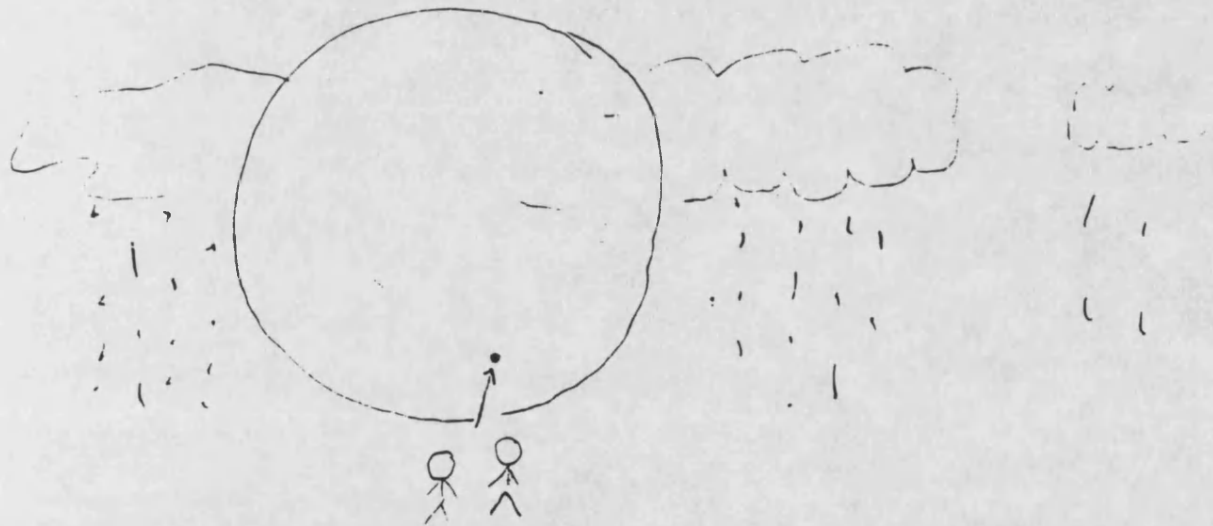


ASTRONOMY KNOWLEDGE

J, 10/11

name is Sally Chommon 3LB 3F 14 YEARS

Use the space for your drawing.



ASTRONOMY KNOWLEDGE

J, 10/11

name is Gracy Shapland Age 14

10

Use the space for your drawing.



EAST

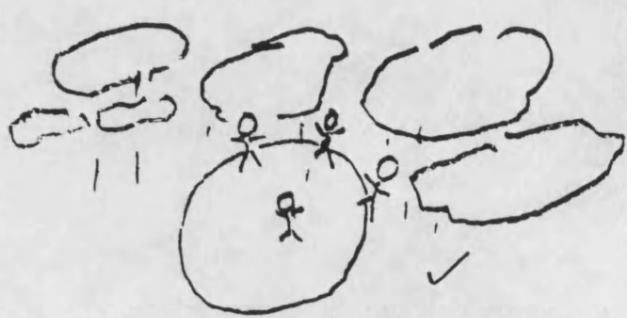
ASTRONOMY KNOWLEDGE

15

J, 10/11

name is Emme Bullard (2007) Age 15 960734

Use the space for your drawing.



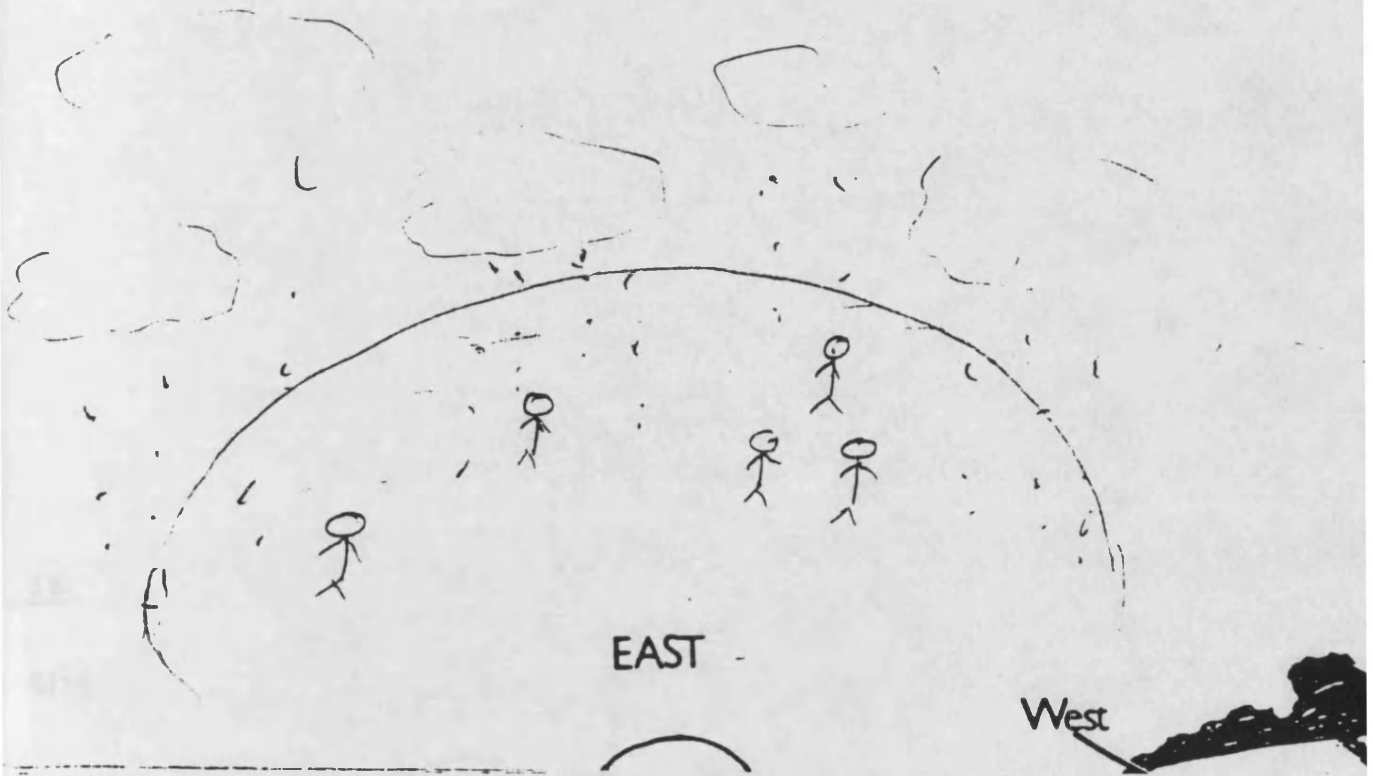
EAST

ASTRONOMY KNOWLEDGE

J. 10/11

name is Sally Blackburn Age 13

Use the space for your drawing.



ASTRONOMY KNOWLEDGE

J. 10/11

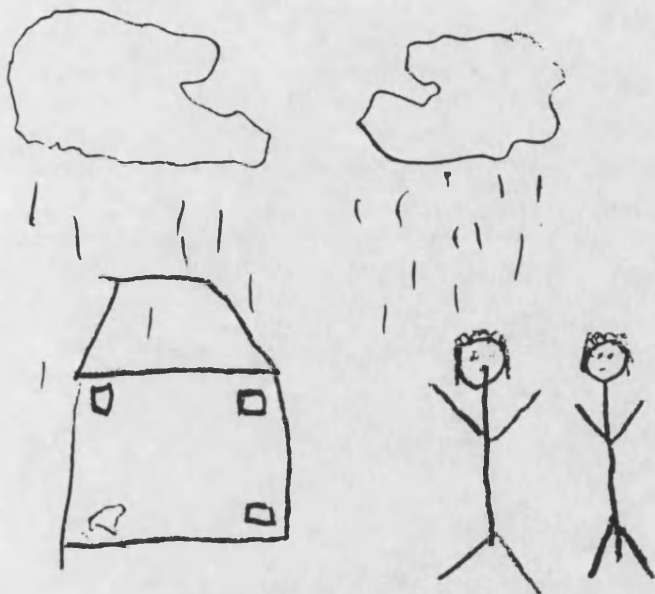
name is ELIZABETH CLAFFORD Age 16

Use the space for your drawing.



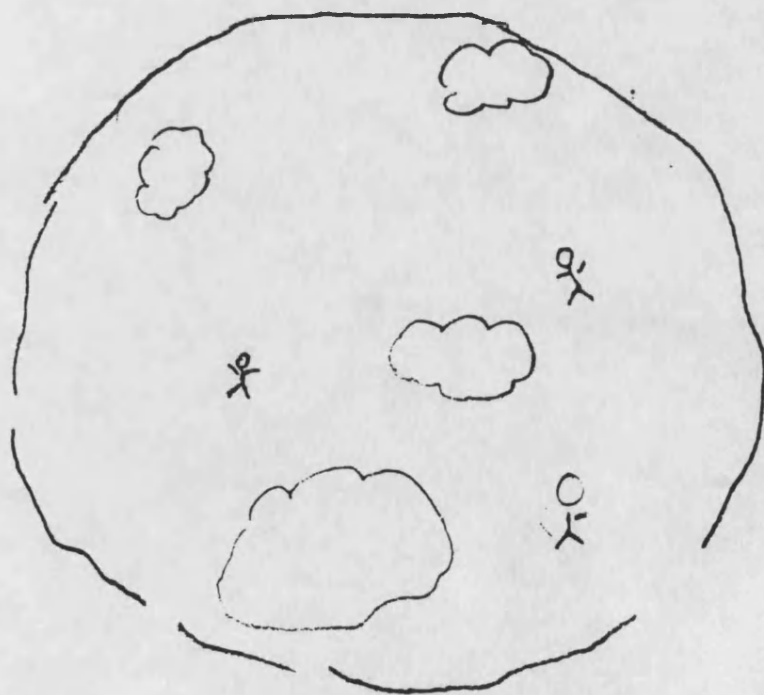
is Melanie Angell age 10

the space for your drawing.



is Melissa Chatfield 11 years old

the space for your drawing.



EAST

West



SUN

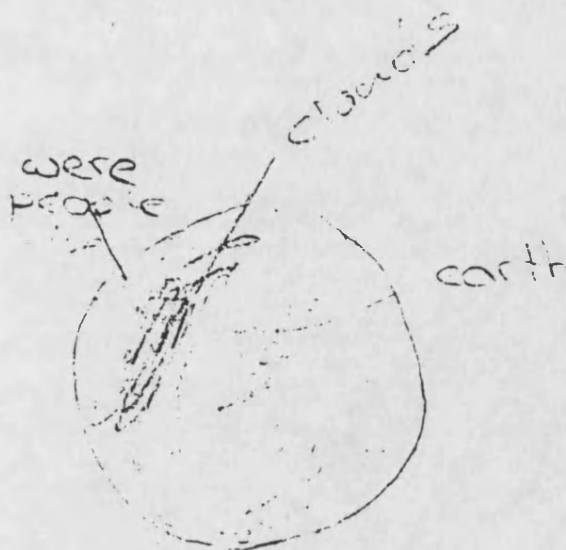
ASTRONOMY KNOWLEDGE

J. 10/11

name is Jennifer Barton

Age 12

Use the space for your drawing.



ASTRONOMY KNOWLEDGE

10

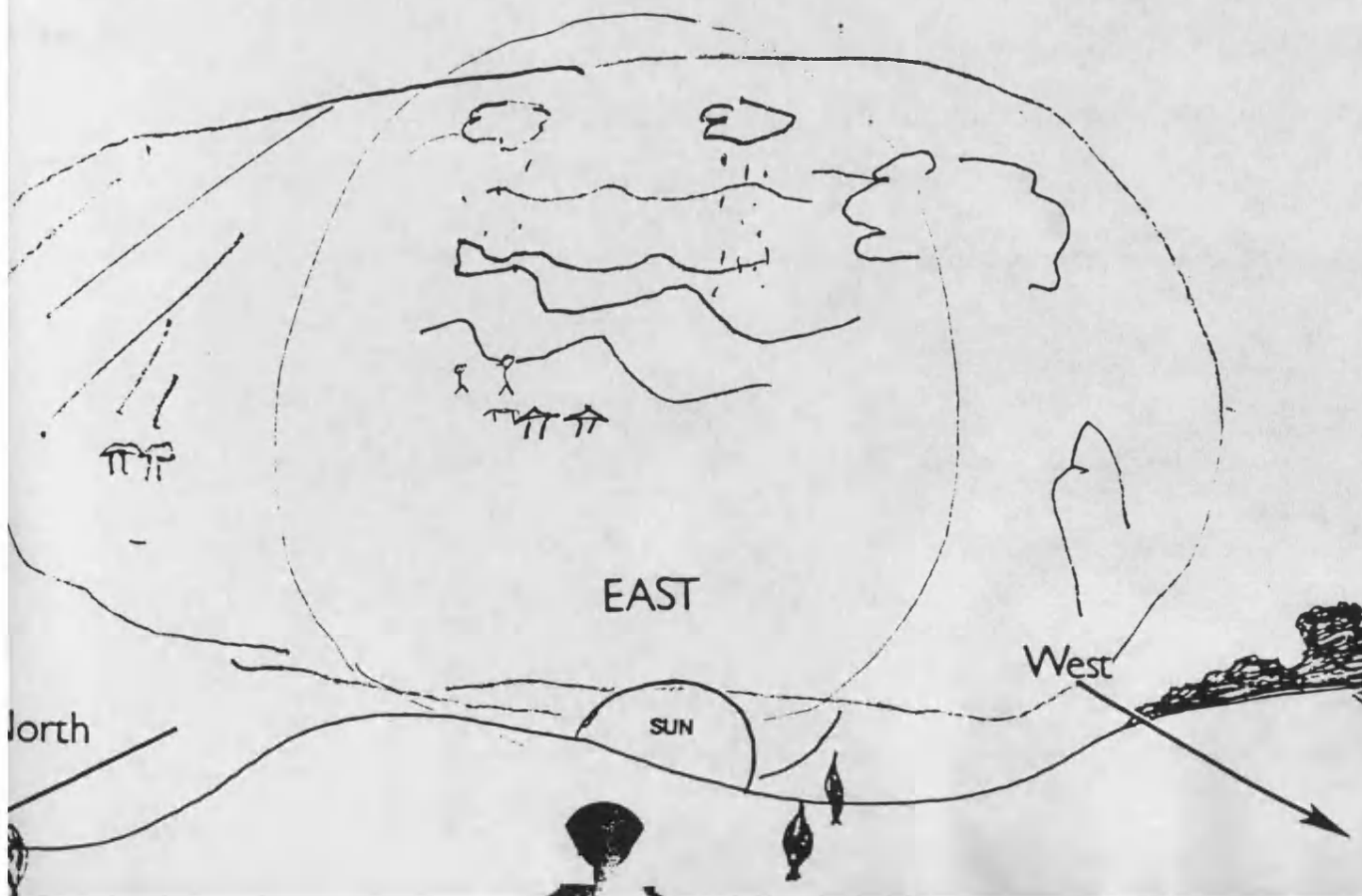
J. 10/11

name is

Lucy Eveleigh

age 10

Use the space for your drawing.



ASTRONOMY KNOWLEDGE

J. 10/11

name is Amanda Buxton 24.12.74

13 years at time of test

Use the space for your drawing.

12/30



ASTRONOMY KNOWLEDGE

J. 10/11

name is Joanne Dafforn

28.9.74

10

13 years at time of test

Use the space for your drawing.

gemland



EAST

ASTRONOMY KNOWLEDGE

J, 10/11

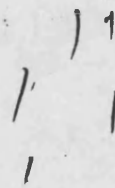
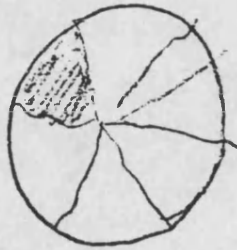
name is MARK THOMPSON

Age 15

9

14.10 months

Use the space for your drawing.



EAST

ASTRONOMY KNOWLEDGE

J, 10/11

name is Vilho Antton

17 years

1 month

10
34

Use the space for your drawing.



EAST

Phases of the Moon

12/11 year olds

6 we get the different shapes of the moon by the sun which shadows the moon at different place and makes the shapes different if its

7 The sun causes the different shapes of the moon. The sun covers the moon



8 We get the different shapes of the moon like a full moon, half moon or crescent, is because the moon is tilted on an axis and may turn a little so you can only see half or quarter

1 The sun makes the moon change shape by it moves across half of the sun & blocks a corner off, but you can't see the sun.



2 When it's dark all the clouds cover some parts of the moon up so it goes in to different shapes like this



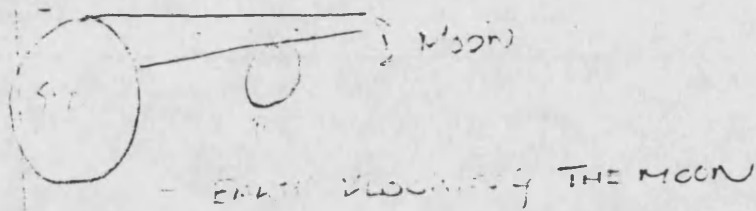
3 As ~~the~~ the moon turns different planets cover it to make different shapes.



4 The clouds might cover a bit of the moon and the clouds move so it might get bigger or smaller how big the clouds are.

5 The moon changes shape because the earth moves and some times get's in the way or it could be clouds.

PHASES OF THE MOON

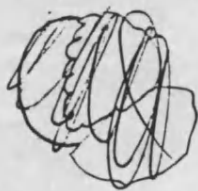


Male 10 years

2. The moon changes its shape because the sun goes behind it and blocks off the light and also I think it is to do with the seasons of the year.

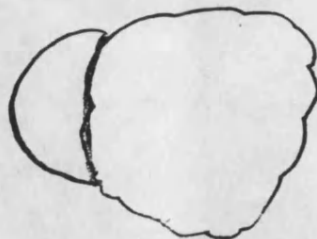
Female 10 years

the moon changes shape because the clouds shades it and you only see the part which hasn't been shaded.



Male 9 years

The moon changes shape because the clouds cover it.



Female
10 years

It could be what sort of day

Phases of the Moon

13/14 years old

12 The moon changes shape when the sun reflects on it in different places depend on which angle



13 It is behind clouds gradually comes out to see a full moon every so often



As the moon goes round the earth you can see less and less and then more and more

15 The moon changes its shape because ~~it is~~ wind from the sun gradually ~~to~~ full moon every so often, not always drawn.

Day and Night

13/14 years olds

11

We get day and night by the sun. At night it is round the other side of the earth in the day it's on our side.



12



13

In the ~~evening~~ the sun sinks and it becomes dark. In the morning it rises and it becomes light. Also the earth turns round at night so it is not facing the sun.

8 We get day and night from the time of year in winter it goes dark quickly as the sun and moon are going



© sun The earth might move round passing the sun, moon at different intervals

round the earth all the time and clouds sometimes hide them.

9 We get day by the earth spinning around and as it spins only part of it is seen the sun which is the day and the dark part is night as the earth spins the part that is light slowly becomes dark



10 We get day and night when the the earth spins round. And when the the certain part of the earth is facing the sun the other side is dark



Gradually spinning around

1 The ~~earth~~^{Moon} something how
move's and it blocks
the sun so it turns
dark very slowly. I don't do
know how it become light
probably the sun away but
in reverse.

2 we get day and that be cause the
world moves away from the sun
so that is night and if moves towards
the sun that is day.



3 on the day the sun is
out it may not be that
but it is out on the night
the sun is not out so it
is dark at night but on the
other side of the night world
it is hot because the sun
is on the other side of the
world

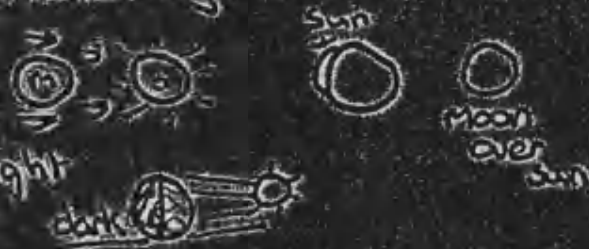
Day and Night

11/12 year olds

4

The sun lights up the earth in the day -
time. The moon move across in the time when
the sun is up and moves right in front of
it like an eclipse.

So half of the earth
in night and half is light



5

The sun lights up the earth so the earth is shining
brightly it comes over the hills and mountains
and when it starts to get dark the sun goes
back behind the hills and mountains.

6

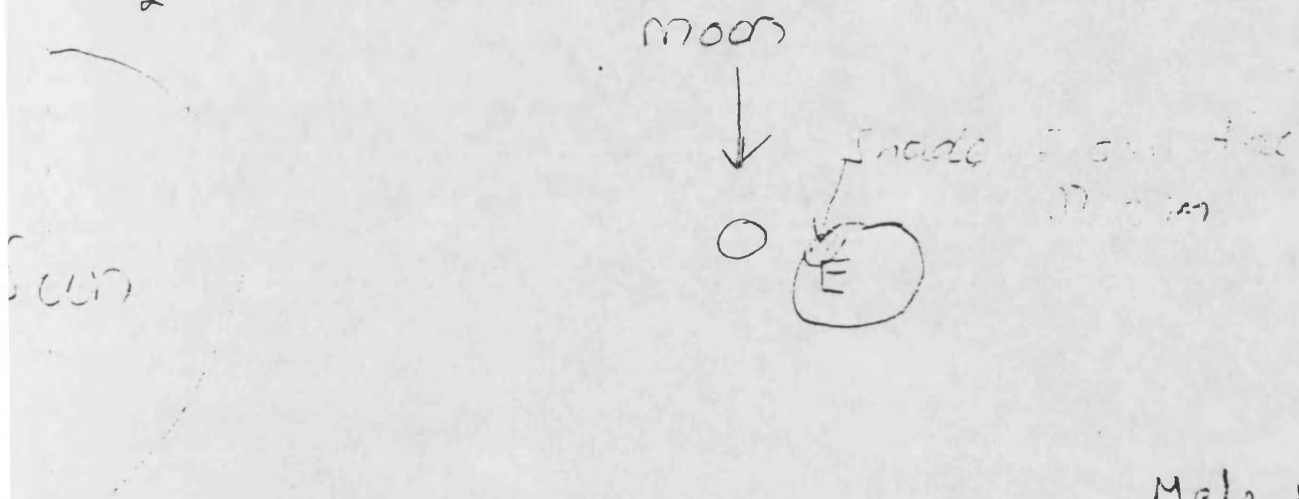
The Sun moves turning
round in half a day it
has nearly turned right round
so in a small turn
it's light and in a ~~big~~ full turn
it's dark

7

Because at night it gets so dark
and maybe the sun goes behind
a cloud

DAY & NIGHT

It is when the moon gets in front of the sun and stops us getting sun light and we call that night and then it moves and gives us the sun light and we call that day



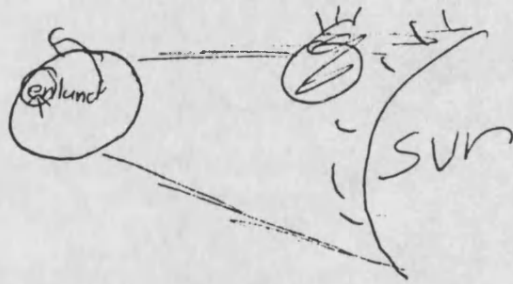
Male 10yrs

the moon shades bit of the Earth and that's why we have different times.

Male 9yrs

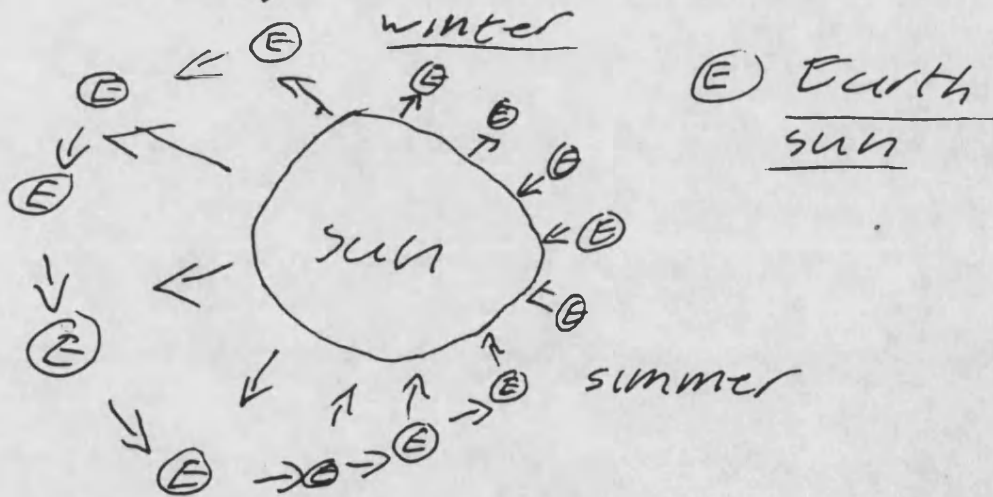
THE SEASONS

The seasons change because the world tilts as it is revolving round and the sun stays in the same place all the time. ~~and the~~ this is a picture.



Make 10 years

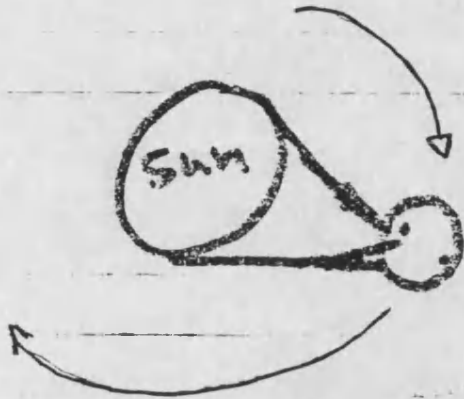
Earth going away from sun



Female 10 years

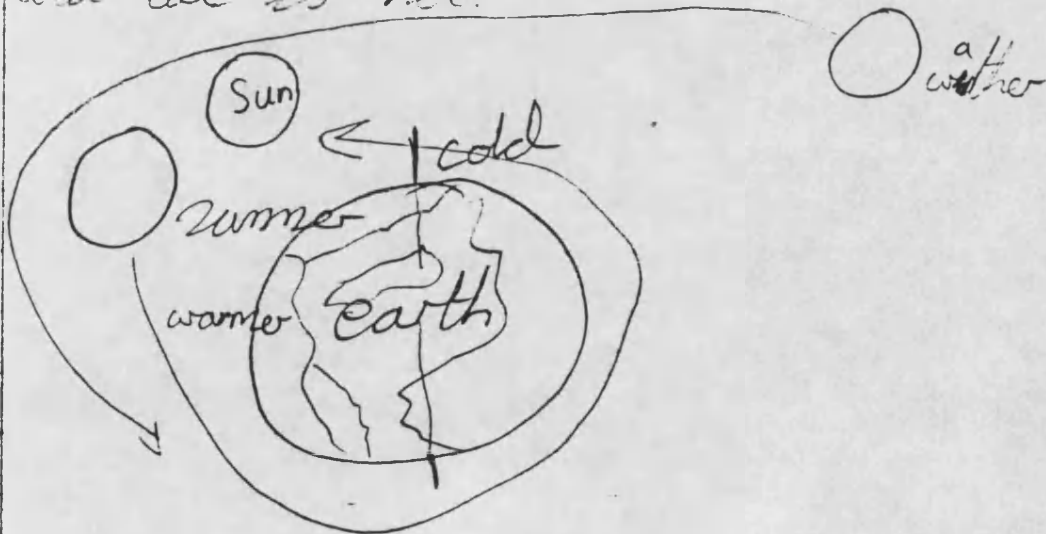
THE SEASONS

The sun shines in ~~in~~ ^{oastaler} and they have summer and we have winter.



Made 9 years

In the summer the sun is next to us and in the winter the sun is a long way away. So all the bright water comes and then go's some we have a summer and all is hot.



Made 10 years

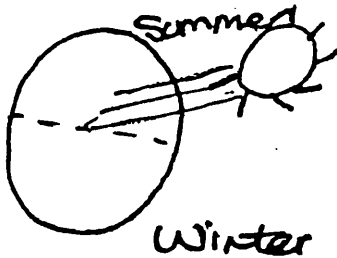
This pupil thought that the weather was an object (shown as O top right) which came closer to the Earth in summer.

Seasons

12/13 years old

6 we get these different seasons because as the earth moves around the weather changes when the sun moves around the earth.

7 we get the four seasons by the ^{sun} ~~the sun~~ moving around and if the ^{World} ~~the sun~~ moves away from ~~the sun~~ it will get colder and if the ^{World} ~~the sun~~ moves closer to a ^{Sun} ~~the sun~~ it will be warmer

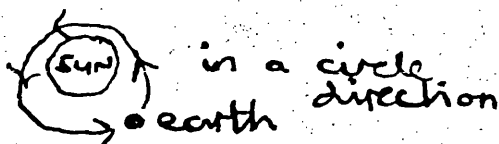


8 We get different seasons because ~~the~~ ^{as} as the earth goes round the sun different parts of the world are closer to the sun therefore they have summer the parts of the world that are not facing the sun have winter.

Seasons

13/14 years old

- 9 It's when the earth circles the ~~earth~~ sun and is further away at times



- 10 How do you think we get the different seasons? When the earth turns round, sometimes it moves away and the earth gets colder this is Autumn when it has stopped moving it's freezing this is winter. Then when it starts moving back this is ~~spring~~ Spring then when it stops altogether it is Summer.

- 11 As the earth goes round the sun its rays are slanted more in winter than in summer. Because the rays are slanted heat is lost. It is day when we are facing the sun and night when we're facing away.

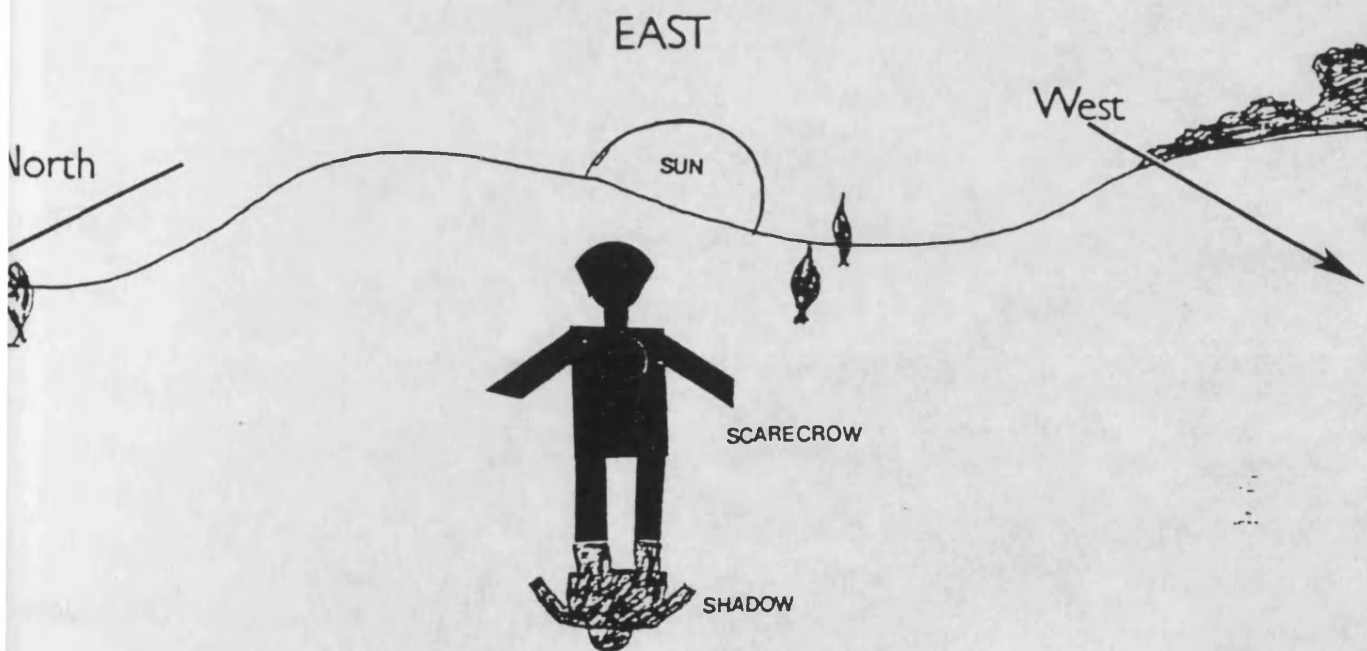
- 12 I think the seasons change because there is the clouds going round earth and it just happens that Britain gets winter in December, January etc. It is connected with the sun & moon.

APPENDIX IX

ASTRONOMY CONCEPTUAL SURVEY INSTRUMENT






Name is _____

Use the space for your drawing.



This is a drawing of a scarecrow early in the morning. Draw an arrow show which way its shadow will move throughout the day.






> We get day and night because the Earth goes around the Sun once every
9.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong






> Which diagram compares the real size of the Moon and Sun best ?

A	B	C	D
---	---	---	---

> The Earth turns around once a day to give day and night.

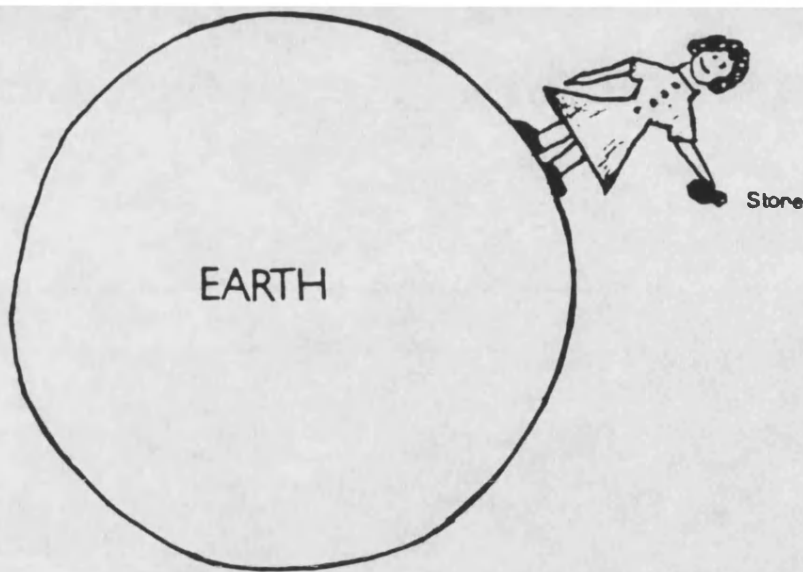
				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

> This is a diagram of sunset.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

> How many hours are there in one day ?

6	12	24	36	48
---	----	----	----	----



Draw an arrow to show which way the stone will fall if she gently lets it

The Sun goes around the Earth once a day to give day and night.

I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong






Which diagram compares the real size of the stars and Moon best?

A	B	C	D
---	---	---	---






Which diagram compares the real size of the Earth and Moon best.

A	B	C	D
---	---	---	---






2) Clouds cover the Sun to give day and night.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong






3) The stars stay in the same place throughout the night.

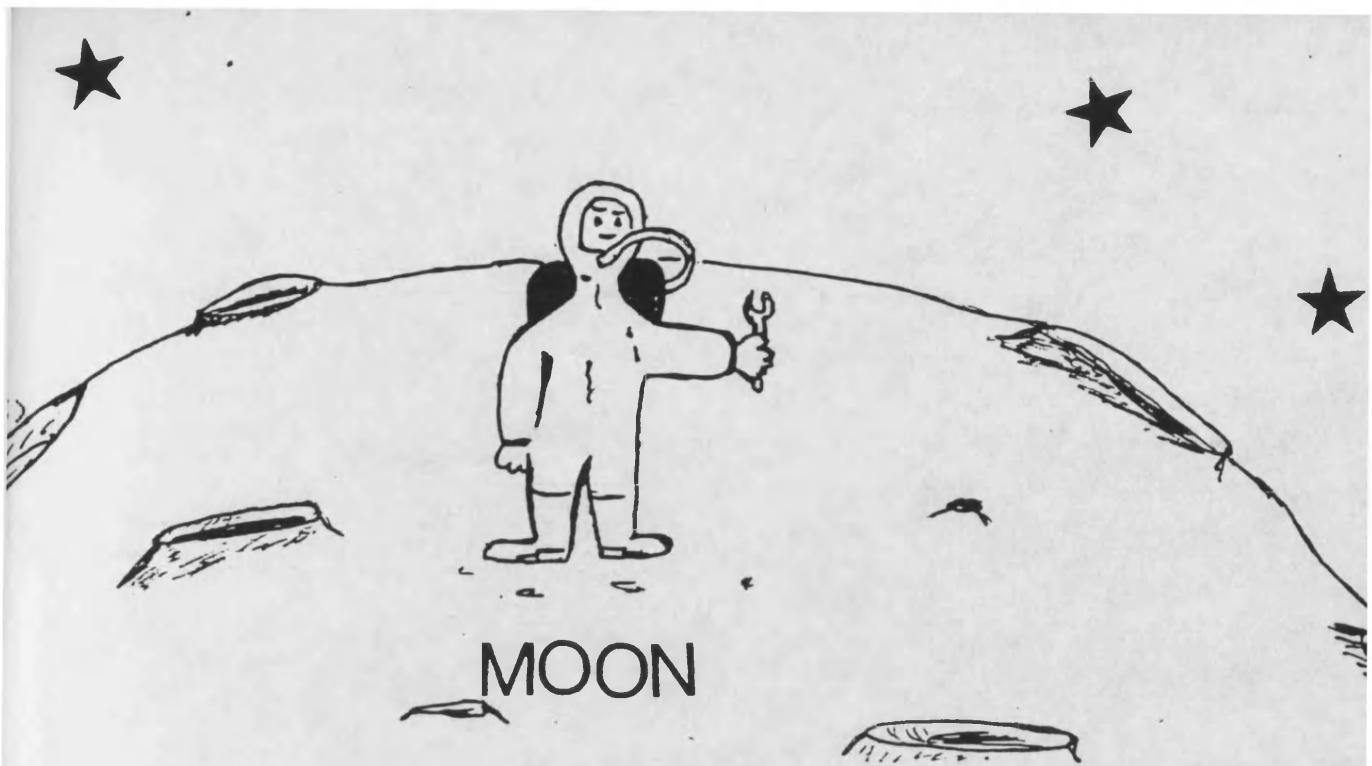
				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

4) It is cold in the winter because the Sun is further away from the earth.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

5) The Moon covers the Sun to give day and night.

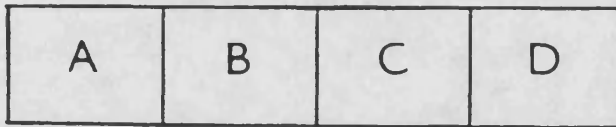
				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong



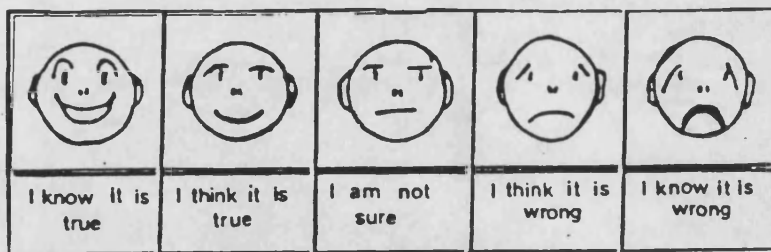
MOON

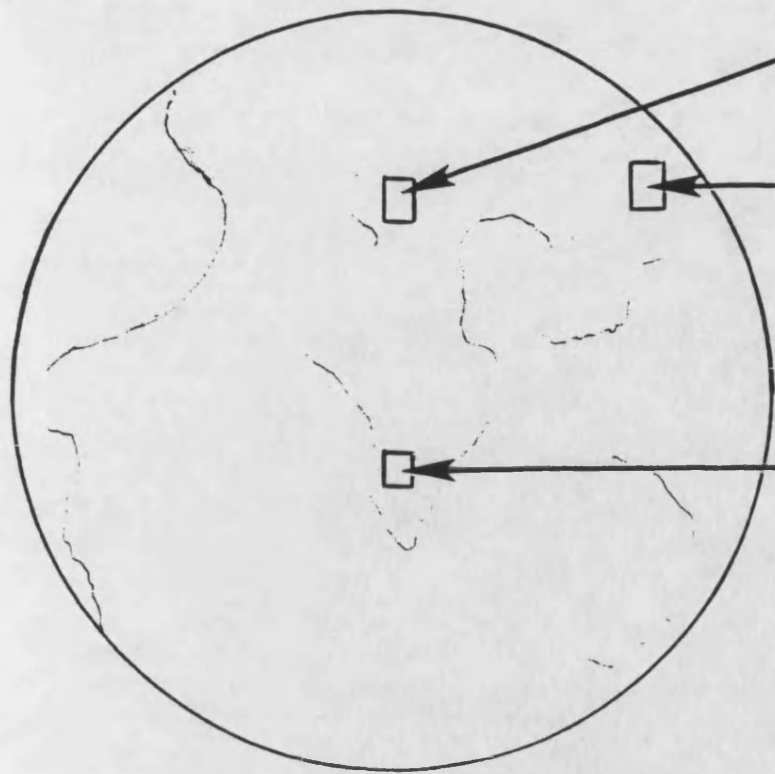
7) Draw an arrow to show which way the spanner will fall if he lets it go.

8) One part of our Earth has day while the other half has its night. Which drawing shows the correct day/night division?



9) It is cold in the winter because clouds stop the sun from shining.





asleep in middle of night



going to school



coming home from school



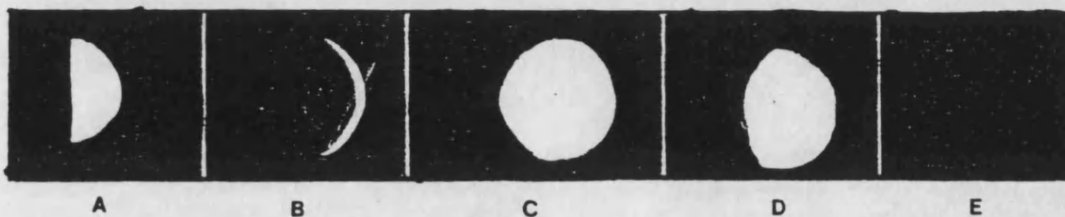
watching evening T.V.



8) It is cold in the winter because the north Pole tilts away from the sun.

I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

9) Tick the shape the person will see the moon make.



A

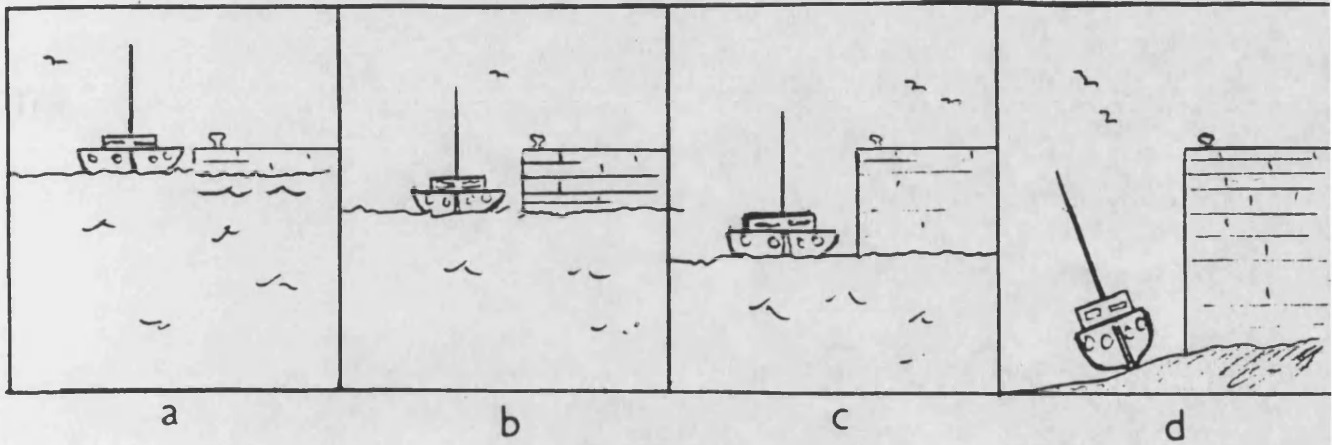
B

C

D

E

2) Tick the drawing which shows how the boat will look twelve hours later.



3)








4) This is a drawing of sunset.

I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong




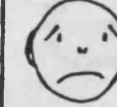
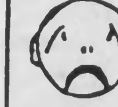
1) Which drawing compares the real size of the Sun and Earth best.

A	B	C	D
---	---	---	---

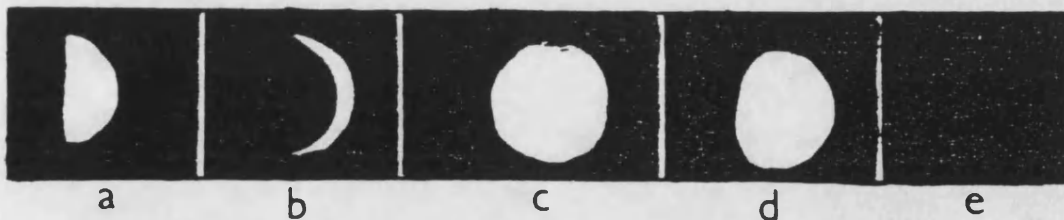
2) The Moon sometimes makes this shape in the night sky.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

3) The moon can sometimes be seen during the day.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

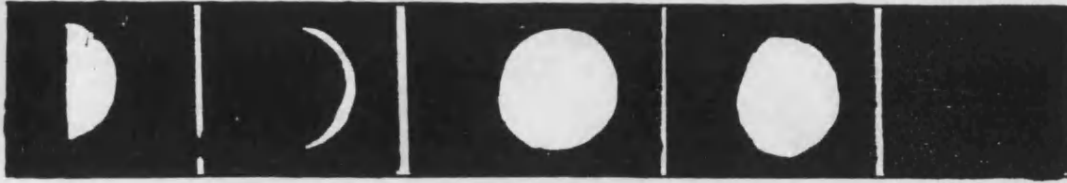
4) Tick the shape the Person will see the Moon make.



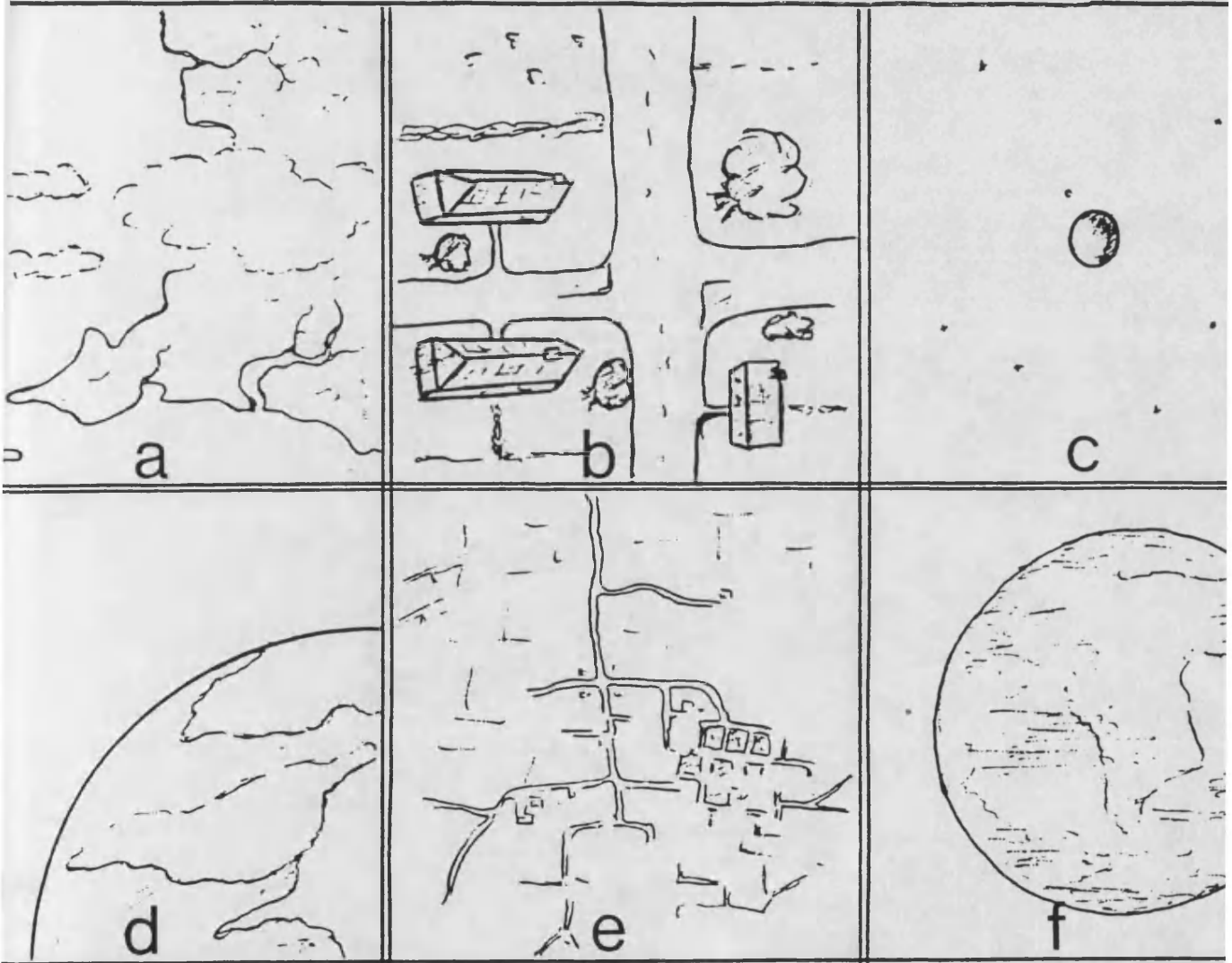
5) What do you think makes the tides go in and out ?

A	B	C	D
---	---	---	---

> Tick the shape the person will see the Moon make.

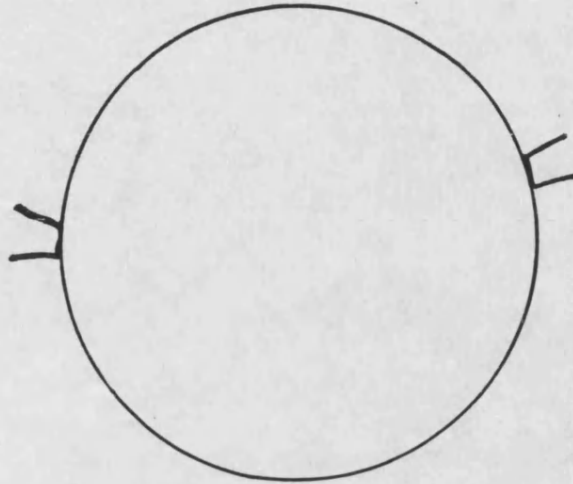


> Put the spaceman's view in order.



--	--	--	--	--	--

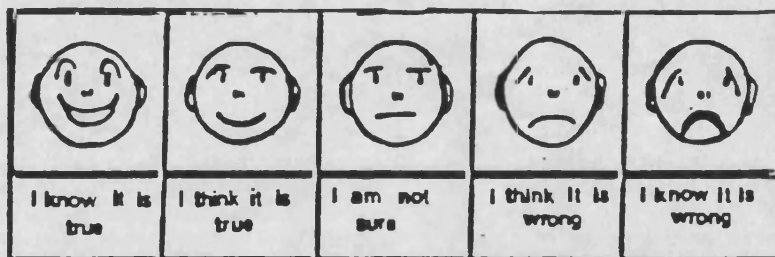
2)



Draw lines to show the water level if both the drinking glasses are half filled with water.

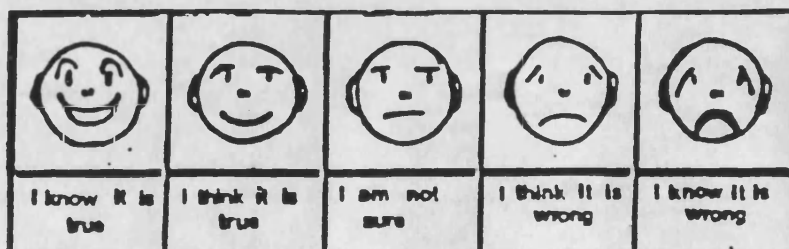
(33)

It gets dark at night because the Sun goes behind the hills.

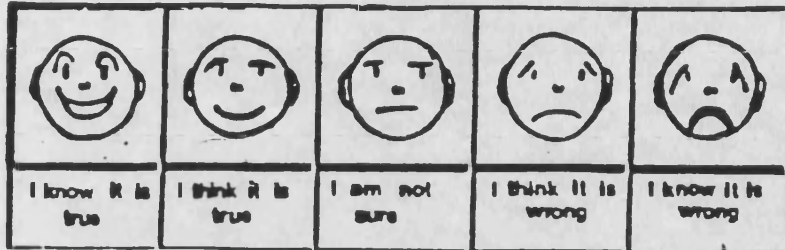


(34)

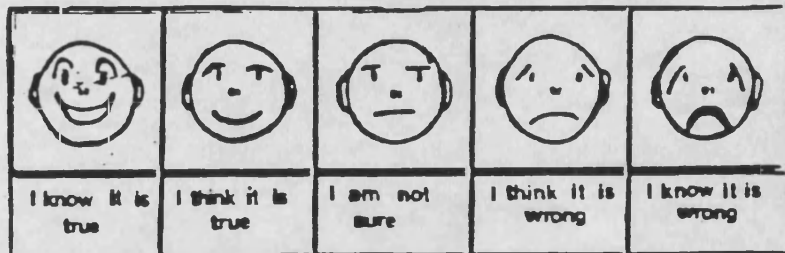
The Moon changes its shape from full, half, and crescent because different amounts of the lit half are visible from Earth.



- (35) The Moon changes its shape from full, half and crescent because the clouds cover part of it.



- (36) The Moon changes its shape from full, half and crescent because different amounts of the Earth's shadow fall on its surface.



APPENDIX X

LETTER FROM PUBLISHER

JOHN MURRAY



50 Albemarle Street London W1X 4BD

HJ/TG

4th July 1985

John H Baxter Esq
Willoughby
Higher Comeytrowe
Taunton
SOMERSET

Dear Mr Baxter

ASTRONOMY PROJECT

Thank you for the letter of July 1st, which to some extent is a fair statement of the situation, except that we are not entirely convinced that the subject receives little attention merely because of the shortage in suitable published teaching material. Percy Seymour's own book was written to meet a range of stated needs in this area. It has been very well received here and elsewhere and there are foreign language edition in print. However, in spite of very active marketing the take up by schools has been rather disappointing and we have no reason to believe that further adventures into this area will prove less so.

Success (or lack of it) in this area seems to be the product of perceived needs (as opposed to desirable options) by people at the 'chalk face'. Syllabuses are still overcrowded and many teachers see their first priority in terms of maximising students' chances in public examinations. Thus most do not spend time on Astronomy, which is virtually non-existent in most syllabuses. Those who want to do work in this area are usually faced with the problem of inadequate funds for book purchase, so mainstream textbooks take priority. If, as is hoped, Astronomy does find a respectable place in 16+ courses, the demand will be for textbooks that contain 'enough Astronomy for examination needs'.

In the 'iffy' future it is possible that main subjects (PCB) will be replaced by a double Science made up of representative Themes/Modules or whatever the in term happens to be at the time. At a stroke, the short-fall of Physics teachers will disappear, a triumph for political statisticians. In practical terms, total time spent on Science will be

contd/...

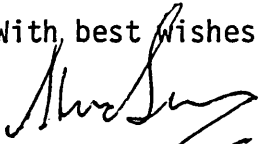
*John Murray C.B.E., John R. Murray, Kenneth Pinnock, Nicholas Perren, Hallam Murray
Company Secretary: Trevor J. Cates*

John Murray (Publishers) Ltd Registered in England: No. 492627
50 Albemarle Street, London W1X 4BD : Telephone 01-493 4361 : Telex 21312 Murray G

reduced, and the competition amongst useful inclusions increased. Thus there might be Astronomy Modules, but unless they are made compulsory, take-up will remain small.

From the above, you will realise that based purely on our perception of the market, prognosis for school books on Astronomy is not particularly good. However, I wouldn't mind being proved wrong and if you care to submit a representative sample, I will be pleased to study the possibilities.

With best wishes



Harvey Johnson
Science/Mathematics Editor

CC Aase Stone

APPENDIX XI

THE EASILY OBSERVED ASTRONOMICAL EVENTS

At a meeting with the A.A.E. curriculum discussion focused on pupils' minimal entitlement of astronomy education.

There had been an ongoing discussion within the curriculum committee of the A.A.E. about using the topic 'solar power' as the central focus for a programme of astronomy education. A flow diagram (fig. 1a) had been circulated to members as a discussion document.

At the A.A.E. Curriculum Committee meeting attended by the author the consensus opinion was that, although containing topics from astronomy which all the members would like to see taught, the flow diagram contained an unrealistic amount of material for inclusion within a limited timetable time. While hoping for a greater exposure, the committee discussed a minimal entitlement, focusing on those astronomical events which are visible from planet Earth.

Day and Night

Moon's phases

Tides

Apparent motion of the stars

The solar system

The seasons

Shadows and sundials

Aspects from the history of astronomy: creation myths, Copernicus, Galileo, Newton.

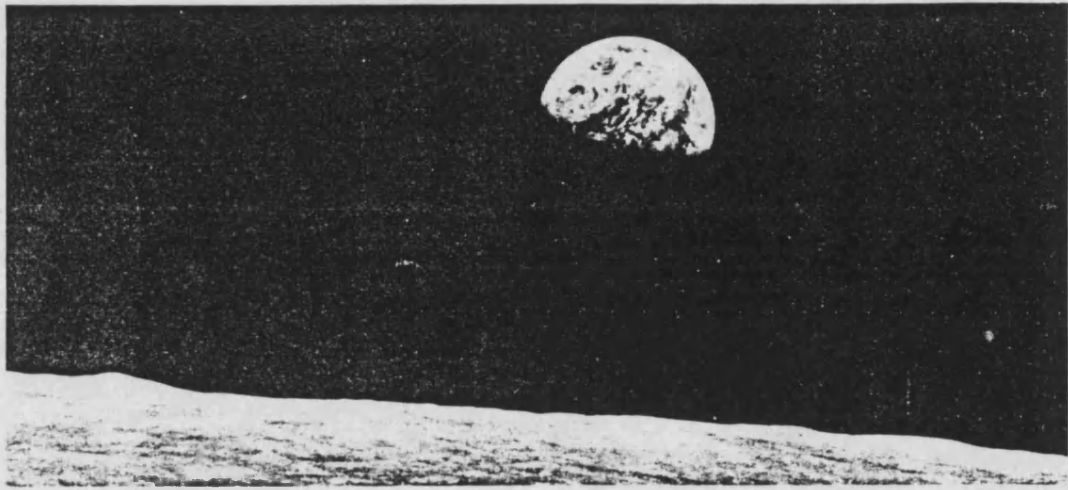
APPENDIX XII

THE ASTRONOMY TEACHING MATERIAL

The astronomy material presented in this appendix is a copy of the final draft of the material produced as a part of this thesis. Apart from being copied at 80% of normal print size for ease of binding, it is identical to the 'Earth in Space' material published by the Resources for Learning Development Unit (RLDU) Bishop Road, Bishopston, Bristol BS7.8LS.

What do you know about the EARTH IN SPACE?

You are about to start a short course in astronomy.
This is the study of the stars, planets, our Sun and the Moon.
It is about the Earth in Space.



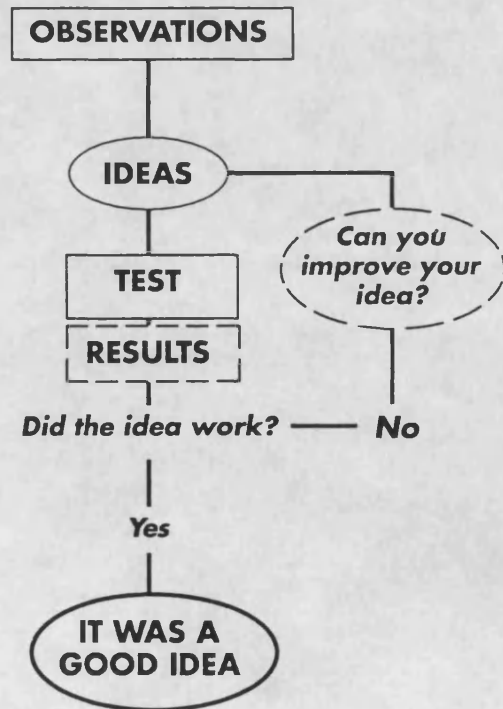
You will already have noticed some important astronomical events like sunrise and sunset. You may have seen an eclipse of the Moon.

For many of these things you will have ideas about how and why they take place.

Some of your ideas may be correct but others may be wrong. You will be able to think about your ideas with others in your group.

The best way to find out if your idea is correct is to carry out an investigation. The results of your investigation will tell you if your ideas are right or wrong.

If your idea is wrong it may need changing, or modifying to improve it. You may need another investigation to test your new idea.





Flat Earth v.

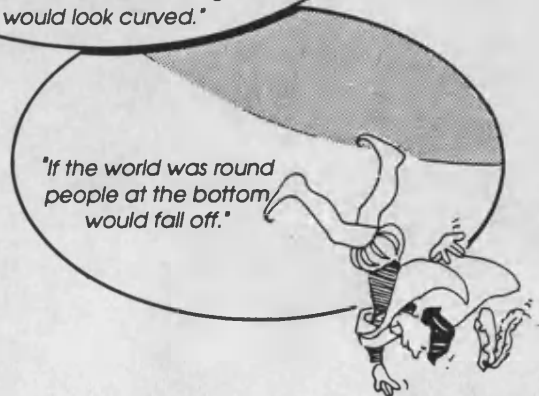
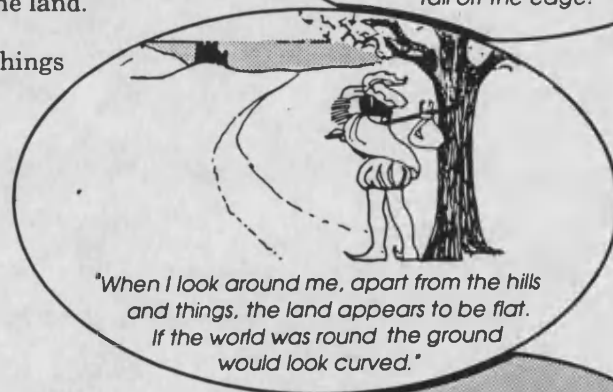
We know the shape of the Earth because we have seen photographs taken from Space. The Earth is a **sphere**. This is the name given to shapes like footballs and oranges.

The idea that the Earth is round goes back many hundreds of years. It is based on careful observation and measurement. However, many groups of people refused to believe in a round Earth. The flat Earth idea lasted in some cultures well into this century.

Flat Earth evidence

In ancient times people thought that the earth was flat, or shaped like a saucer. They thought that all of the land was on top of the saucer-shaped Earth. The great river Oceanus circled the land.

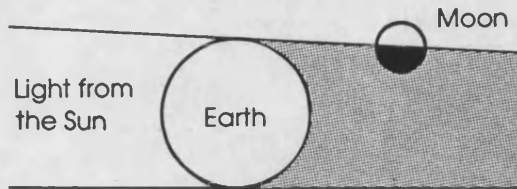
These are some of the things that they said to prove the Earth was flat:



What would you say to people who held these views?
How would you convince them that the Earth is not flat?
What evidence would you use?

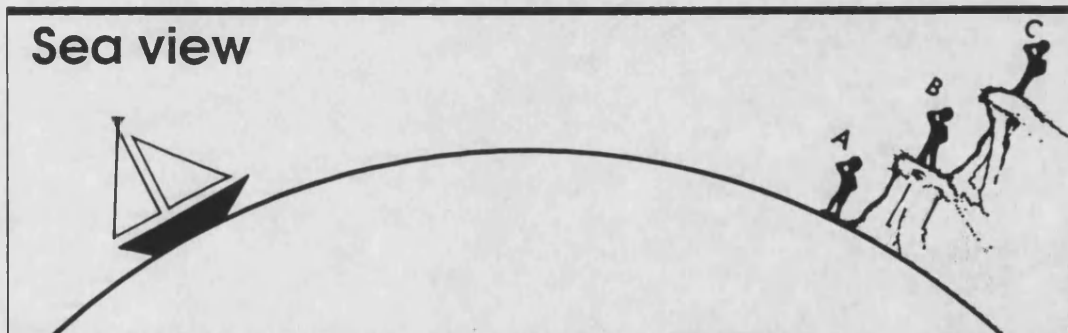
Round Earth

Round Earth evidence



When an **eclipse** of the Moon takes place, the Earth passes between the Sun and the Moon. The shadow of the Earth is cast on the Moon. This can be used to show that the Earth cannot be flat.

Use the equipment available to show how shadow shapes and eclipses show that the Earth must be round like a ball, and not shaped like a saucer.



The diagram above shows three people looking out to sea. Each person is at a different level on the cliff.

They are all looking at a ship some way from the shore.

Copy this diagram, and fill in the view of the ship that each person will see.

PERSON A	PERSON B	PERSON C	
			Sky
			Horizon
			Sea

Now you know quite a lot about the flat Earth v. round Earth argument. Working in groups, write a short play about a debate between *Flat Earthers* and *Round Earthers*.

Day and Night

Other people's ideas

What do you think?

Testing your idea.

Does your idea work?

What if the idea fails?

The explanations below are some pupils ideas about how day and night are formed:

"It gets dark at night because the Moon covers the Sun."

"Because the clouds cover the Sun."

"Because the Sun moves to the other side of the Earth."

Do you think that any of these ideas are correct?

Write down your own idea about how day and night are formed. You may find it easier to use drawings.

Now you need to test your idea. To do this you will have to use a simple model. This is something you will do often in this course.

Some equipment has been provided for you to use. You will find some spheres and a torch or a light box. Use these to test your idea.

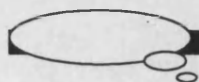
Does your idea give a period of day and night for every part of the Earth? How many hours are there in one day?

This is not a very long time. If your idea means that the Sun or the Earth has to travel a long way, you may need to think again.

If your idea worked, explain briefly how your test showed this.

Try to think of a new idea and test this.

Understanding GRAVITY



Which way do things fall?

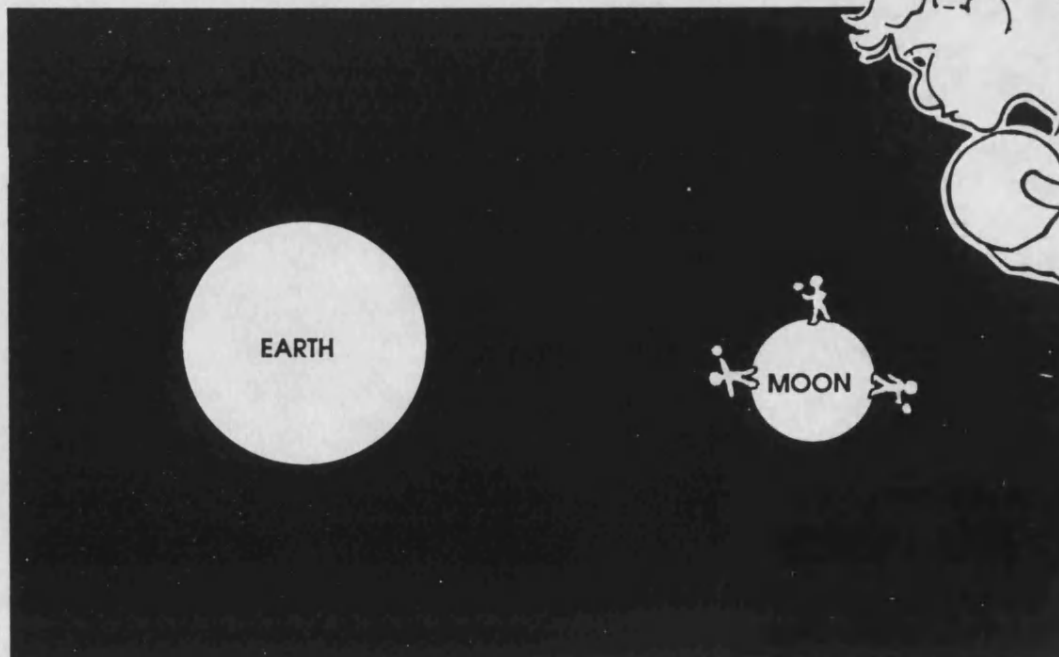
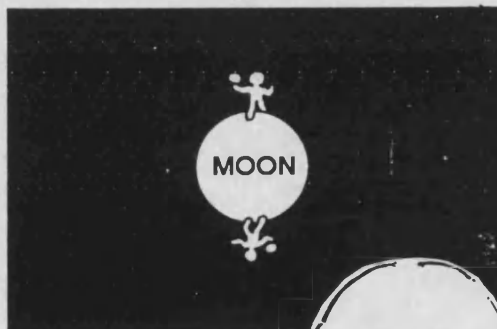
Look at these diagrams.

You drop a ball from your hand.
It falls to the ground.
How does it fall?
Why does this happen?

Imagine you are standing on the Moon.
You drop the same ball.
What happens?
Is this the same as on Earth?
If not, why not?

Discuss these questions in your groups.

When you have reached some decisions,
write these down.

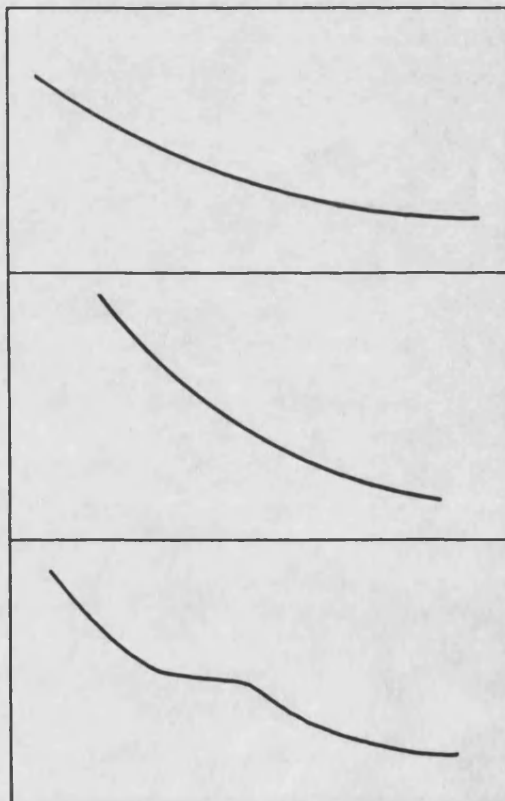


How can you test your own ideas?

It is very difficult to work with objects falling vertically. They fall very quickly. You are measuring short time intervals which is difficult to do accurately. We can "dilute" gravity by using a slope. Objects can be rolled down the slope.

Investigations

- 1 Design an investigation to find out how trolleys of different masses roll down the same slope.
- 2 Make tracks shaped like those in the diagrams. You can use pieces of curtain track.



Use ball bearings or toy cars with different masses on these tracks.

What does this tell you?

Planet Satellites

How does gravity make the and the planets orbit the S

You are going to carry out a "thought" experiment. There is no practical work: you have to think.

Imagine firing a large gun. Draw a diagram to show the path that the shell will follow.

Do not draw on this sheet. You will need a large piece of paper.

Now imagine taking the gun up a hill.

Draw another diagram showing the path the shell will take now. Remember, the Earth is not flat.

Take the gun up an even higher hill.

Draw the path again.

Use this to try to explain how the Moon goes around the Earth.

, Moons, and Gravity

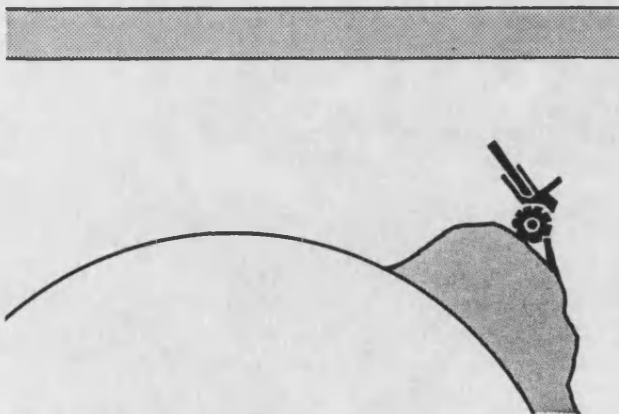
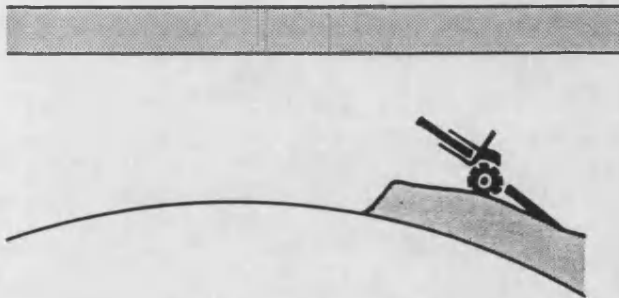
Can you find out about the ideas of **Aristotle** and **Galileo** and the experiments they did?

Moon orbit the Earth,

?

ment.

about what will happen.



Did you know?

It is often said that Sir Isaac Newton "discovered" gravity. Gravity is the force that pulls things towards the Earth. Gravity must have been discovered a long time ago. The first person who realised that if you drop something, it falls down, not up, was the discoverer of gravity.



What Newton did . . .

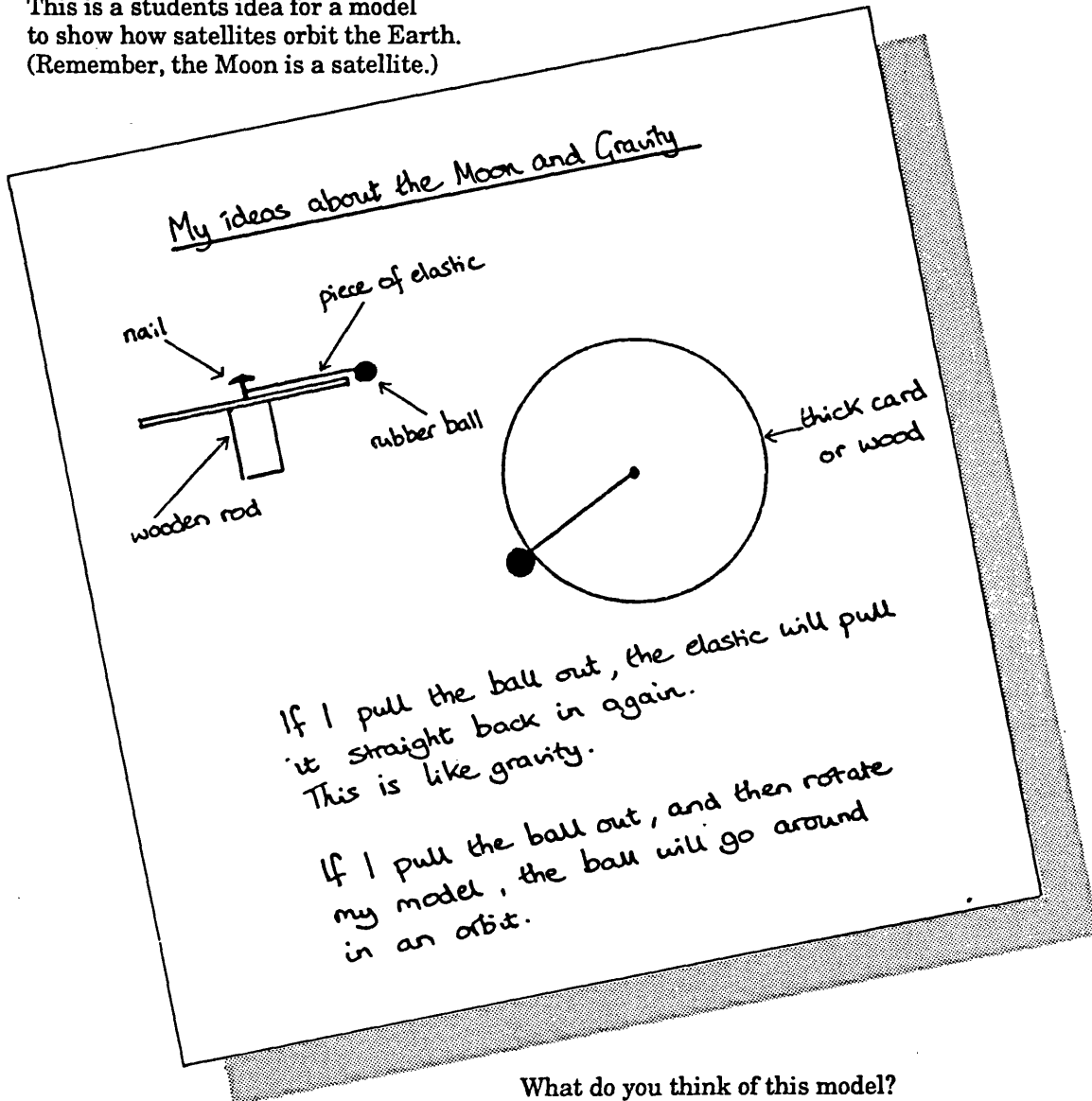
Newton worked out a mathematical theory for gravity. His theory says every body attracts every other body because of gravity.

The Earth is a body with a very large force on other bodies. It is because of gravity that the Earth goes around the Sun, and the Moon goes around the Earth and so on.

Find out what you can about the life of Sir Isaac Newton.

Using a Model

This is a student's idea for a model to show how satellites orbit the Earth. (Remember, the Moon is a satellite.)



What do you think of this model?
Try making one to find out how well it works.
Can you improve it?

Does it explain how gravity keeps satellites moving in orbit around the Earth?

What do you know about **THE SUN?**

The Sun is our nearest star.
We rely on the Sun for warmth and light.
Without the Sun there would be no life on Earth.



Make a list of all of the things that you know about the Sun.

Discuss your ideas with someone else.
Make a poster of your ideas.

Sun Worship

In the past many people have worshipped the Sun.
Like other gods, the Sun seemed to have the power of life or death.
Stories about sun gods give us an idea of the beliefs people held.
It tells us something about the lives they led.



Here are some activities for you:

A Library Search

Go to your library and find some books on sun gods. Think of other things you could look up.

Write about what you found out.

Storytelling

Invent a story about a sun god myth. You may need to find out what this word means. Write your story as if you were telling it to an ancient tribe. Include the good things and the bad things the sun god does.

Stonehenge



Some people think that Stonehenge was built by people who worshipped the Sun. We do not know much about Stonehenge. However, we can make guesses based on the information we have.

Find out as much as you can.
You could make a model of the site.

An investigation for you to try:

Do plants need warmth and light to grow?

Will seeds germinate without warmth and light?

Write down your ideas about these questions. Talk about your ideas in a group.

Design investigations to test your ideas. Show your plan to your teacher.



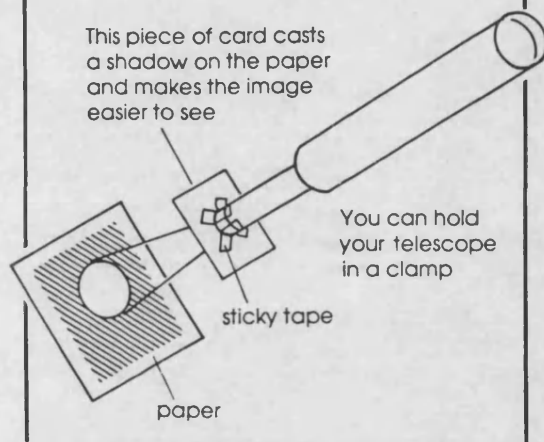
Never look directly at the Sun, even when wearing sunglasses.

DANGER

Do not look at the Sun through a telescope or binoculars. This will cause permanent damage to your eyes.

Observing the Sun

This is the safe way to look at the Sun. You can use your telescope to project an image of the Sun onto a screen.



Sunspots

Often when you look at the Sun this way, dark spots can be seen on its surface. These dark regions are called sunspots. Sunspots are often visible at sunrise or sunset.

Observations of sunspots were recorded in China before 800 BC.

A typical sunspot is as large as the Earth. They can be 10 times bigger than this. They can last from just a few hours to several months. Sometimes there are over 100, sometimes none at all.

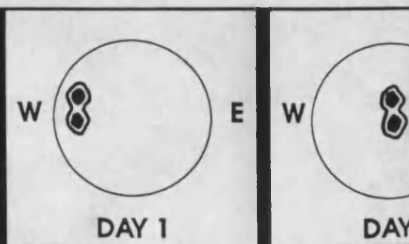
These four diagrams show how the same two sunspots drawn on four different days.

Studies of sunspots like this can tell us a lot about the Sun.

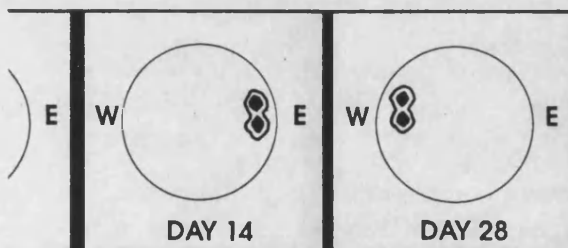
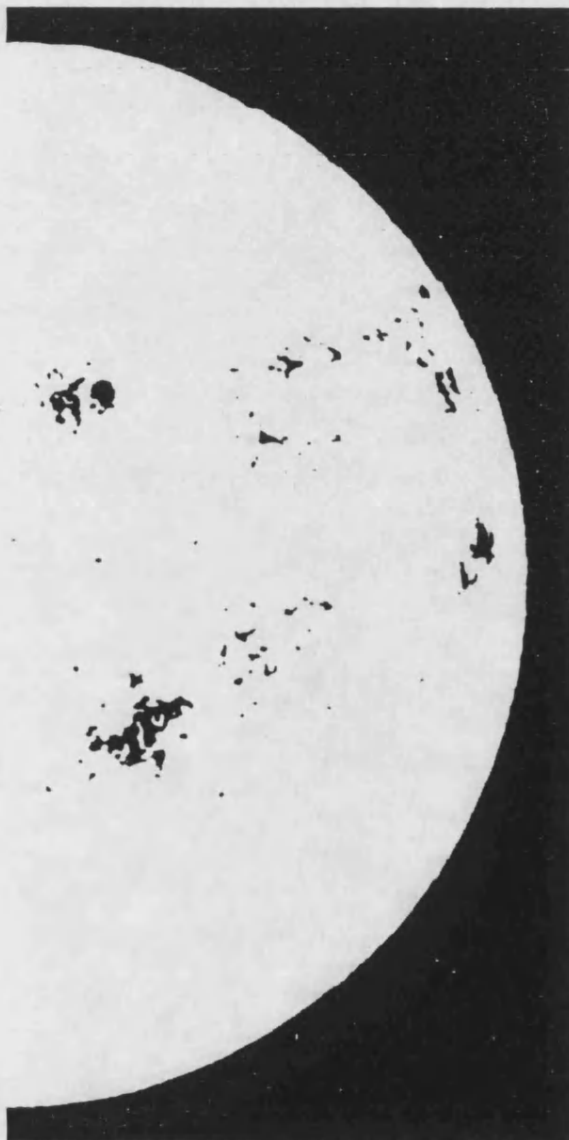
The Sun and



What do these drawings tell you about the Sun?

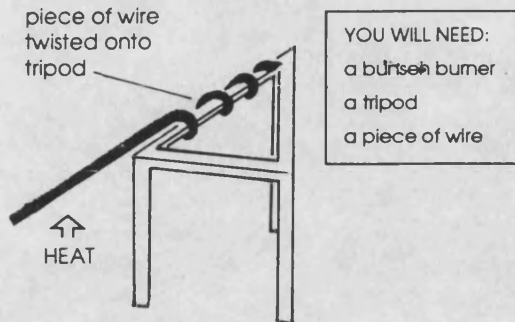


d Sunspots



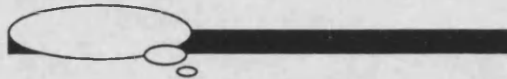
Investigations

What are Sunspots?



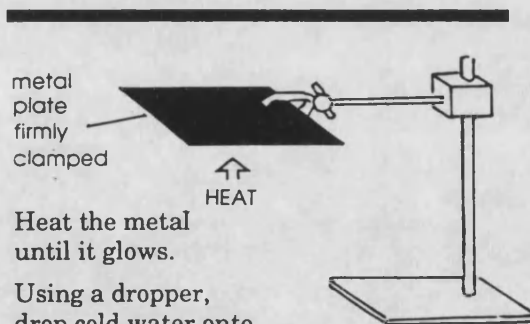
Use the equipment as shown in the diagram.

Heat the wire strongly for five minutes. Write down what you see happening to the wire. Allow the wire to cool. Again, write down what happens.



Why are sunspots darker than the rest of the sun?

Write down your ideas. Discuss them in your group.



Heat the metal until it glows. Using a dropper, drop cold water onto the glowing metal.

What do you see? Does this support your idea about sunspots?

The temperatures on the surface of the Sun are much higher than this, but it may help your ideas.

Looking for a pattern

This table shows the number of sunspots observed over a period of 50 years

YEAR	NUMBER	YEAR	NUMBER	YEAR	NUMBER	YEAR	NUMBER	YEAR	NUMBER
1910	31	1920	41	1930	52	1940	82	1950	91
1911	15	1921	33	1931	29	1941	62	1951	66
1912	11	1922	20	1932	15	1942	42	1952	53
1913	7	1923	12	1933	11	1943	27	1953	25
1914	22	1924	23	1934	19	1944	20	1954	16
1915	49	1925	69	1935	59	1945	50	1955	53
1916	74	1926	87	1936	100	1946	100	1956	163
1917	99	1927	110	1937	125	1947	156	1957	220
1918	90	1928	79	1938	128	1948	144	1958	225
1919	69	1929	74	1939	113	1949	150	1959	204

Put this data onto a graph.

This may be easier to do as a pair,
using a long sheet of graph paper.

Can you see a pattern?

Can you predict the approximate number
of sunspots in:

1960 ; 1970 ; 1980 ; this year?

Where does the Sun's energy come from?

Our knowledge of the Sun has increased through scientific observation. We now know that the Sun is mostly made up from hydrogen. Through a process known as **Thermonuclear Fusion** the hydrogen changes to helium. This process releases energy.

Scientists think that there is enough hydrogen left in the Sun to last another 5 billion years.

Nuclear fusion is being researched as a way of providing energy for us. See if you can find out anything about this.

Information for a Model Newgrange

By now you probably realise the most important information needed to build Newgrange is the direction of sunrise throughout the year.

Use this information to make a model of Newgrange. Remember to mark East on your model clearly. Make sure the tomb is facing the correct direction.

This information is given below.

MONTH	DIRECTION OF SUNRISE
January	15° south of east
February	7° south of east
March	due east
April	7° north of east
May	15° north of east
June	23° north of east
July	15° north of east
August	7° north of east
September	due east
October	7° south of east
November	15° south of east
December	23° south of east

Testing your model

Use a torch as the Sun to test the model. You may need to make a slight alteration to the back of the model so you can see if it works.

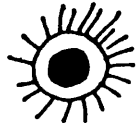
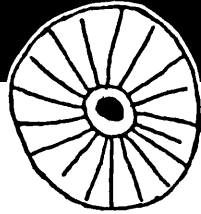
What other piece of information about the Sun was needed to make Newgrange work?



Do you think we are correct to call these ancient people primitive or simple?

Write down or discuss why you think like this.

Sun Worship



Drawings of suns carved on stones at the tomb of Dowth, near Newgrange.

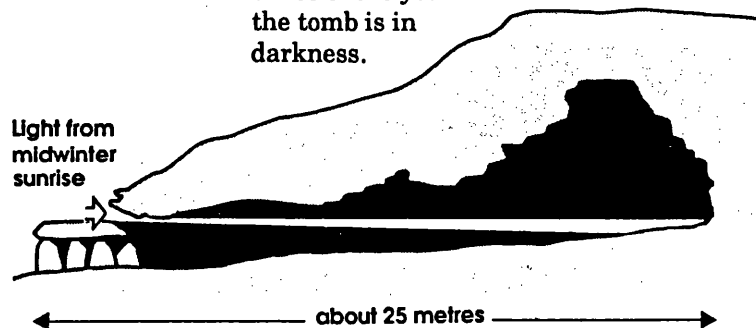
Sun Worship has been practiced for many thousands of years. Many of these ancient worshippers made very accurate observations of sunrises and sunsets throughout the year. This is why we now have so much data about these events.

One of the finest examples of an understanding of sunrises is to be found at Newgrange, which is about twenty-eight miles north of Dublin.

Newgrange Tomb

The diagram below shows the inside of the tomb at Newgrange.

Some 3300 years BC a tomb was built at Newgrange. It was built in such a way that the light from the mid-winter sunrise reaches the far end of the tomb. At other times of the year the tomb is in darkness.



Sunlight on the bones

For about seven days before and after December 22nd the Sun shines through the small opening. At each of these sunrises a shaft of light spreads along the length of the tomb. Some people think an urn containing cremated bones was placed at the end of the tomb.

No one knows exactly why these people wanted the mid-winter sun to shine into the tomb. We can only guess why they would want the sunlight to fall on cremated bones at a certain time of year.

Why do you think they went to such great lengths to build this tomb? You may like to invent a story which they may have used to justify all this effort.

We say the Sun rises in the East and sets in the West. It is true that the Sun rises in an Easterly direction and sets in a Westerly direction, but the exact direction changes throughout the year. The ancient people who built Newgrange must have understood these slight changes in sunrise direction.

Remember, the sunlight only shines into the tomb during the seven days around December 21st.

Direction of Sunrise

Tomb building

Imagine yourself as the builder of Newgrange tomb. You want the mid-winter sunrise to shine into and along the length of the tomb. You do not want sunlight to enter the tomb at any other time of the year.

Make a list of the information you would need before you started building. If you lived 3000 years BC where do you think you would get this information?

Tracking the Sun

As the Sun appears to move across the sky, it changes its height above the horizon. You can use your **astrolabe** to measure this height at different times of the day. It is best if you can start at sunrise and take measurements during the day up to sunset.

You will need to use a compass to find out the direction of the Sun.

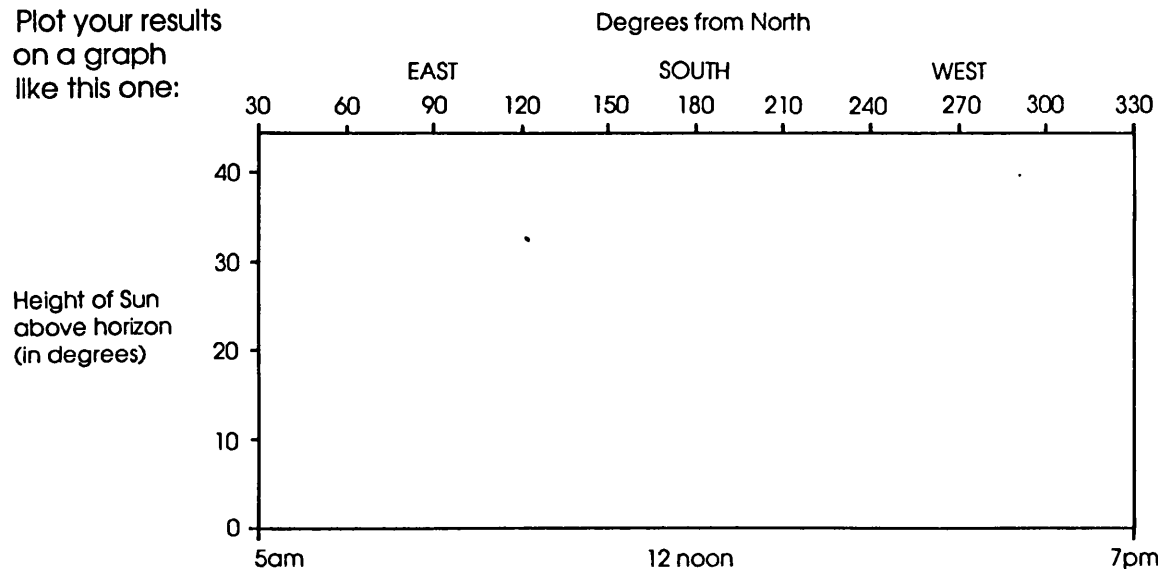
Try to repeat this at different times of the year.

You will need to collect results from everyone in the class. The class needs to talk about a way of doing this.

You also need to talk about how the results will be displayed.



Plot your results on a graph like this one:



Interesting dates to try:

21 December
the day with the shortest daylight

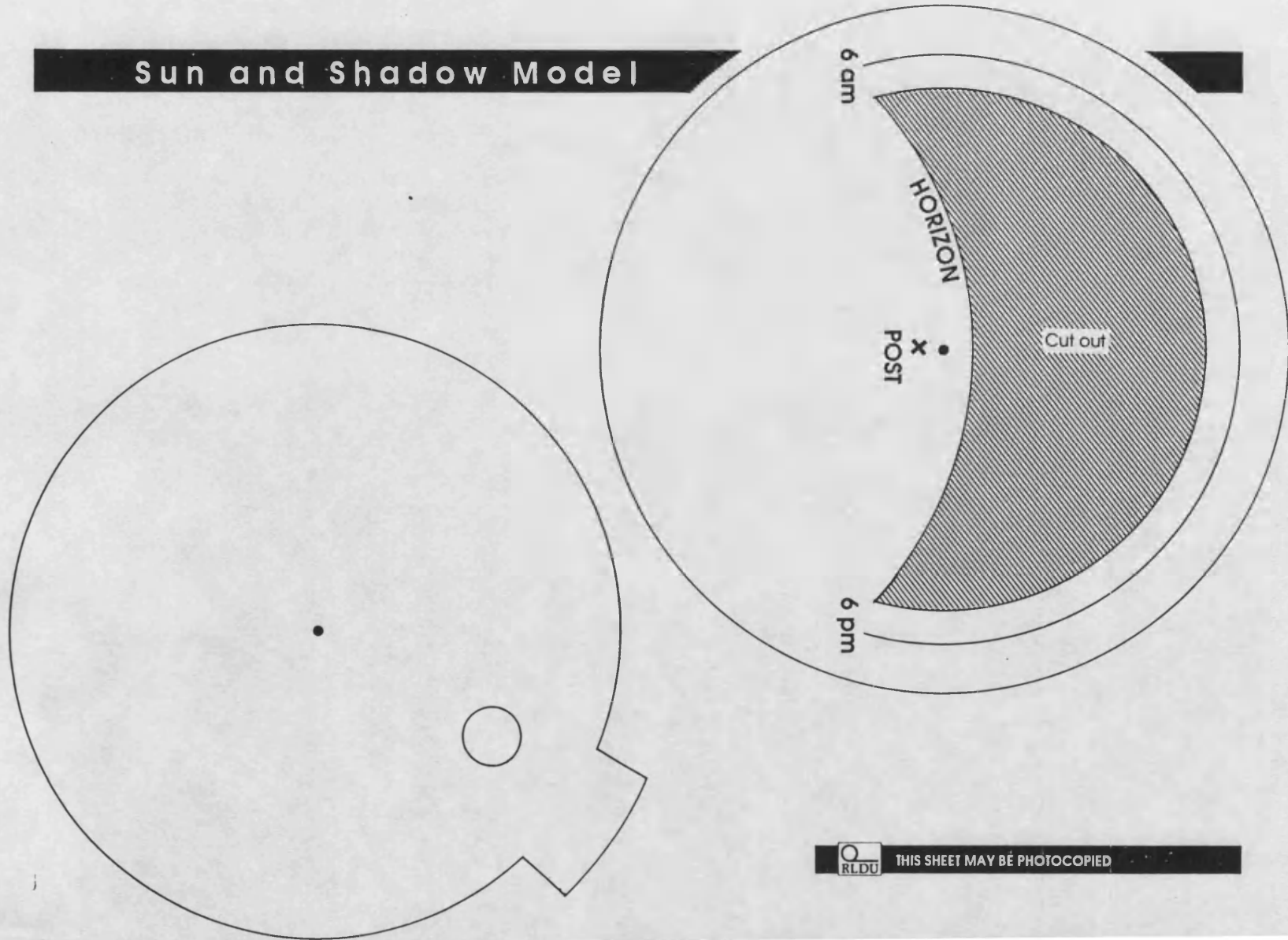
21 June
the day with the longest daylight

21 March / 21 September
days with equal light and dark

If these are not possible,
dates close by will still be useful.



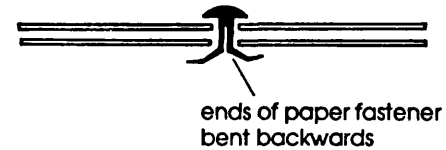
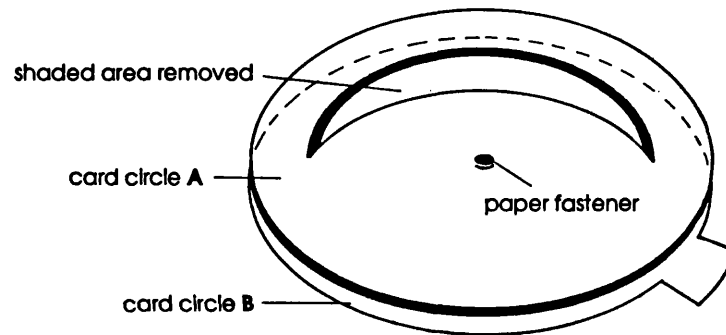
Sun and Shadow Model



THIS SHEET MAY BE PHOTOCOPIED

Making a Sun and shadow model

This model should help you to understand your observations of shadows.



YOU WILL NEED:
a pair of scissors
glue
a ruler
a paper fastener
a sheet of stiff card
a Sun model sheet

This is what to do:

- 1 Glue the Sun model sheet to the stiff card.
- 2 Cut out both circles A and B.
- 3 Cut out the shaded part of circle A.
- 4 Make a hole in each circle at the points marked ●
- 5 Place A on top of B and push the paper fastener through the holes.
- 6 Bend the ends of the fastener back to fix both circles together.
- 7 Make sure that circle B can turn about circle A.

Using the model

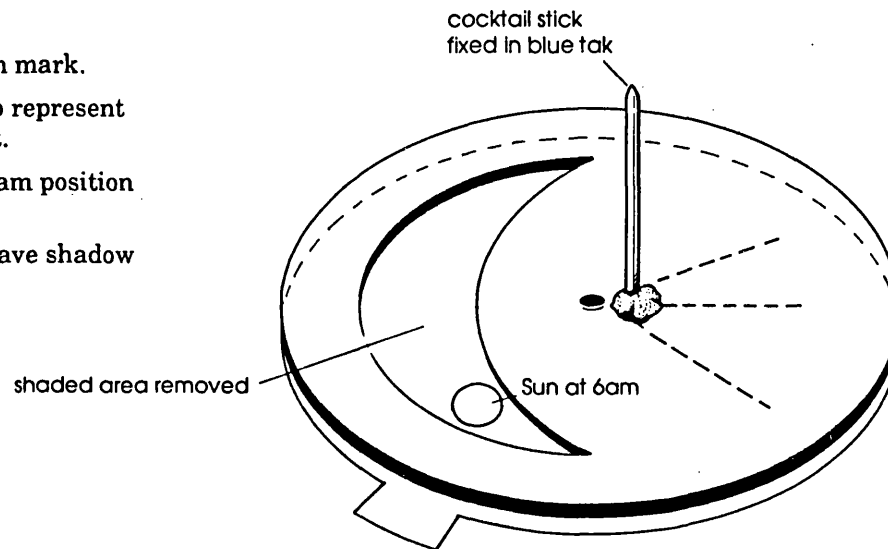
Turn the lower circle (B) in a clockwise direction while holding the top circle (A) still. You will see a small circle appear in the cut-out section. This small circle represents the Sun.

Label east and west on your model.

Predicting shadows

- 1 Place the piece of blue tak on the point marked post.
- 2 Stick the cocktail stick into the blue tak to form a post.
- 3 Position the Sun at the 6am mark.
- 4 Draw a line on the model to represent the shadow cast by the post.
- 5 Now move the Sun to the 7am position and draw another line.
- 6 Keep doing this until you have shadow lines from 6am to 6pm.

YOU WILL NEED:
your Sun model
a cocktail stick
a piece of blue tak
a pencil and a ruler



Testing the model

Your model should act as a shadow predictor.
How can you test to find out if it works?

Do you need any other equipment?

Try it out.

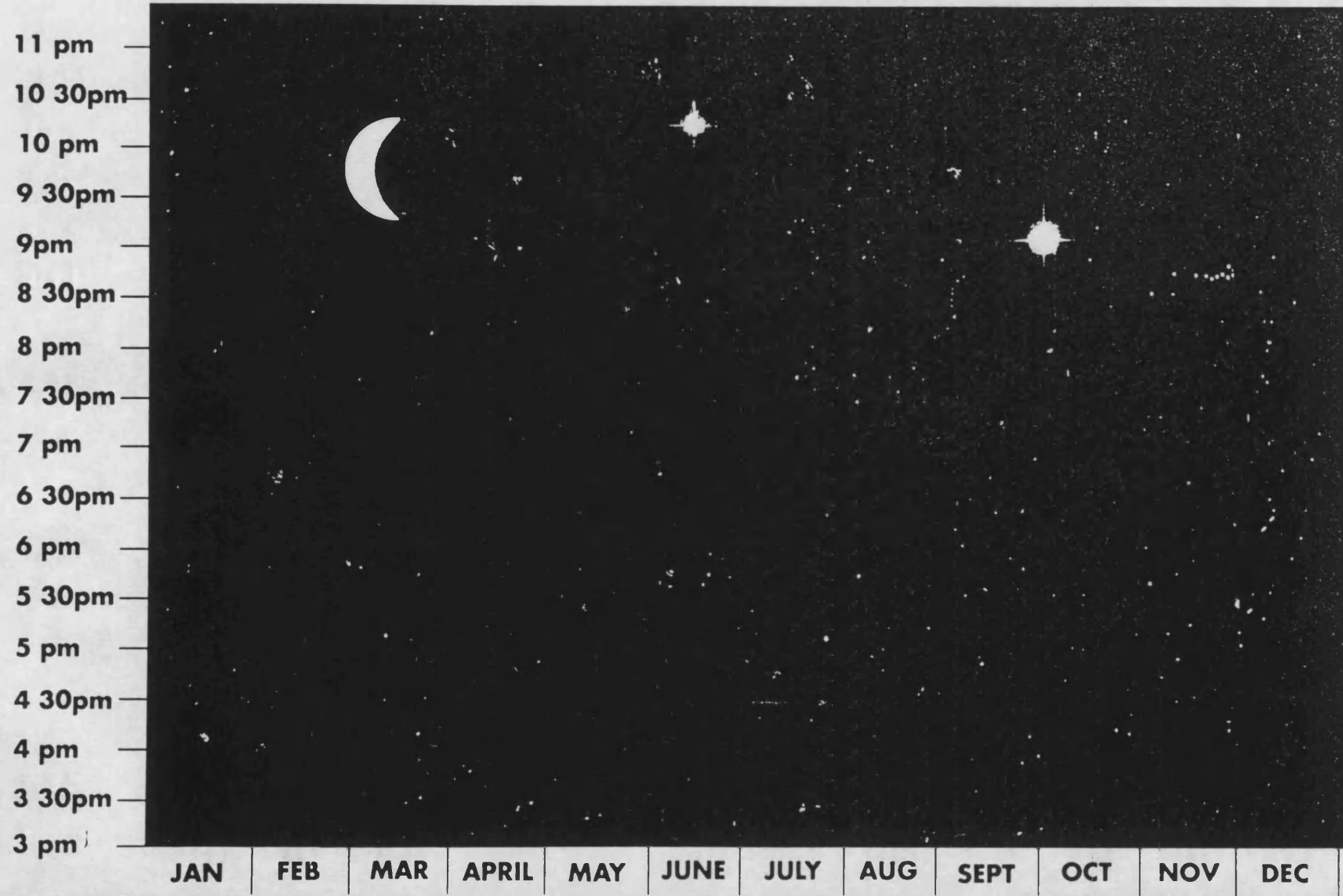
Write about the model and how you used it.

LIGHTS ON YOUR BIKE

LIGHTING UP TIMES

MONTH	LIGHTS ON
JANUARY	HALF PAST FOUR
FEBRUARY	HALF PAST FIVE
MARCH	HALF PAST SIX
APRIL	HALF PAST EIGHT
MAY	NINE O'CLOCK
JUNE	HALF PAST NINE
JULY	NINE O'CLOCK
AUGUST	HALF PAST EIGHT
SEPTEMBER	SEVEN O'CLOCK
OCTOBER	HALF PAST FIVE
NOVEMBER	FOUR O'CLOCK
DECEMBER	FOUR O'CLOCK

LIGHTS ON YOUR BIKE - RESULTS SHEET



11 pm
10 30pm
10 pm
9 30pm
9pm
8 30pm
8 pm
7 30pm
7 pm
6 30pm
6 pm
5 30pm
5 pm
4 30pm
4 pm
3 30pm
3 pm

JAN | FEB | MAR | APRIL | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC

TIME AND CLOCKS

What would life be like without clocks and watches?

Can you tell the time using the Sun?

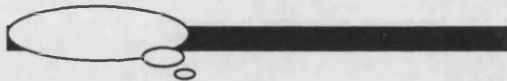
Can you tell the time at night using the Moon and the stars?



Who first divided up a day into hours, minutes and seconds?

Why did they do this?

Why is it so important to be able to measure time accurately?



Find out what you can about the history of clocks.

Make a poster or write an interesting story.

Do you believe in time travel?

Write a story about travelling back or forwards in time.



Investigations in the Laboratory

In the laboratory you will measure time using a stopwatch, a stopwatch or a digital timer. Find out what you will be using. Make sure that you know how to use it.

Work with a partner and discuss your ideas.

You need to write something about each investigation. Write down what you did, and what you found out. You can use drawings to help.

You can use posters to make a display.

Try to think of interesting ways of presenting your results.

Now try some of the investigations on the next page.

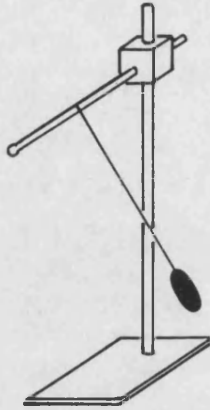
OBSERVATIONS

IDEAS

TEST

RESULTS

Swinging Pendulums



Does the time the pendulum takes for one swing depend on

- how heavy it is?
- how long it is?
- how far it is pulled back?

You may find it difficult to measure one swing. Try 5 or 10.

Investigating T

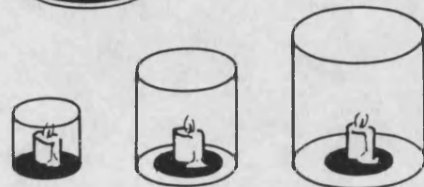
Candles

Does a candle burn evenly?



Measure the length of the candle every 5 minutes.

How can you show the results of this investigation?

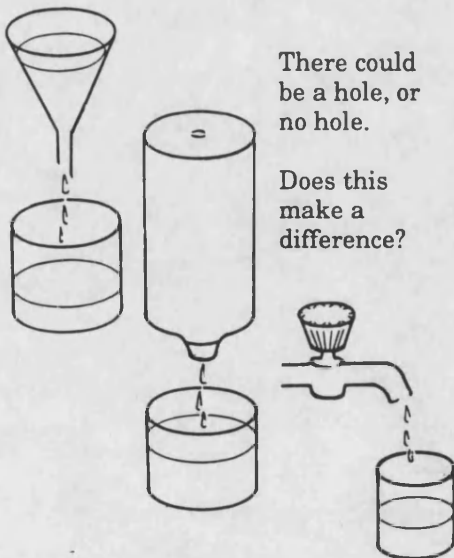


How long does it take for the candle to go out each time?

Does this tell you anything?

Water and Sand

Try making a water or a sand clock. Here are some ideas.

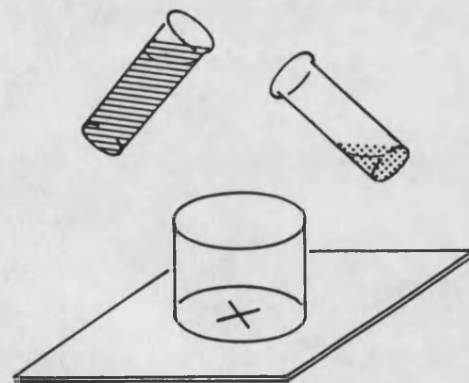


There could be a hole, or no hole.

Does this make a difference?

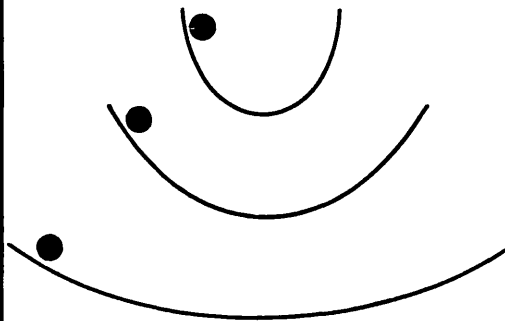
A Chemical Clock

You will need at least 2 people in your group. One person will mix the solutions, the other will do the timing.



me and Clocks

Ball bearings



Roll the ball bearing in each track.
How long does it take to roll from
one side to the other?
What does this tell you?

Draw an X on a piece of paper.

Place a beaker over the X.

Add 50 cm³ of liquid A.

Add 50 cm³ of liquid B.

How long does it take for the X
to disappear?

Things to try:

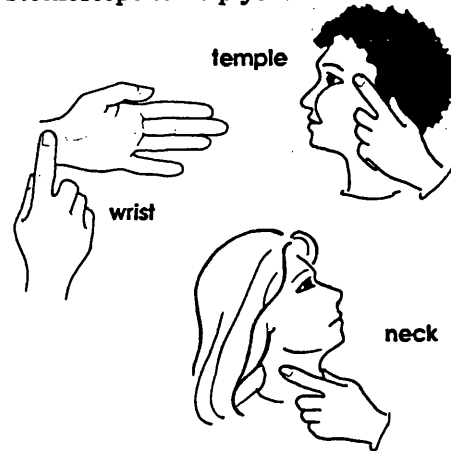
Using different amounts of liquid B.

Diluting liquid B with different amounts
of water.

Heating liquid A to different
temperatures.

Pulses

Try these different ways of finding
your pulse. You might use a
stethoscope to help you.

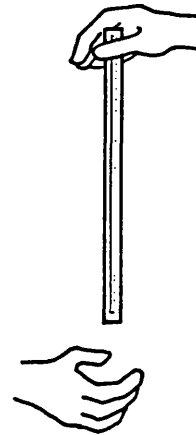


What is your pulse rate?

Find out the rate
for each member of your class.
Think of an interesting way of
presenting this data.

How fast are your reactions?

Dropping a ruler.



How does this
tell you how quick
your reactions are?

Measure the reactions of
people in your class.
How can you present this information
in an interesting way?

You might be able to use an electronic
reaction timer.

Some problems for you to try

1 Can you make a model of a "fairground attraction" that will last for 30 seconds?


2 What happens to your pulse rate when you exercise?
Does it depend on how long you exercise for?

3 Can you make a clock that will accurately time:
2 minutes ; 5 minutes?
You must be able to reset your clock.
Can you make your clock set off an alarm?

4 Can you write a simple computer program that could be used as an accurate clock?

5 Can you make a clock from a spring.
Investigate a range of springs to find out how they "bounce" when different masses are hung on them.

Labels in diagrams: BALL, STRING, PIVOT, FUNNEL, RAMP, CATCH, PENDULUM, PIN, BALLOON FULL OF WATER.



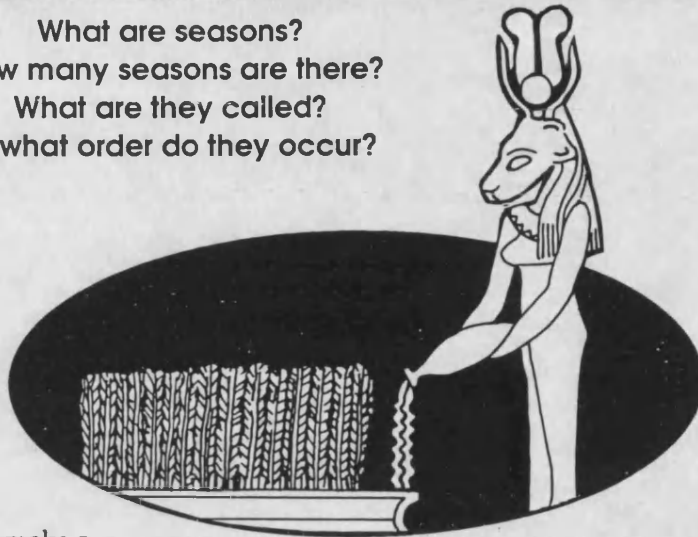
THE SEASONS

What are seasons?
How many seasons are there?
What are they called?
In what order do they occur?

Write something about each of the seasons. Make this as interesting as you can.

Try to include everything you know about the seasons. You can use pictures to help.

You could work in a group and make a poster for each of the seasons.



The annual flooding of the Nile and the beginning of the fertile season was heralded in Ancient Egypt by the first appearance of Sirius in the morning sky. The cow-headed goddess Isis waters the sprouting corn.

Does every part of the world have the same seasons?

Find out what you can about seasons in other countries.

Why do we get different seasons?

These are some childrens ideas:



"The seasons change because the Earth goes around the Sun once a year and passes through different atmospheres."

"The Sun is further away in the winter."

"Because winter clouds stop warmth from the Sun."

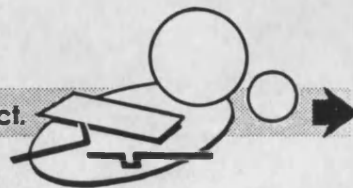
What do you think?

Do you think any of these ideas are correct?

Write down your own ideas.

Discuss these ideas in your group.

Now you can use the model to find out if you were correct.



YOU WILL NEED:

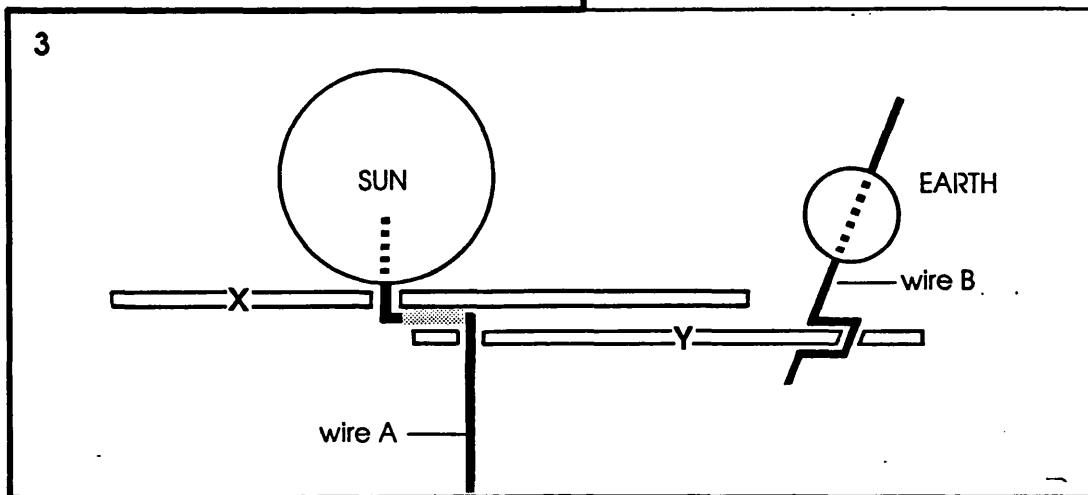
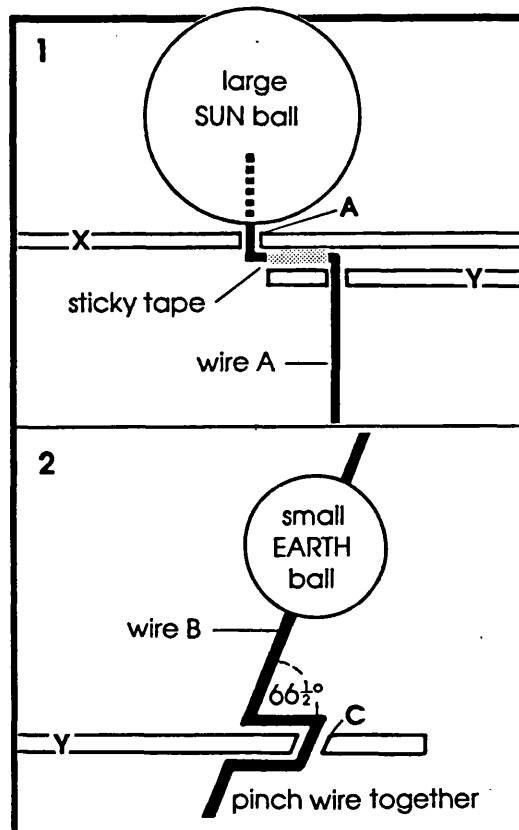
- | | |
|---|-----------------------|
| a large RED ball (SUN) | a piece of stiff card |
| a small GREEN ball (EARTH)
max. 2cm diameter | 2 pieces of wire |
| a seasons model sheet | scissors and glue |

A Sun and

We often use models to
This Sun and Earth model
what causes the

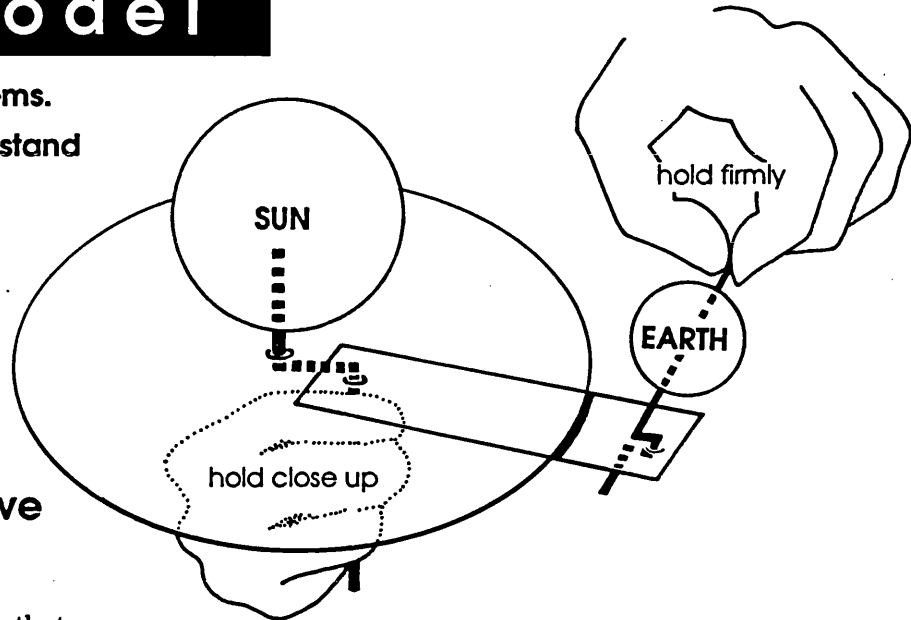
Making the model

- 1 Stick the seasons model sheet to the piece of stiff card.
- 2 Cut out the two shapes X and Y.
- 3 Make small holes at A, B, and C.
- 4 Bend one piece of wire to shape A. Bend the other piece to shape B.
- 5 Push wire A through hole A until it touches the card. Push the end into the large SUN ball. (See diagram 1.) Line the bent part along the line on A. Stick it down.
- 6 Take shape Y. Put wire A through hole B. (See diagram 1.)
- 7 Push wire B through C. Push the end into the small EARTH ball. (See diagram 2.)
- 8 Your model is now ready for use. (See diagram 3.)



Earth Model

Help us to solve problems.
May help you to understand
reason to change.



Using the model to solve the problem

Position the Earth so that it is as far away from the Sun as possible. Make sure that the angle of wire B is facing the Sun.

Holding the top of wire B in one hand and the bottom of wire A in the other, rotate the Earth around the Sun.

What do you notice about the direction the North Pole is facing as the Earth orbits the Sun?

Things to do with the model

Can you find two positions on the Earth's yearly orbit when the North Pole is neither facing away or towards the Sun?

What two seasons do we get when the Earth is in these positions?

Which way is the North Pole facing when we get our winter?

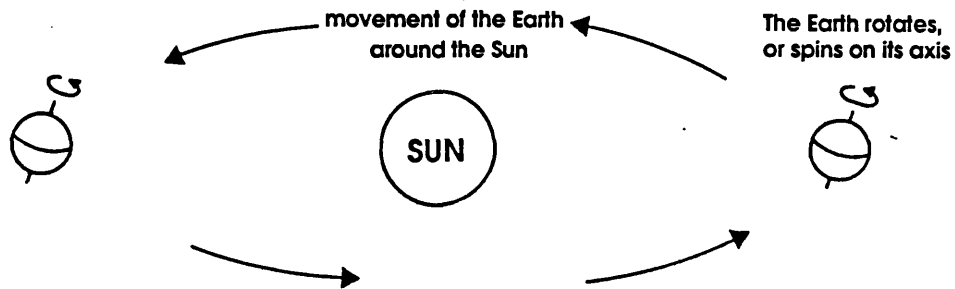
Can you use the model to help you explain why Australia gets its summer when we get our winter?

Find your place on the Earth and mark on the card the four seasons of the year.

Can you now explain why the seasons change?

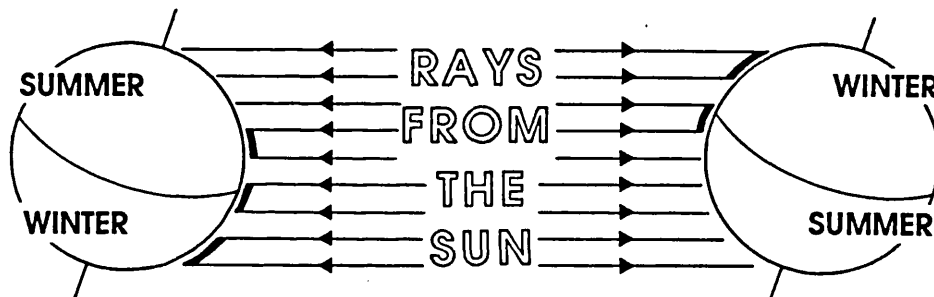
Why do we get seasons?

This diagram shows the Earth moving around the Sun.
It shows the Earth in two different positions.
(It is not drawn to scale)



How long does it take the Earth to move completely around the Sun once?

How long does it take the Earth to move between the two positions shown?



Find out where you are on the Earth.
Look at the shaded areas.

Use a torch to find out what happens
if you shine it onto a piece of paper.
Hold the torch at different angles.
Look at the pool of light on the paper.

Now write down your ideas about why
we have seasons.

Can you use this model to explain:

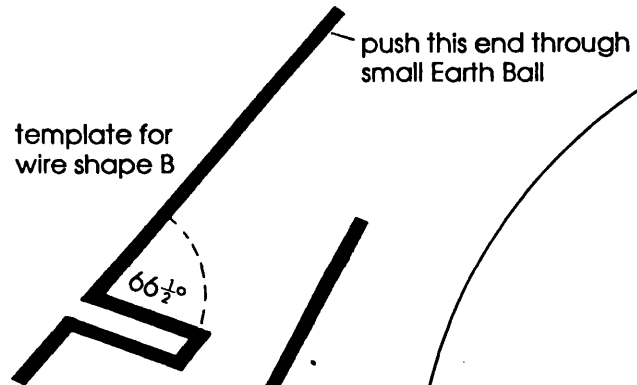
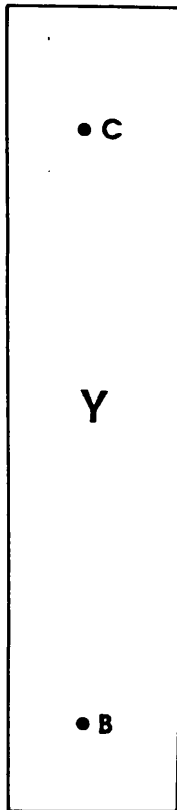
why the amount of daylight changes
from one season to another?

why the position of the sun in the
sky changes?

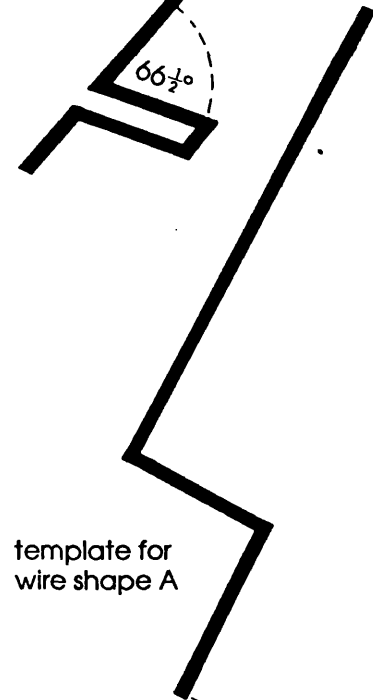
Seasons Model



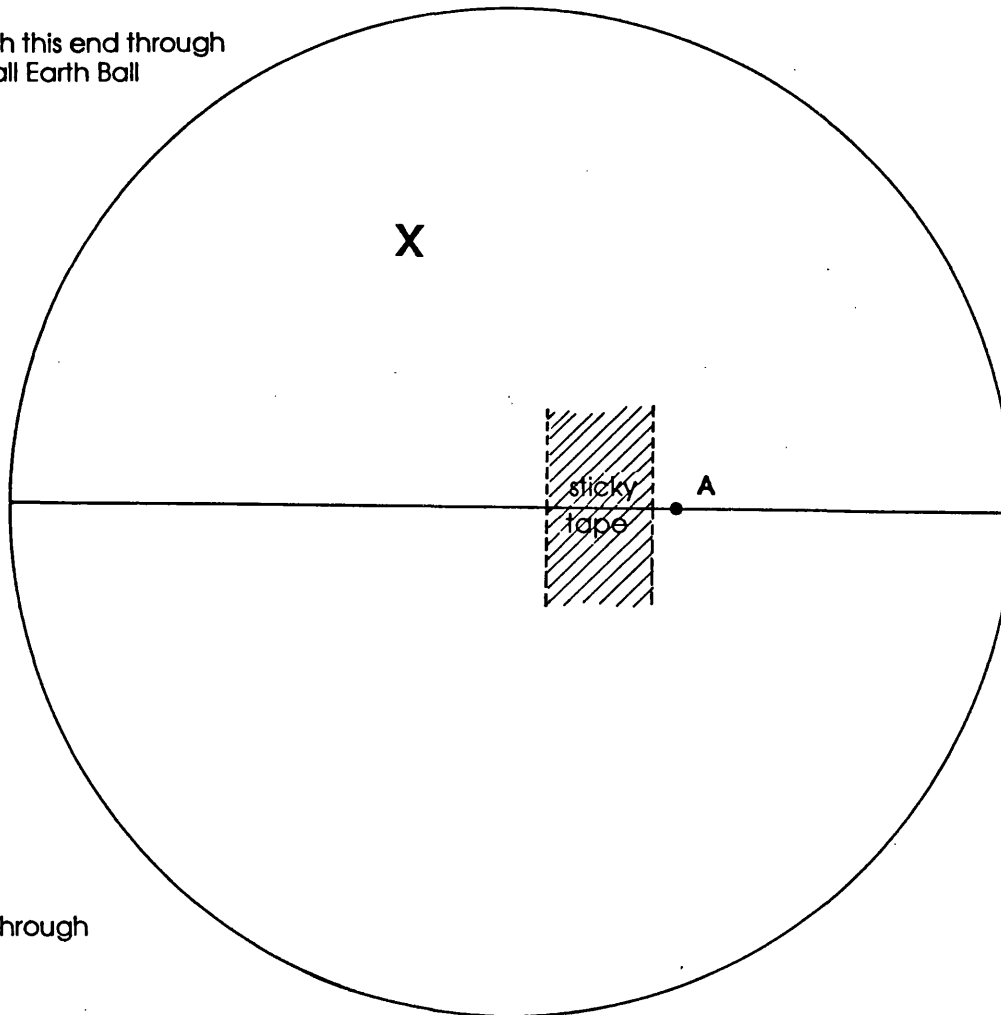
THIS SHEET MAY BE PHOTOCOPIED



push this end through small Earth Ball



push this end through large Sun ball

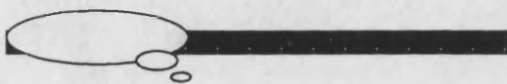


What do you know about **THE MOON?**

**The Moon is our nearest neighbour in space.
It is 384,404 km from Earth.
It is the only body in space that has been visited by human beings.**

In the past, people used to worship the Moon. They thought it had a great influence on their lives. The Moon god was second only in importance to the Sun god.

Why do you think this was?



Write down five things that you have noticed, or that you know about the Moon.

Now talk to someone else and compare your ideas. List of your five best ideas.

Now join another pair to compare. Talk about your ideas and again make a list of the best ideas of the group.

Make a poster of this list. You will discuss this with the class.

Very few people today are superstitious about the Moon. However, film makers often make use of the Moon and tales about the Moon to give atmosphere to stories.

Make a list of superstitions you know about which involve the Moon. You will find more by using books from the library.

Write a story which uses the Moon in some way.

Some things to think about . . .

What makes the Moon shine?

Does the Moon shine on every night of the year?

Can the Moon be seen during the day?

Does the Moon stay in the same position?

Draw the different shapes you have seen the Moon make.



"Tranquility base here. The Eagle has landed."

These were the first words received from the first men on the Moon.

What can you find out about them, and their mission?

Make a poster display about this event.

This photograph was taken through a telescope pointing at the Moon.

You can use your telescope or a pair of binoculars to look at the Moon. Your teacher will tell you the best times to look. Sometimes you can see the Moon during the daytime.

Here are some of the things to look for . . .

You could try to draw a map of the Moon showing where these are:

1 "The Man in the Moon"

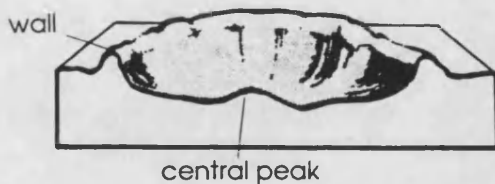
The Moon sometimes looks as if it has a face on it. These are flat areas of darker rock. Ancient astronomers thought that they were seas and oceans. They called them "*maria*". "*Mare*" (plural "*maria*") is the Latin word for sea.

One of these is "*Mare Tranquillitatis*". Why is this famous?

2 Craters

These are depressions in the surface of the Moon.

This is what a crater would look like from the side:



3 Mountains

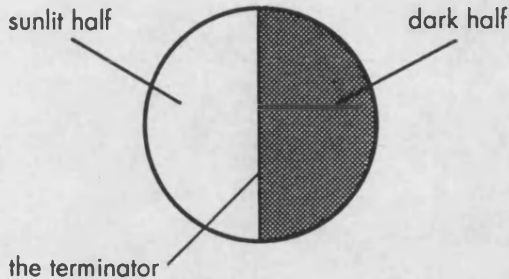
The Moon is a very hilly place.

You should be able to see these features with your telescope.

Looking at



the Moon



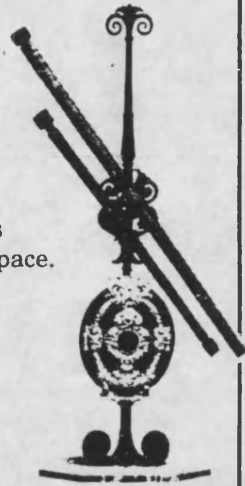
To see all of the features of the Moon, you really need to watch it through all of its phases. They show up best on the "terminator". This is the line between the sunlit half and the dark half. Features are easier to see because the shadows are very long and obvious.

Galileo

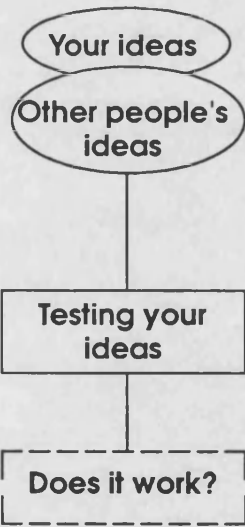
Galileo, in about 1600, was the first scientist to see mountains on the Moon through a telescope. He wrote about this in 1610.

The invention of the telescope allowed astronomers to look deeper into space.

Their observations laid to rest many superstitions about the Sun, Moon and the planets.



The craters of the Moon



How were the Moon's craters formed?
Write down your ideas.

Discuss your ideas with your partner. You may be able to talk about them in a group. Try to reach an agreement.

Put your ideas onto a poster.

To test your ideas you will have to use a model. Can you think of a way to test your ideas?

You may get some ideas by looking at the equipment available.

Write down your idea for a test. Use drawings to help.

Carry out your test . . . *Does your idea work?*
Does it explain why some craters are bigger than others?

The Moon is covered in these craters. There are very few craters like this on the Earth. Can you think of a reason why this is so?

Try to think of ways in which the Earth and the Moon are different. Write down your ideas and discuss them with your partner.

The phases of the Moon

One of the things you have probably noticed about the Moon is the way it seems to change its shape.

Moon Shape Sheet

How long is it from one full Moon to the next?

What part of our calendar do we get from this?

The class will keep a record of the shape of the Moon over a period of time. You will have your own sheet to record this on. There will also be a class display.

You will not be able to record the shape every day, but will fill in the chart when you can. Try to work out what the shapes must have been and fill in the gaps in a different colour.



How would you explain to someone the reason for the Moon's changes in shape?

Write down your idea.
Use diagrams to make it clear.

Testing your ideas

Test your idea using spheres and a torch or light box.

Did it your idea work?

If your idea works it should form all of the shapes on your Moon Shape record sheet. A sheet showing the shapes is available if you need it.

Does your model show the Moon changing its shape over a period of time?

If your model does not work, think again.

Your teacher may be able to show you a large scale model.

Testing a superstition - the Moon and seeds

In the past many people thought that any seeds planted during the time of a full Moon would grow better.

You probably know some old sayings that often seem to make sense. However, as scientists we should look for evidence to support this claim.

This means designing an investigation to test this idea.



YOU WILL NEED:
soil & a seed tray
seeds
Dates of Moon phases
You can find these out by looking in most diaries.



The problem:
Do seeds grow better if they are planted at full Moon?

Design and carry out an investigation to find out the answer to this problem.

Think about how you will record your results.

Write a letter to a friend telling them what the problem was, and what you found out.

ASTROLOGY CONNECTION

Many people believe that the Sun, Moon, stars and planets have an effect on our lives

An astrologer is a person who claims to be able to tell a person's future and personality by "reading their stars".

Most popular newspapers, magazines and some television programmes have a section on the "stars". These claim to tell us what the day or week has in store for us.



ORPIO
23 to Nov 21
You will be thinking about your long-term security possibly making some important arrangements now. You may have some quite exhausting work to deal with, so rest up.

PISCES
Feb 19 to March 20
Resolve to keep friends and finances apart this week. Avoid any kind of gambling, even if you're buying gifts. Your marriage or standing relationship is on the rocks.

ARIES
March 21 to April 19
The outcome of a busy week will be very much to your advantage and bring you some good news. But look forward to your partner and feel ne...

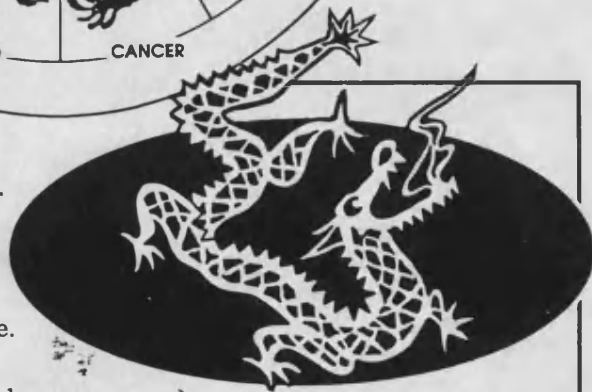
Astrology has a long history.

In ancient times astrologers were very important people. It was the astrologer who read the stars and advised on many important matters.

This is why astronomy, through astrology, is probably the oldest science.

It explains why we have so much information about the stars, comets and the movement of planets.

There are many examples from ancient cultures - Chinese, African, Indian, Islamic and Greek.



Find out as much as you can about the history of astronomy.

Make a poster or write stories about parts that interest you.

Is there any truth in astrology?

Astronomers do not believe in astrology. They think that it is impossible to tell someone's future or personality by looking at the position of the stars and planets at the time of their birth.

What do you think?

Do you believe in astrology?
Explain to your partner what you think.
Listen to their opinion.

Scientists need evidence

It is bad science to dismiss or accept an idea without testing it. We should not dismiss or accept astrological "star charts" without investigating their claims.

Looking for evidence

The "star charts" in newspapers and magazines are written by different astrologers. However, they all use the same star patterns to make their predictions.

Do you think the message given by each astrologer for the same sign should be similar?
How can you find out?

Collect the "star charts" from a range of newspapers and magazines.
Compare the predictions for the same date.
Look for the number of similar messages for each sign, and the number of different messages.

Think of an interesting way of presenting your results.

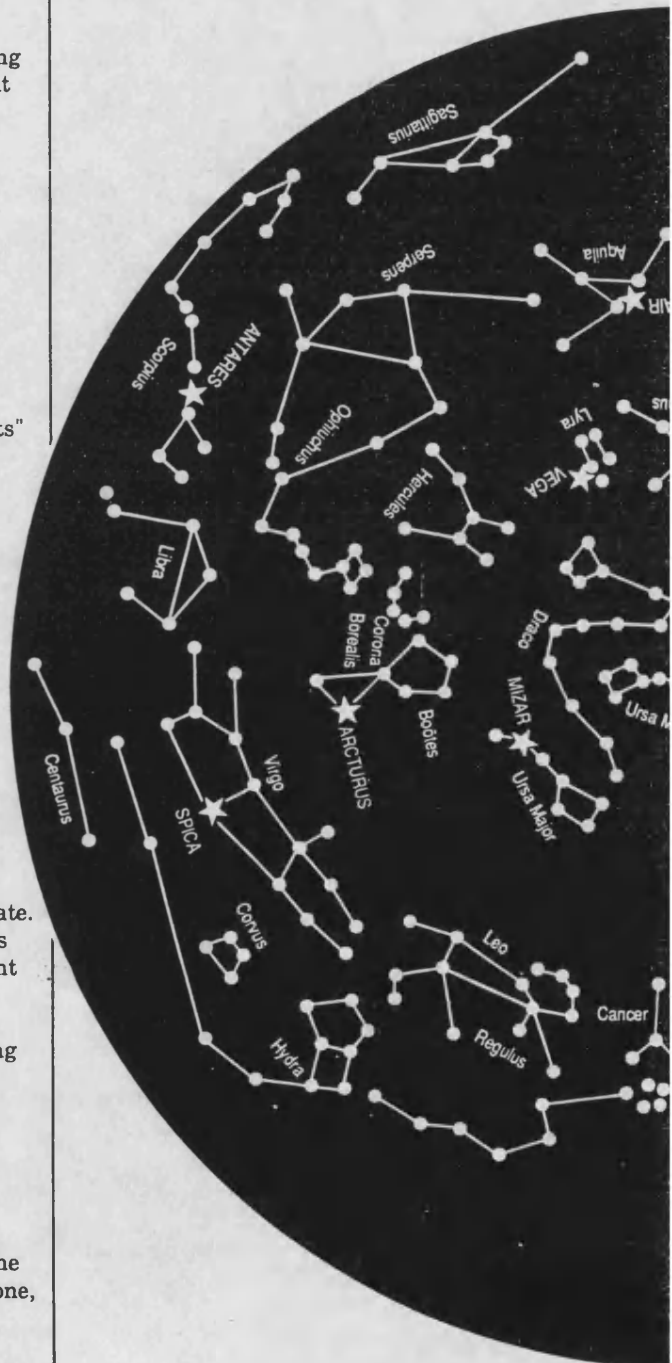
What do your results tell you?

Clever with words?

Some people say that the messages are worded in a clever way. They say that the predictions can mean something to anyone, no matter what their "star sign".

How can you test this idea?

Const

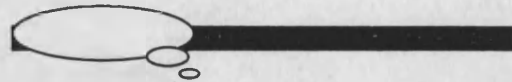
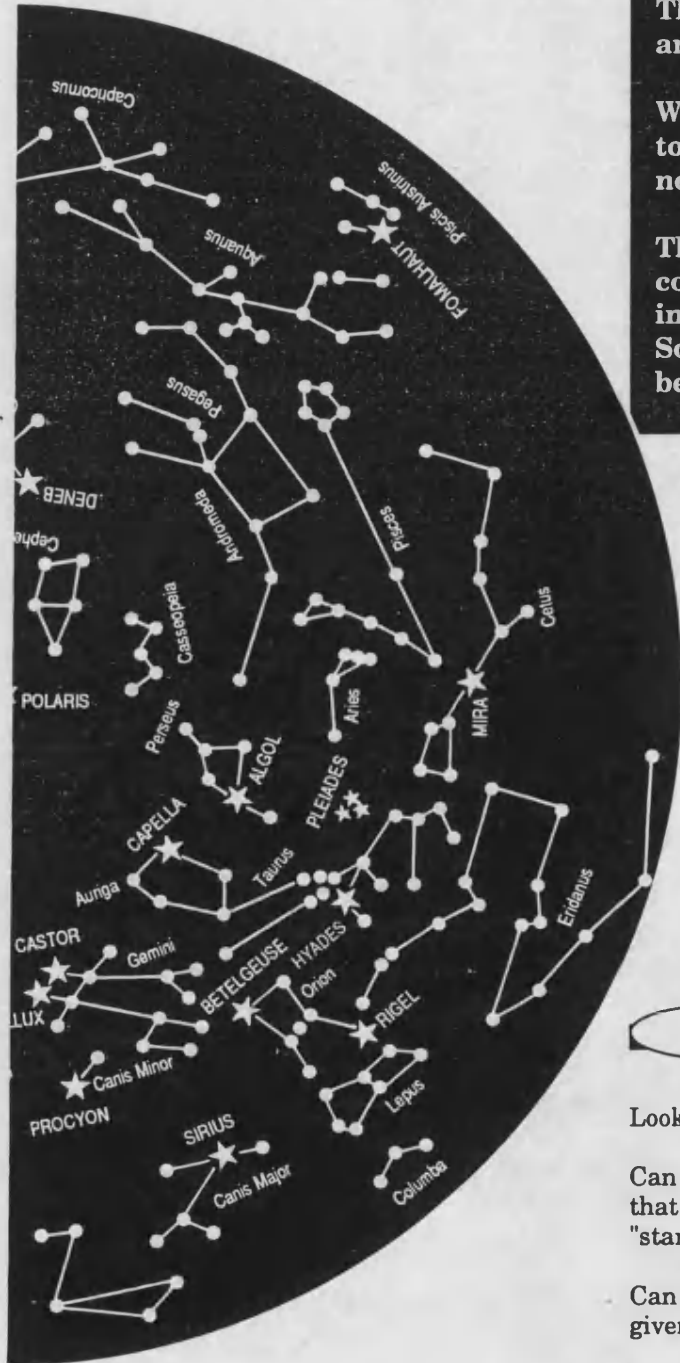


Constellations

Ancient astronomers grouped bright stars together into patterns called *constellations*. They named these after people, animals and gods.

We use these constellations today. Many have been given new English names.

The map shows all of the constellations that can be seen in the Northern Hemisphere. Some bright stars have also been labelled in capital letters.



Look at the map.

Can you find the twelve constellations that have given their names to the "star signs"?

Can you work out why they have been given their names?

You can make up your own stories about some of the constellations.

Observing the night sky

You do not need any special equipment to begin astronomy. However, a pair of binoculars will be very useful.

To find out more it is a good idea to join a local astronomy society. Your teacher will be able to give you an address to contact. You might like to start an Astronomy Club in school if you do not already have one.



Some practical hints

- ★ A problem for astronomers is the amount of unwanted light from street lamps, houses and so on. Even if you cannot avoid this, you can still see the Moon, the main constellations and some of the planets.
- ★ Some newspapers have monthly star maps. Your teacher will be able to help you with these.
- ★ It will take about half an hour for your eyes to become fully adapted to the dark. If you use a torch, cover it with red cellophane. Red light has less effect on your "night vision".
- ★ It can become cold at night. Make sure that you wear suitable clothing.
- ★ Keep notes of your observations.

Comets

Read the article about comets.



Halley's Comet passed close to the Earth in 1986. It was hoped to learn a great deal about comets and our solar system from this visit. There was a lot of interest and scientific activity. A space craft was sent to intercept the comet to obtain information about it.

Complete the task on the sheet.

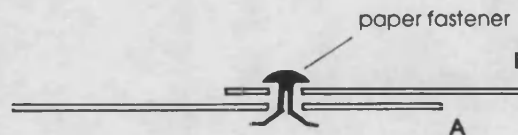
Making a Moon phase predictor

Making and using this predictor will help you to understand more fully why the Moon appears to change shape. You will also be able to work out how many days there are in a full Moon cycle. It will help you to plan the best times to look at the Moon.

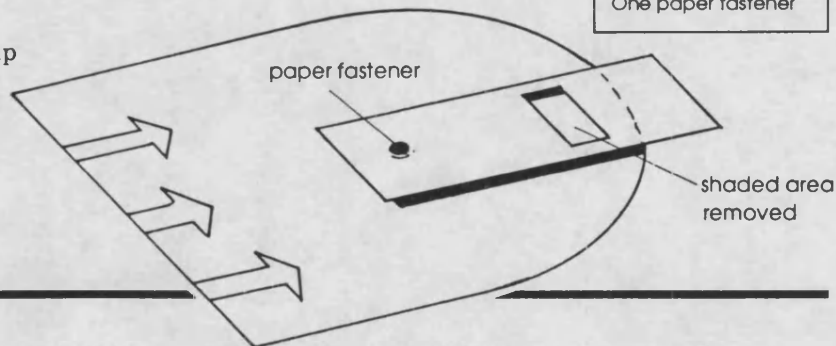
The predictor is not exact, but it will help you with your ideas about the Moon.

Using the predictor

Turn the rotating arm so that one of the Moon diagrams appears in the small cut-out. The amount of unshaded portion showing is the amount of lit portion of the Moon visible from Earth.



YOU WILL NEED:
One Moon phase predictor sheet
One sheet of stiff card
Scissors and glue
One paper fastener



Things to do . . .

On the predictor, label in the new Moon, full Moon, and half Moons.

Each of the Moon diagrams is equal to 3.5 days. Labelling the new Moon as Day 1, continue to number each diagram working in the direction of the arrows.

Your predictor only shows you how much of the Moon is visible. It does not tell you the shape. Can you use a predictor to work out the Moon's shape on each of the days?

Can you redesign the Moon phase predictor to give the Moon's shape for every day of the cycle?

Calenders

Except for February, our months have either 30 or 31 days.

Can you find out anything about other calenders?

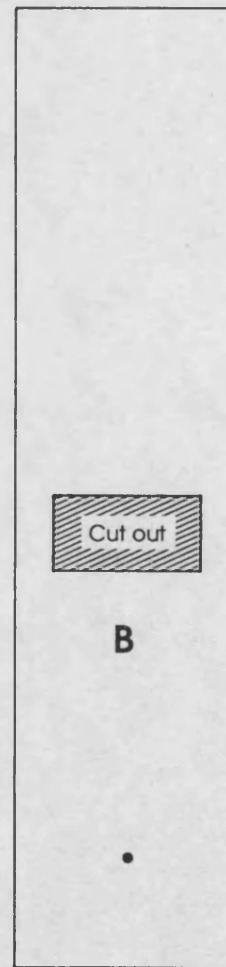
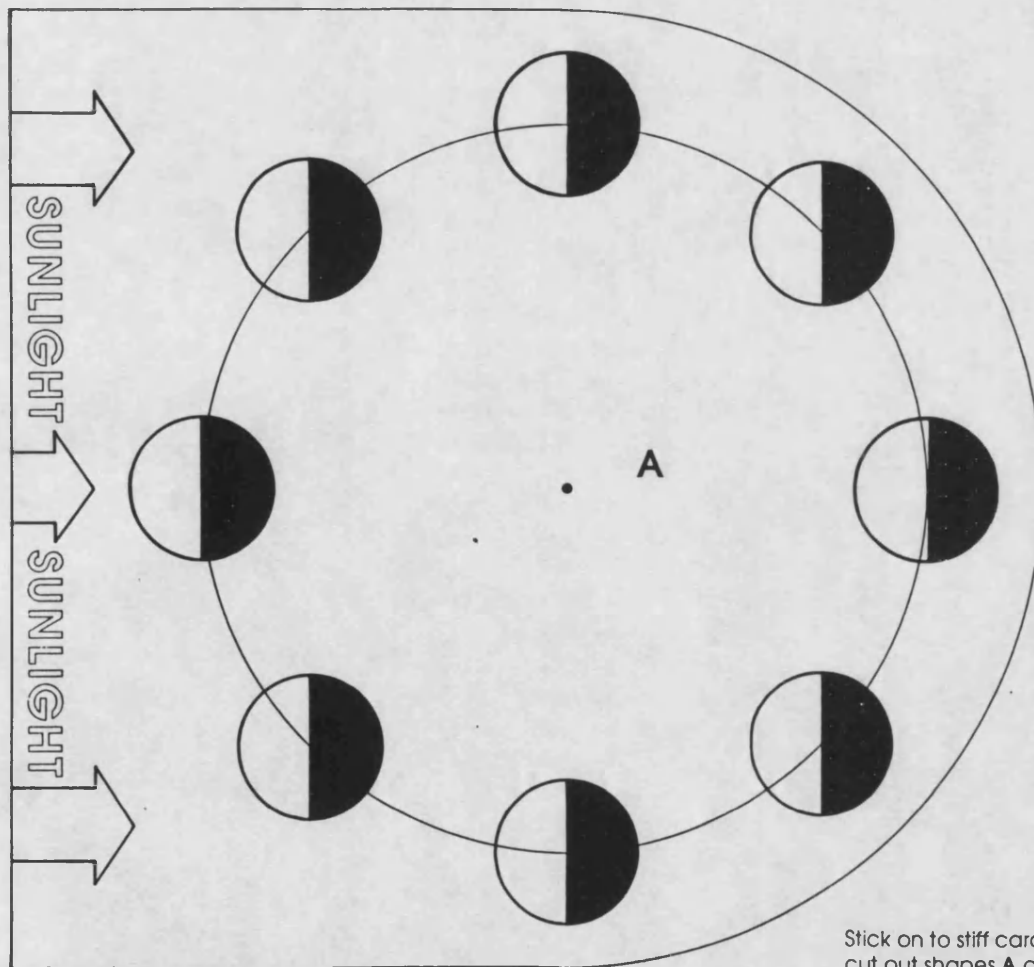
Why does Easter occur on different dates in each year?



Moon Phase Predictor



THIS SHEET MAY BE PHOTOCOPIED



Stick on to stiff card and cut out shapes A and B.

Cut out the shaded area in shape B.

Moon Shape Sheet



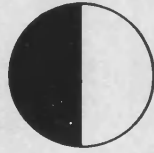
THIS SHEET MAY BE PHOTOCOPIED



new



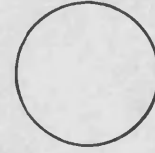
crescent



first quarter



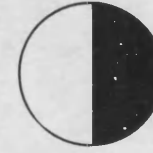
gibbous



full



gibbous



last quarter



crescent

Comets



THIS SHEET MAY BE PHOTOCOPIED

Comets have produced fear and awe since the beginning of time. Ancient people were alarmed by their sudden, unexpected appearance. They did not know where they came from, or where they went when they vanished from sight. They did not know when they would appear next.

Because comets were so unusual, their appearances have been recorded since at least the 22nd century BC. The Chinese recorded a comet in 467 BC. A comet blazed through the night sky as Atilla the Hun marched through Gaul on his way to invade Rome. Another comet appeared in the sky in 1066 on the eve of the Battle of Hastings. William the Conqueror told his Norman soldiers that this was a bad omen for the English. The Bayeux Tapestry shows a frightened King Harold looking up at the comet in the sky from his throne. In 1456 a bright comet caused great panic among Christians who thought it must be connected with the fall of Constantinople to the Turks. Pope Calixtus III issued a bull of excommunication against the comet, *"to rid the earth and mankind of its calamities"*.

Comets were often blamed for all sorts of disasters including armies losing battles, crops failing, floods and so on.

We now know that comets orbit the Sun with elliptical orbits. The time of the orbits varies from 3.3 to several hundred

years. They are thought to be made up from debris left over from the formation of our solar system.

The most famous comet of all was discovered by the English astronomer Edmond Halley. He calculated the orbit of a comet he observed in 1682. He then calculated the orbits of comets that appeared in 1531 and 1607. He found that they were the same. He concluded that the same comet had appeared three times, with an interval of about 75 years. The comet reappeared in 1758 proving him correct. We now know that the comet recorded by the Chinese in 467 BC, the comet that terrified King Harold and the comet that angered Pope Calixtus in 1465 were all appearances of *"Halley's Comet"*.

Exact calculations showed that it would appear in 1910. There was a great panic as people knew that the Earth would pass through the tail of the comet. They thought they would be poisoned by noxious gases; people bought gas masks and "comet-pills" to avoid this. Although the tail did contain carbon dioxide and other gases no harm was caused.

It is possible to calculate other appearances of this comet. Scientists prepared for its visit in 1986. A spacecraft was sent up to intercept the comet and send back information that would tell us more about the origins of our solar system.

Scan the text to find out what it is about.

Now read the text carefully.

Now work with a partner.

There are several main parts to the article - what do you think they are? Use colour or a code to mark parts of the text connected with each part.

Either:

Write your own paragraph about each part; or make a word burr / spider diagram about comets.

Calculate the dates when Halley's Comet would have appeared from 1531.

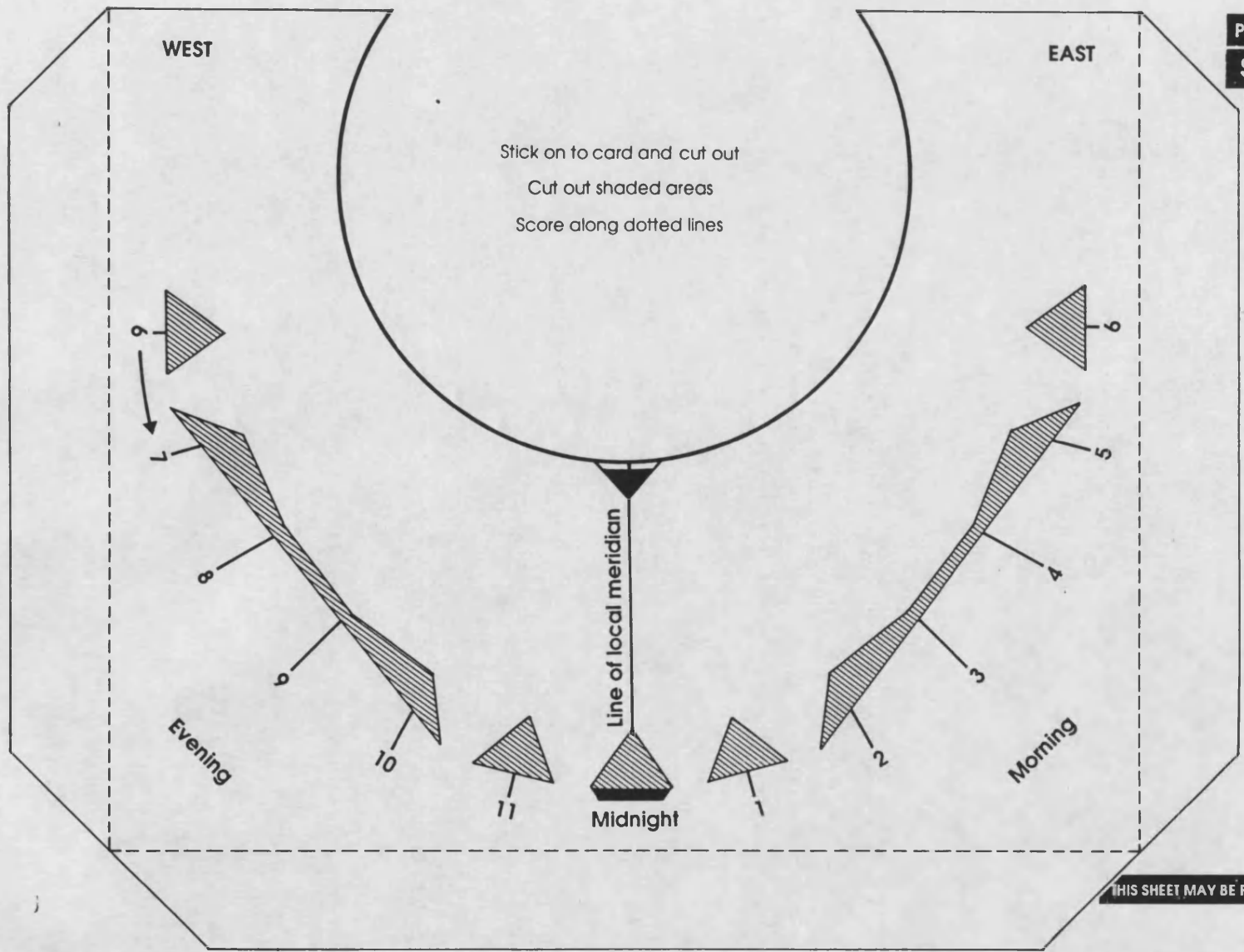
Can you find historical events for these dates?

Planisphere

Sheet B

Stick on to thin card and cut out

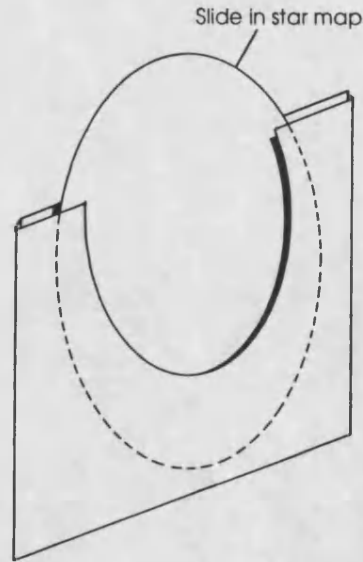
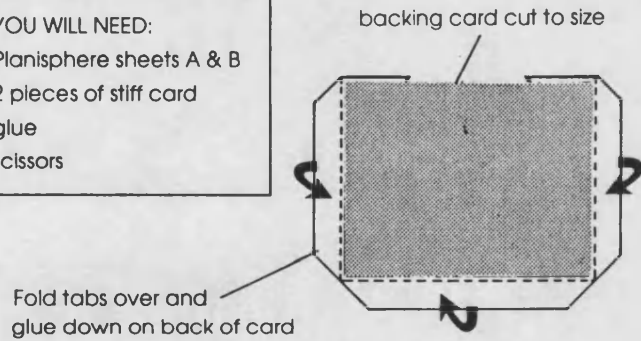




Making a Planisphere

YOU WILL NEED:

- Planisphere sheets A & B
- 2 pieces of stiff card
- glue
- scissors



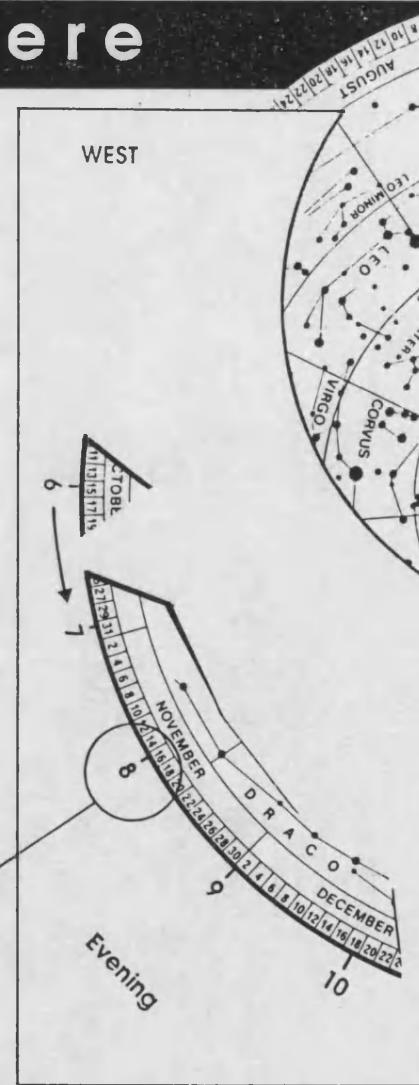
Using your model planisphere

The planisphere can be used to find out what stars you can see at any time on any day of the year.

It actually shows the stars you could see if you were in London. It will not be much different for other places in Britain.

Find your time on the bottom scale. Move the star map to line up your date with the time.

The map now shows you the stars you can see on a clear night.



THE PLANETS

The Earth is one of nine planets that orbit the Sun.



What are the differences between stars and planets?

Although we often use the words *stars* and *planets*, many of us find it difficult to explain the difference between them. They often look the same when we see them in the night sky.

Make a list of your ideas.
Discuss them with your partner or in your group.
Explain your ideas to each other.
Are there any differences?
Agree a new list and write this down.

Star and planet information.				
NAME		TEMPERATURE	DISTANCE FROM THE SUN	SIZE RELATIVE TO EARTH OR SUN
STAR	PLANET			
ALDEARAN	MARS	- 140°C to 20°C about 3000°C	2.279 x 10 ⁸ km 641 light years	0.5 size of Earth 36 times bigger than the Sun
	NEPTUNE	-216°C	2.87 x 10 ⁹ km	4 times bigger than Earth
ARCTURUS	SATURN	-180°C about 3000°C	1.43 x 10 ⁹ km 361 light years	9.4 times bigger than Earth 23 times bigger than the Sun
BETELGEUSE	VENUS	about 3000°C 480°C	650 light years 1.08 x 10 ⁸ km	370 times bigger than the Sun about the same size as Earth

NOTE: The diameter of the Sun is about 100 times that of the Earth.

Use the information in the table.
Make a list of differences between stars and planets.

Think about:

distance from Sun

temperatures

size

Discuss these in your group.
Compare this with your first list

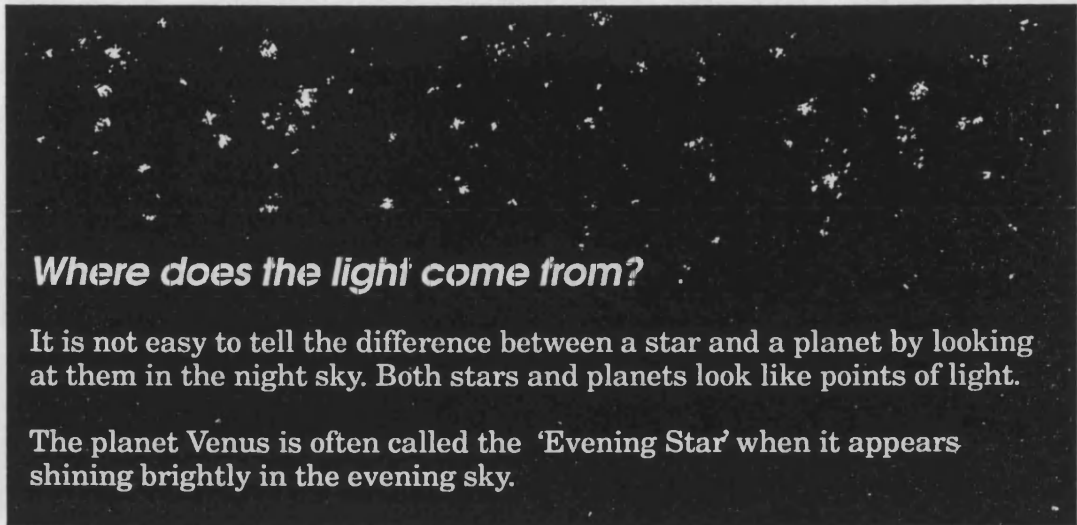
Look at the star and planet information table (cover page).
Look at the temperatures.

What do things look like when they are very hot?

Why do you think we can see the stars?

Now look at the temperatures of the planets. Do you think they give out their own light?

Where does the light come from which allows us to see the planets?



Where does the light come from?

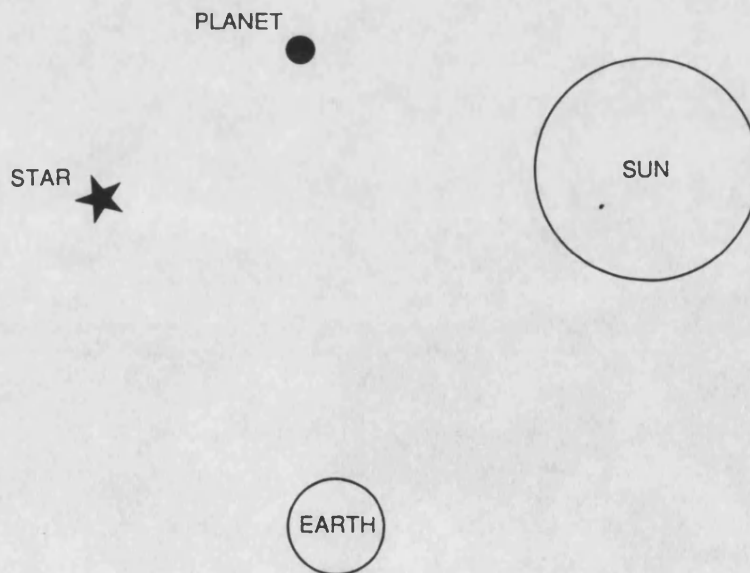
It is not easy to tell the difference between a star and a planet by looking at them in the night sky. Both stars and planets look like points of light.

The planet Venus is often called the 'Evening Star' when it appears shining brightly in the evening sky.

Copy this diagram.

Draw lines to show how the person on Earth can see the planet and the star.

Write down the difference between the way we see stars and the way we see planets.



Scaling the Solar System

One of the problems of studying astronomy is that the distances it involves are very large. In astronomy one million kilometres is very near!

The only way we can get an idea of the scale of our solar system is by making a model of it.

Collect these 9 items from your teacher:

two peas	a plum
two oranges	a cherry
a mustard seed	two pins.

Each of these represents a planet. Imagine a wall to be the Sun. Place the planets where you think they should be on this scale.

When you have done this collect the Scale Answer Sheet.

How close were you?

You could make a scale drawing to display on a wall.

You may try this exercise on your school field.

Information about the Planets						
NAME	SIZE (DIAMETER) km	DISTANCE FROM THE SUN millions km	TIME TO SPIN ONCE	TIME TO GO AROUND THE SUN ONCE	NUMBER OF MOONS	TEMPERATURE ON SURFACE °C daytime
Mercury	4880	60	59 days	88 days	0	350
Venus	12104	108	243 days	224 days	0	480
Earth	12756	150	24 hours	365 days (1 year)	1	22
Mars	6787	228	24 hours	2 years	2	- 23
Jupiter	142200	778	10 hours	12 years	16	- 150
Saturn	119300	1427	10 hours	29 years	17	- 180
Uranus	51800	2870	23 hours	84 years	14	- 210
Neptune	49500	4497	22 hours	165 years	2	- 220
Pluto	3000	5900	6 days	248 years	1	- 230

A *day* is the time taken for the Earth to spin once. Other planets take different times to spin once.

A *year* is the time taken for the Earth to go around the Sun once. Other planets take different times. Their 'years' are different.

Looking for patterns

In your group, talk about the patterns that you can find in this data.

Life on the Planets

What state (solid, liquid or gas) would water be in on each of the planets?

Does this tell you anything about the possibility of life on any other planet?

Exploring the Planets

Until 1962 everything we knew about the planets had been found out using telescopes. On August 27th 1962 the unmanned spacecraft *Mariner 2* was launched. *Mariner 2* flew past the planet Venus. This was followed by:

Mariner 4 in 1965 - first "fly past" of Mars.

Mariner 9 in 1971 - first spacecraft to go into orbit around another planet - Mars.

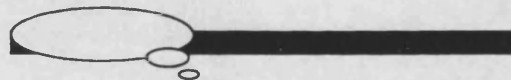
Mars 2 and *Mars 3* in 1971 - Soviet probes dropped probes onto surface of Mars.

Mariner 10 in 1973/4 - first probe to Mercury, and first to "visit" two planets, Mercury and Venus.

Venera 9 and *Venera 10* in October 1975 - Soviet probes landed on Venus.

Pioneer, a modified *Mariner* spacecraft, has recently flown past Jupiter and Saturn.

Voyager 1 and *Voyager 2* have sent back photographs of Saturn, Uranus, Neptune and their moons.



Can you find out about space missions to other planets?

Your library should have information.

Make a poster or write about one of these planets, or a space mission. Make it as interesting as you can.

You may watch some videos of space missions.

Space missions have told us about the rings and moons of **JUPITER** and **SATURN**, and about their atmospheres.

What have we found out?

MERCURY

We used to think that it only turned once each time it went around the Sun. This would have meant that the same side would always be facing the Sun. This side would be very hot. We also thought it had an atmosphere. The *Mariner* missions told us that we were wrong.

We now know that it takes 88 days to go around the Sun, and spins once every 59 days. It has no atmosphere. The temperature on the surface varies from about 350°C in the day to -170°C at night.

VENUS

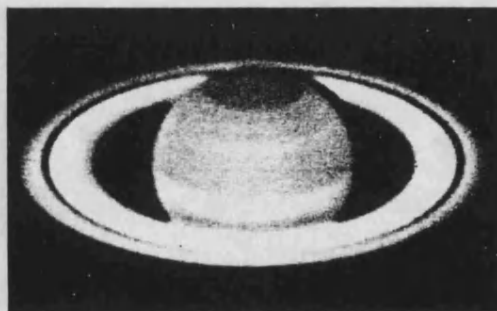
Only about 30 years ago we thought that Venus was like Earth. We thought that there may be life on Venus.

Now we know that it is a very hot desert. Temperatures in the day reach 480°C. Rain falls as a mixture of acids.

MARS

30 years ago we thought that there may be life on Mars.

Now we know there is no life. It is a dry, dusty planet with volcanoes. There is water on the planet, but it is mostly chemically bound in the rocks.



The Earth in Space

Teacher's Guide



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The Earth in Space
Teacher's Guide



This pack on *The Earth in Space* is based on the ideas of John Baxter developed during his research with children in both Primary and Secondary schools. The test pack has been developed from materials used during this research.

The pupil resources were written by John Baxter with additional material by Jim Sage.

The background booklet for teachers was written by Rodger Sleight.

The teacher guide was written by Jim Sage and John Baxter.

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Introduction

Including an Attainment Target on "The Earth in Space" in the National Curriculum for Science has provided a firm place for Astronomy in the education of all children. Apart from being a fascinating subject in its own right, it provides excellent opportunities for showing the contributions of other cultures and societies to the development of science. It is also an area where many adults, let alone children, suffer from serious misconceptions. This pack allows children to explore their own ideas and test them against available evidence. Often this evidence is provided by investigations designed and performed by themselves.



Organisation of the pack

The pack is made up of :

- 1 A set of pupil resources.
- 2 A test pack that can be used to find out pupils prior understanding. This is made up of a consumable pupil answer booklet and a set of masters for a series of test cards. These can be used to make transparencies for OHP or be stuck onto card. Detailed notes on the use of this pack are given later.
- 3 A background booklet for teachers. This includes some of the theory needed to teach the pack, and suggested activities for use with pupils. These are "teacher led" activities where no pupil materials have been produced. It also includes details of how to construct a simple telescope and other useful equipment.
- 4 This Teacher's Guide for the whole pack.

Aims

- 1 To stimulate and interest children, and to allow them to find out about the development of some important ideas in science, and about the people involved. This will allow them to develop their ideas about the nature of science, and about the contributions of different cultures and societies.
- 2 To identify and resolve childrens' confusions and misconceptions about astronomical phenomena: to build on their ideas and explanations, and develop their understanding.

In meeting the above aims some of the requirements of the National Curriculum will be met as indicated on the next page.

Matching with Science in the National Curriculum

The Programme of Study for Key Stage 3 includes:

"Pupils should further develop their study of the solar system both by direct naked eye observations and the use of secondary sources. They should consider changes of day length and seasonal changes, chart the passage of time using a sundial, consider ideas about the position of the Sun and planets within the solar system, and the position of the solar system in the universe. They should study the extent of human exploration of space".

Details of how all of this is covered within **Attainment Target 16: The Earth in Space**, is shown below.

Also included in the Programme of Study for Key Stage 3 are the statements [linked to **AT17: The nature of Science**:

"Pupils should be given opportunities to:

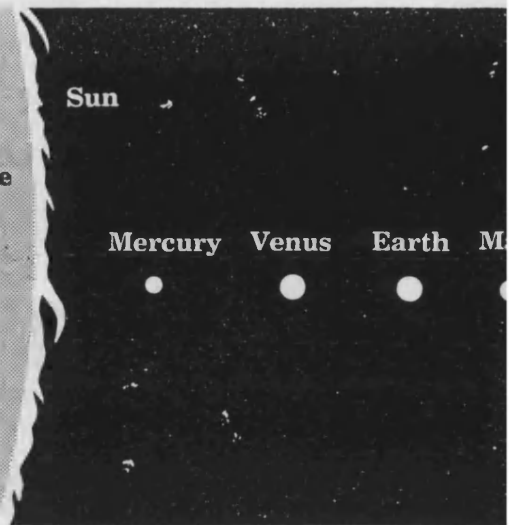
- * study the ideas and theories used in other times to explain natural phenomena
- * relate such ideas and theories to present scientific and technological understanding and knowledge
- * compare such ideas and theories with their own emerging understanding and relate them to available evidence"

Opportunities are given to pupils within this pack for pupils not only to study the development of accepted ideas in science, but also the development of their own ideas and compare these with the accepted ideas. This latter approach would seem to be the best way of interpreting parts of AT17.

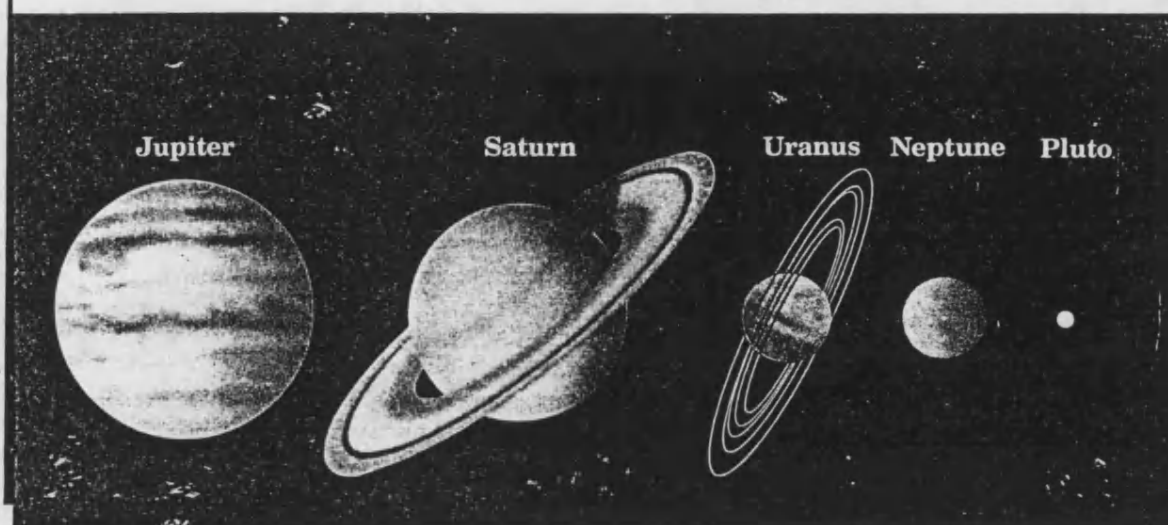
There are also many activities that allow pupils to develop the investigative skills outlined in **AT1: Exploration of Science**.

Attainment Target 16: The Earth in Space

Pupils should develop their knowledge and understanding of the relative positions and movement of the Earth, Moon, Sun and solar system within the universe.



Level	Statement of Attainment	Section of pack where this is covered
	Pupils should:	
1	be able to describe through talking, or other means, the seasonal changes that occur in the weather and in living things	The seasons
	know the danger of looking directly at the Sun	What do you know about the Sun?
	be able to describe, in relation to their home or school, the apparent daily motion of the Sun across the sky	What do you know about the Sun?
2	be able to explain why night occurs	What do you know about the Earth in space?
	know that the day length changes	What do you know about the Sun?
	know that we live on a large, spherical, self-contained planet called Earth	What do you know about the Earth in space?
	know that the Earth, Moon and Sun are separate bodies	What do you know about: the Earth in space, the Moon, the Sun?
3	know that the inclination of the Sun in the sky changes?	What do you know about the Sun?
	be able to measure time with a sundial	Teacher's booklet
4		



Level	Statement of Attainment	Section of the pack where this is covered
4	know that the phases of the Moon change in a regular and predictable manner	What do you know about the Moon?
	know that the solar system is made up of the Sun and planets, and have an idea of scale	The planets, and in Teacher's booklet
	understand that the Sun is a star	What do you know about the Sun?
5	be able to relate a simple model of the solar system to day/night and year length, changes of day length, seasonal changes and changes in the inclination of the Sun	The seasons
	be able to observe and record the shape and surface shading of the phases of the Moon over a period of time	What do you know about the Moon?
6	be able to argue, using relevant scientific language how the Earth, Moon, Sun and planets move relative to one another	Ideas from various parts of the pack
	be able to explain that the solar system forms part of a galaxy which is part of a larger system called the universe, and that the position and nature of the component parts of the universe change over long time scales	Partly covered in The Astrology Connection
7	be able to argue with the aid of supporting evidence that the Earth is not flat	What do you know about the Earth in space?
	understand that gravity acts towards the centre of every astronomical body	Understanding gravity

Teaching Strategies

There are many opportunities in the pack for the use of active learning strategies. The use of group discussions, 1-2-4 snowball techniques, use of posters for display, creative writing, drama and role play are all strongly recommended.

Pupils are encouraged to explore and discuss their own ideas and explanations, compare these with others in their group or historical viewpoints, and then devise ways of testing these ideas. This greater pupil involvement will reinforce their learning.

Pupils should also be encouraged to evaluate their own work and what they have learnt. A self assessment sheet has been included to help with this. This sheet can be linked to a pupil's Record of Achievement and can be photocopied as required.

The teaching strategies adopted have been strongly influenced by the Children's Learning in Science Project. For further information contact:

**The Children's Learning in Science Project,
Centre for Studies in Science and
Mathematics Education,
School of Education,
The University,
LEEDS LS2 9JT.**

Common Misconceptions

These are the common misconceptions discovered during the surveys and interviews with pupils conducted during the development of these activities.

Almost all of the pupils embarking on attainment target 16 will have observed many of the basic astronomical phenomena covered in the National Curriculum. For many aspects of astronomy the pupils will have formulated their own explanations for particular events before receiving any formal education. They will enter the laboratory, not as empty pots ready to be filled with astronomical information, but with their own explanations and ideas which may be resistant to change. Many of these misconceptions are commonly held and while each group of pupils will contain a few members with unique ideas, the majority will fall into a few common categories. The implicit teaching strategy used in this pack is that pupils challenge their ideas by following the scientific process of:

IDEA→TEST→RESULTS→REFORMULATE

The evidence of research suggests that if the misconception is not challenged it may form a hybrid notion which is a mix of the teacher's science and that of the pupil.

The list of commonly observed misconceptions on basic astronomy given below is intended to draw teachers' attention to the ideas their pupils may bring with them into the class. Armed with some ideas of the pupils' misconceptions, the teacher is in a stronger position to help pupils challenge their ideas and update them if necessary.

TOPIC AND TYPICAL AGE

MISCONCEPTIONS

PLANET EARTH IN SPACE AND GRAVITY

A.T. 16 Level 2, 7, 9.



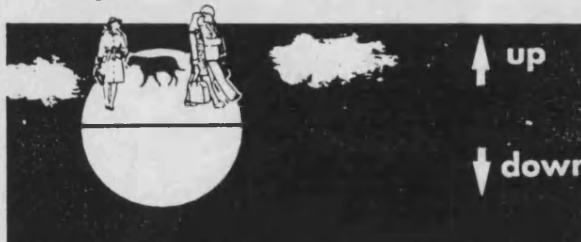
7 - 9 Years

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

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

9 - 12 years

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



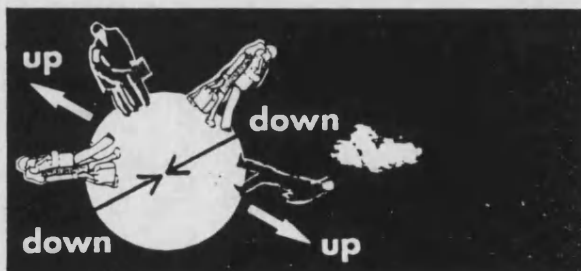
12 - 14 years

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



14+ years

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



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

DAY AND NIGHT

AT 16 Levels 2, 5

7 - 10 years

PUPILS REASONS WHY IT GETS DARK AT NIGHT

- i The Sun goes behind the hills.
- ii Night clouds over the Sun
- iii Moon covers the Sun
- iv Planets get in the way of the Sun

10 - 16 years

The drawings below are typical of those done by pupils supporting notions (v) (vi) and (vii)



- v Sun goes to the other side of the Earth
- vi Sun goes down to Australia
- vii Earth goes around the Sun once a day

Many of our pupils are pre-Copernican in their world view.

PHASES OF THE MOON

AT 16 Levels 2, 4, 5, 6

Many 16 year old pupils are not aware of the regularity of the Moon's phases, or that the period of one month is derived from the period of time between successive new moons. New Moon and the Full Moon are often thought to be the same thing. There appears to be confusion between the phases of the Moon and eclipses. It is commonly thought that the Moon produces its own light and can only be seen at night. Many pupils between 7 to 10 years think that the Moon has something to do with causing darkness at night.

7 - 10 years	Clouds cause the Moon to change its shape
7 - 13 years	Sun blocks out part of the Moon. Planets get in the way
10 - 16 years and commonly in adults	Shadow of the Earth causes the phases of the Moon.
<p>THE SEASONS</p> <p><i>AT 16 Levels 1, 5, 6</i></p>	<p>It is not uncommon to find pupils of 13 years + who are unsure of the spring, summer, autumn, winter sequence. Pupils of all ages often fail to relate the life cycle of plants and animals to the seasons, eg. drawing apple trees in the spring with fruit. Many pupils find it difficult to picture an Earth spinning in front of the Sun to give day and night, while at the same time making its annual orbit which gives rise to seasonal changes.</p>
7 - 10 years	<p>PUPILS' REASONS FOR THE SEASONS</p> <p>Winter clouds stop heat from the Sun. Changes in plants cause the different seasons.</p>
7 - 16 years	<p>Earth further from the Sun in the winter. Sun moves to the other side of the Earth to give them their summer. As the Sun goes around the Earth it goes through different atmospheres which give the seasons.</p> <p>It is not uncommon for pupils to merge knowledge they have gained from popular science programmes with their view, thus forming a hybrid notion. eg: seasons caused by the 'greenhouse effect'; seasons caused by cold planets like Pluto taking heat from the Earth. These ideas appear to be constructs of individuals rather than common notions.</p>

SUN AND SHADOWS

AT 16 Levels 1, 5, 6

Position of sunrise and sunset often not known and pupils have a poor knowledge of the points of the compass.

Movement of shadows throughout the day, both in direction and shadow length, poorly understood, as is the apparent change in the Sun's position and altitude throughout the day and year. Reason for changes in daylight hours throughout the year generally not understood.

Few pupils know that the Sun is a star and most consider that the Sun is burning in a conventional way similar to burning coal.

TIDES

AT 16 Levels 4, 6, 8, 9, 10

Many pupils are unaware that there is a regular pattern to the tides and few know that there are two high tides per day.

Relationship between the Moon, tides and gravity not often observed.

STARS AND PLANETS

AT 16 Level 4, 6, 8, 9, 10

It is not often that pupils under 13 years of age know that the stars are like our Sun. Most consider the stars to be smaller than the Earth and Moon.

PUPILS. IDEAS ABOUT THE STARS AND PLANETS

Age 7 - 13

Stars go to the other side of the Earth during the day.

People or living things could survive on the stars.

The stars stay in the same place at night.

Age 11-16

The planets are bright stars.

Pupils are generally unaware that changes occur in the universe.

For a majority of pupils the only time they consider the stars and planets is for astrology. Many pupils regularly read and believe in their birth star predictions.

Other Useful Resources

Videos:

These are strongly recommended:

Apollo 11 "The Eagle has Landed"

Apollo 12 "On the shoulders of giants"

Both about manned visits to the Moon

Journey Into Space - history of the Space Race

Spacewatch - Video Encyclopedia of Space

Planet mars

Space Shuttle

Voyager

Graphic Guide to the Heavens

Space - the Frontiers and Beyond

Voyage to the Outer Planets - Issac Asimov

All are available at very reasonable prices from:

Spaceprints, 117A High Street, Norton,

Stockton-on-Tees, Cleveland TS20 1NN

Telephone: 0642 555401

A catalogue of videos and films on astronomy is available from:

The Association for Astronomy Education

38 Victoria Crescent, Birkdale Road, Dewsbury,

West Yorkshire WF13 4HJ.

The price at May 1989 was £1.50 incl. p & p

Useful Addresses

A variety of resources are available from:

The Armagh Planitarium, College Hill,

Armagh BT61 9DB NORTHERN IRELAND.

Cochranes of Oxford Ltd., Leafield

OXFORD OX8 5NT.

NASA

John F Kennedy Space Centre

Kennedy Space Centre

Florida.

Computer Software

Astronomy - BBC Software

has sections on phases of the moon, eclipses, seasons, planetary motion and Lander.

Starseeker - Mirrorsoft

Pupils will need help in using this.

Wallcharts

Relating to Satellites; The Moon - Apollo Exploration/ Mapping Space; Exploring the Planets; Man in Space; Day, Night, Seasons, Moon and Tides.

Are available from:

Pictorial Charts Educational Trust

27 Kirchen Road, London W13 0UD

Books

Pupils:

Adventures in Astronomy.

P. Seymour. Pub. John Murray 1983

Key Definitions in Astronomy.

J. Mitton. Pub. Muller Ltd. 1980

The time and space of Uncle Albert.

R. Stanford. Pub. Faber and Faber. 1989

Magazines:

New Scientist

Scientific American

Teachers:

Exploring the Heavens, D.V. Clish.

Pub. Glenmore Publications, Exeter. 1983.

Time. Published for the Schools Council

by MacDonald Ed. 1977 (4th impression)

Coming of Age in the Milky Way. T. Ferris.

Pub. Anchor Books (Doubleday) 1988.

The Practical Astronomer. C.A. Ronan.

Pub. Pan Books 1989.

Space Biology. C. F. Stoneman.

Biology Topic Books. Pub. Penguin 1972.

Chemistry in Dimension. B. Slater et. al.

Pub. Macmillan Ed. 1987.

(Section 2 : Where do chemicals come from?)

You should contact your local astronomical group, they will probably be prepared to help you.

USE OF THE TEST PACK

This test has been devised to elicit pupils' knowledge of the easily observed astronomical events. The check list was drawn up from the findings of surveys and open ended interviews to ascertain pupils ideas. The topics covered are those which the Curriculum Committee of the Association for Astronomy Education and a majority of science teachers who took part in a national survey, considered should be a part of all pupils experience.

The surveys and interviews uncovered a number of commonly held misconceptions which have been used as central themes in the check list and in the resource pack. The questions relate to particular units in the pack and can be used to discover the extent of a pupil's knowledge and understanding. Pupils can then select or be directed to the units from the pack which relate to areas where they show some confusion. In this way pupils will not cover work already known to them. This is particularly useful if a resource based approach is used. Some questions could be used for homework if required.

Every attempt has been made to eliminate testing reading and writing skills by displaying the questions in graphic form accompanied by a verbal statement. Answers are then given on a graphic five point agreement scale, or by selecting from a range of possible answers; both of these require an answer in tick form or by putting a circle around the selected box.

The test can be carried out with class groups if an OHP is used, but no more than eight to ten pupils if the cards are used.

These recommendations should be followed to obtain meaningful comparisons:

- 1 Pupils should be told that this is not a formal test. We are not interested in "right" or "wrong answers", only in what they think.
- 2 Pupils need to be familiarised with the graphic agreement scale. A simple mock test covering the full range of answers could be used.
- 3 The tester must read each statement to the pupils while showing the graphic card, [or the OHP transparency].
- 4 Pupils should be told to answer in their booklets.
- 5 Pupils should be positioned so that they can see all the cards, or the OHP screen, but cannot see each other's answers.
- 6 There should be no discussion during the test.

Pupils should keep the booklets so that they can monitor the development of their ideas.

CHECK LIST

This shows how the questions in the test pack relate to the pupil resources.

QUESTION[S]	PUPIL RESOURCE
1, 3, 5, 7, 9, 12, 15, 31	What do you know about the Earth in Space?
21, 22, 26, 27, 28, 29, 30, 32, 33	What do you know about the Moon?
2, 6, 17, 19, 23, 24	What do you know about the Sun?
14, 18, 20	The Seasons
7	The Planets
8, 16	Understanding gravity
34	The Astrology Connection
4, 10, 11, 13, 25	These questions relate to activities that are described in the Teacher's Booklet

Test Statements

Question	Card No.	Statement
1	None	In the space draw what you think planet Earth looks like from the Moon. Draw in some clouds and where people live.
2	1	This is a drawing of a tree early in the morning. Draw an arrow to show which way its shadow will move as the day goes by
3	2	We get day and night because the Earth goes around the Sun once a day [NB: Remind pupils about the graphic agreement scale]
4	3	Which diagram compares the real size of the Moon and Sun best? A Sun larger than Moon B Sun and Moon same size and small C Sun and Moon same size and large D Sun smaller than Moon
5	4	The Earth turns around once a day to give day and night
6	5	This a drawing of sunset
7	None	How many hours are there in one day
8	6	This is a drawing of a woman standing on the Earth. Draw an arrow to show which way the stone will fall if she gently lets it go.
9	7	The Sun goes around the Earth once a day to give day and night

Question	Card No:	Statement
10	8	Which diagram compares the real size of the stars and Moon best? A Stars larger than Moon B Stars and Moon same size and small C Stars smaller than Moon D Stars and Moon same size and large
11	9	Which diagram compares the real size of the Earth and Moon best? A Moon smaller than the Earth B Moon and Earth same size and small C Moon and Earth the same size and large D Moon larger than the Earth
12	10	Clouds cover the Sun to give day and night
13	11	The stars stay in the same position throughout the night
14	12	It is cold in the winter because the Sun is further away from the Earth
15	13	The Moon covers the Sun to give day and night
16	14	The drawing shows a spaceman on the Moon. Draw an arrow to show which way the spanner will fall if he lets it go
17	15	One part of our Earth has day while the other half has its night. Which drawing shows the correct day/night division?
18	16	It is cold in the winter because clouds stop the Sun from shining

Question	Card No:	Statement
19	17	The drawing shows planet Earth. There are three arrows pointing to different countries. The first arrow shows that the children in this country are in bed. It is the middle of the night. Join the other arrows up to the drawing which shows what you think the children will be doing in the other countries
20	18	It is cold in the winter because the North Pole tilts away from the Sun at this time of the year.
21	19	Tick the shape the person will see the Moon make
22	20	The first diagram shows a boat in a harbour Tick the drawing which shows how the boat will look twelve hours later
23	21	The drawing shows a man stranded on an island. Draw an arrow to show which way he will have to move if he wants to stay in the shade
24	22	This is a drawing of sunset
25	23	Which drawing compares the real size of the Sun and Earth best? A Sun larger than Earth B Sun same size as the Earth and large C Earth larger than Sun D Sun same size as the Earth and small
26	24	The Moon sometimes makes this shape in the night sky
27	25	The Moon can sometimes be seen during the day

Question	Card No:	Statement
28	26	Tick the shape the person will see the Moon make
29	27	Which drawing gives the correct reason for the tides coming in and going out A Lots of boats in the sea makes the water level rise B The Moon pulls on the sea and makes the tide rise C Wind causes the tides to come in and go out D Changes in the weather cause changes in the tides
30	28	The Moon changes its shape from half to full to crescent because parts of it get covered by clouds
31	None	The drawings are of photographs taken by a space-man as his rocket left planet Earth. He got the photos muddle up. Can you place them in order? Start with the one taken just after lift-off and end with the one taken farthest from Earth. Place the letters in the box
32	29	The Moon never makes this shape in the night sky
33	None	The half-moon weighs less than the full moon
34	None	The drawing shows the Sun and Earth. Draw in where you think the stars are
35	None	The Moon appears to change its shape because we see different amounts of the illuminated half from Earth
36	None	The Moon changes its shape throughout a month because different amounts of the Earth's shadow falls on the Moon's surface

Notes on Pupil Resources

AN INTRODUCTORY LESSON

To introduce this pack on astronomy it is a good idea to have an introductory lesson where pupils discuss "astronomical" events that they have experienced. This will include such things as sunrise/set, the Moon - change in the length of daylight, the position of the Sun in the sky, etc. This will get the children talking about these events and give them an opportunity to share their ideas. Some of these ideas could be turned into posters than can be displayed and referred back to as their ideas develop.

WHAT DO YOU KNOW ABOUT THE EARTH IN SPACE?

A discussion of the Observation-Ideas etc. model may be needed.

Equipment: torch/ray box, spheres of different sizes, saucer shapes, card to make shapes, screens to cast shadows onto. For the flat Earth / round Earth activity, pupils could fold a piece of paper to give a curved surface. A model boat can be used to show the effect.

WHAT DO YOU KNOW ABOUT THE MOON?

Use a 1-2-4 snowball technique for the discussion. See the notes on the Moon in the background booklet for teachers. The cratering experiment needs to be tried out in advance.

Moon phase experiment needs: torch/ray box, spheres of different sizes.

Moon phase predictor needs: copies of the sheets, stiff card, scissors, glue, paper fastener.

Seed problem needs: soil or compost, seed trays or cartons, seeds that will grow quickly, dates of moon phases.

WHAT DO YOU KNOW ABOUT THE SUN?

Warning about looking directly at the Sun needs reinforcing.

Growing seeds investigation: some discussion should take place on the Sun as the initial source of all of our energy. Pupils will design their own investigations and need to be reminded of the need for planning the equipment that they will need.

Sunspot experiments: use steel wire and fairly thick steel plate; give appropriate safety warnings about not touching hot metal.

Sun shadow model needs scissors and glue, paper fasteners, stiff, card, consumable sheets.

"Tracking the Sun" has been included as a long term investigation involving the whole class.

What time must I put lights on my bike?

This is an additional activity that can be used for pupils who are having difficulty with the idea of changing length of daylight. You need to make copies of the two sheets included with the masters. You also need glued ticker tape and scissors.

Pupils to find January on both the lighting up times and the black results sheets, and note the lighting up time. Then place a white strip on the base line [x axis] of the black results sheet, laying it flat and cutting it when it is just long enough to reach the lighting up time for January. Stick the strip on the results sheet above the January label making sure to start at the base line, thus producing the first block.

Continue for the other lighting up times. When the blocks are completed the white represents daylight and the black night. Pupils may place a Sun on the daylight section, the black sheet already has Moon and stars.

When completed the block graph will show that the length of daylight hours changes throughout the year. It should be noted that it is the daylight hours which alter, not - as suggested in the National Curriculum - the length of day, which we take as remaining constant at twenty four hours!

Teachers may get pupils to divide their chart into the four seasons; pupils may notice that spring and autumn have similar daylight hours. This idea will be developed when the seasons are investigated.

THE SEASONS

This is a difficult area for many pupils; you may need to use some simple experiments using a heat source and a blackened plate or solar cell at different angles to help pupils understand.

For the model you need: different sized spheres for the Earth and the Sun [coloured green and red if possible], or suitable, two pieces of stiff wire, pieces of stiff card, scissors and glue. You may need to use a large demo. to reinforce pupils ideas.

Cross-curricular activities - Vivaldi, The Four Seasons; paintings/photographs of seasons.

THE PLANETS

This section is the most obvious for the use of video. For a cross-curricular activity play some of The Planets Suite by Holst.

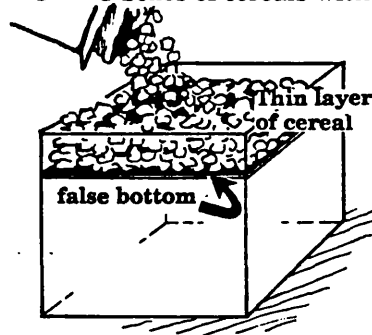
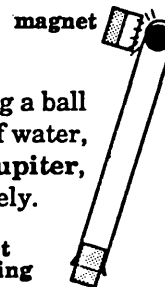
UNDERSTANDING GRAVITY

Gravity is a very difficult concept for many pupils. These activities will not be suitable for some pupils. After the initial activity, this may need to be teacher led.

The following activity is recommended to give pupils an experience of different gravitational forces in familiar situations. It is not intended to be a mathematical comparison.

Equipment needed:

1. 3 long tubes each containing a ball bearing; 1 with air, 1 full of water, 1 full of glycerine labelled **Jupiter**, **Earth** and **Moon** respectively. 1 Magnet.
2. 3 balloons - 1 fully blown up, 1 half blown up and the other full of water, labelled **Moon**, **Earth** and **Jupiter** respectively.
3. 3 boxes of cereals with false bottoms.

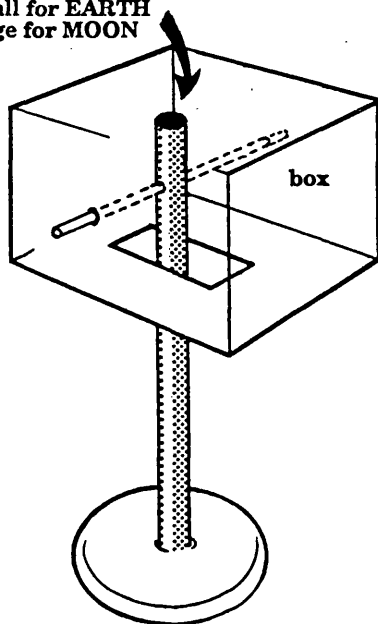


- 1 with weights stuck on six sides labelled **Jupiter**, 1 with 2 weights labelled **Earth** and 1 with no weights labelled **Moon**.

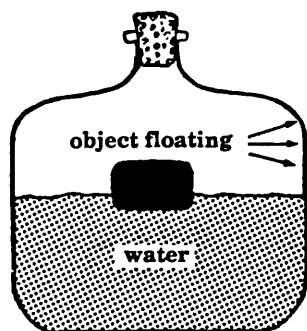
4. 3 springs with masses hung on the end the masses in boxes labelled '100 N' but one containing 100 N labelled **Jupiter**, 1 with 10 N labelled **Earth** and 1 with 2N labelled **Moon**.

5. Three pendulum boxes.

Mass
none for JUPITER
small for EARTH
large for MOON



6.



very light for MOON
medium for EARTH
heavy for JUPITER

You should also add things that are not affected by gravity eg. metre rules and stopclocks.

No pupil resource has been produced for this. Pupils should be asked to observe and try to explain the differences. This will give them an opportunity to formulate their ideas about gravity.

THE ASTROLOGY CONNECTION

Pupils will require access to the library or reference books for some of this activity.

TIME AND CLOCKS

These activities have been added to follow on from work on sundials. Details of sundials are in the background book for teachers.

EQUIPMENT :

- ◆ stopclocks/watches/timers
- ◆ modelling clay to make pendulum bobs, string, clamp stand, etc.
- ◆ metre/half-metre rules
- ◆ filter funnels, beakers, washing-up/ plastic drinks bottles, sand
- ◆ three different sized beakers, candles on bases
- ◆ plastic curtain track fixed to board with different steepness slopes [see sheet], ball bearings or marbles
- ◆ stethoscope
- ◆ thiosulphate solution, dilute hydrochloric acid, thermometers, beakers, measuring cylinders, safety goggles/ face shields

MASTERS FOR PHOTOCOPYING

- ◆ Lights on your bike (x 2)
- ◆ How well did I do?
[self assessment sheet]
- ◆ OHP transparency masters for the test

HOW WELL DID I DO ?

Name _____

Class _____

1 How well do you feel you:

explained your ideas?

tested your ideas?

presented your results?

made the models?

2 The most important things I have learned are:

3 The things I found most difficult were:

4 The things I need to improve are:

TEACHER COMMENT:



The Earth in Space

Pupil Activity Booklet

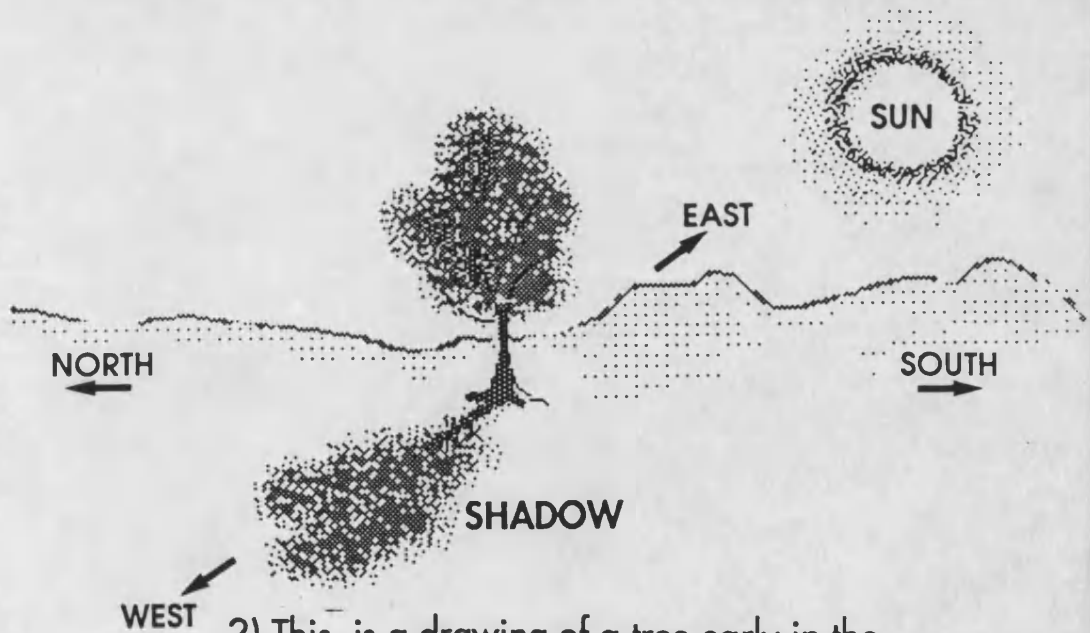
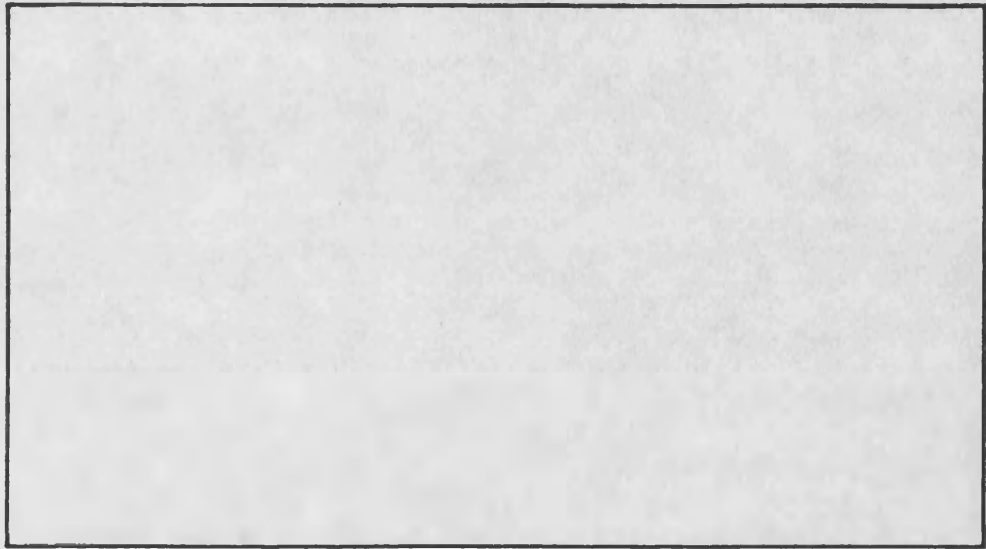
NAME _____

CLASS _____





1) In the space draw what you think planet Earth looks like from the Moon. Draw in some clouds and where people live.



2) This is a drawing of a tree early in the morning. Draw an arrow to show which way its shadow will move throughout the day.



3) We get day and night because the Earth goes around the Sun once every day.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

4) Which diagram compares the real size of the Moon and Sun best ?

A	B	C	D
---	---	---	---

5) The Earth turns round once a day to give day and night.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

6) This is a diagram of sunset.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong



7) How many hours are there in one day?

6	12	24	36	48
---	----	----	----	----

8) Draw an arrow to show which way the stone will fall if she gently lets it go.



9) The Sun goes around the Earth once a day to give day and night.

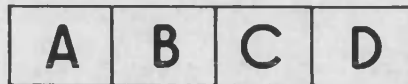
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

10) Which diagram compares the real size of the stars and Moon best?

A	B	C	D
---	---	---	---



11) Which diagram compares the **real** size of the Earth and Moon best?



12) Clouds cover the Sun to give day and night.



13) The stars stay in the same place throughout the night.



14) It is cold in the winter because the Sun is further away from the Earth.

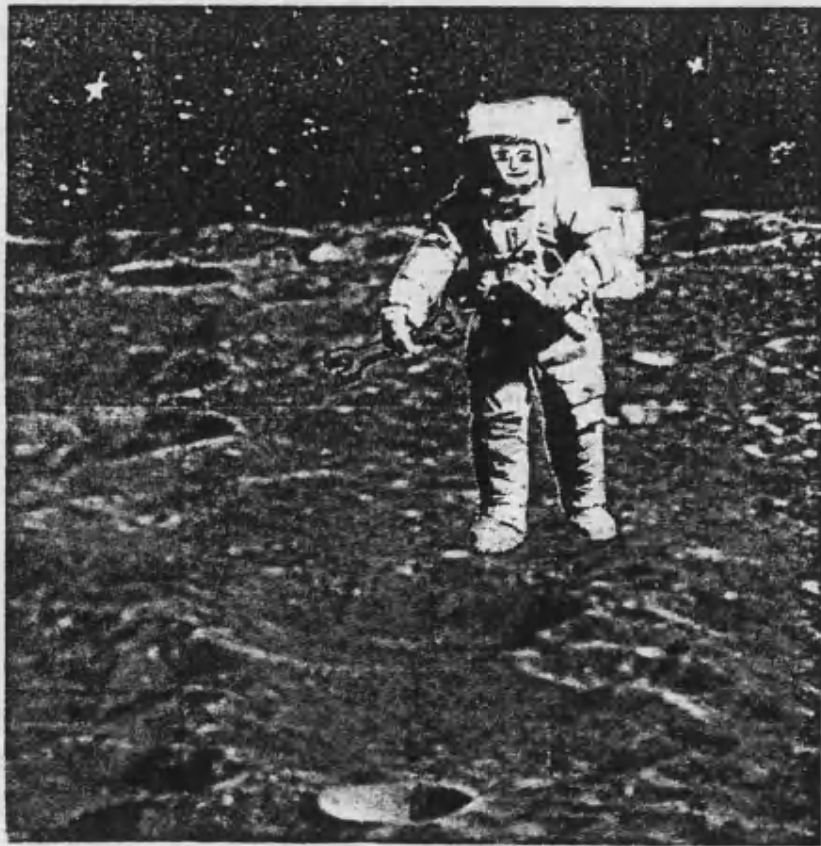




15) The Moon covers the Sun to give day and night.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

16) Draw an arrow to show which way the spanner will fall if he lets go.





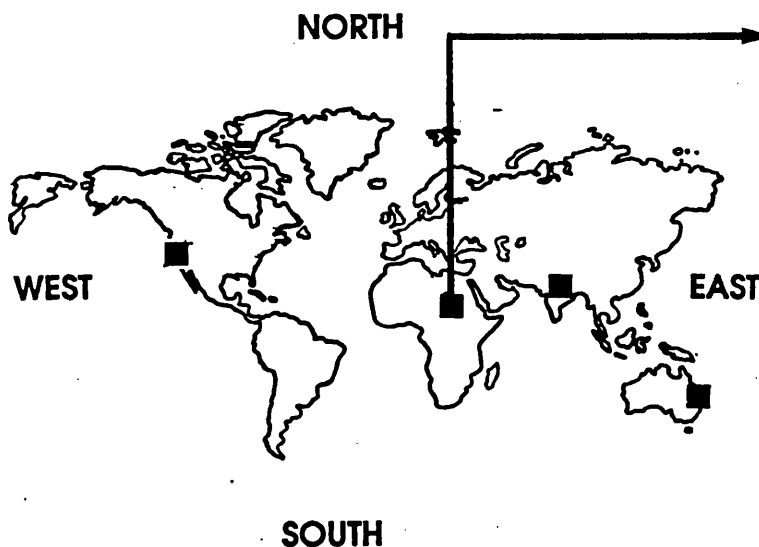
17) One part of our Earth has day while the other half has its night. Which drawing shows the correct day/night division?



18) It is cold in the winter because clouds stop the Sun from shining.

I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

19) Match each picture to the correct box.






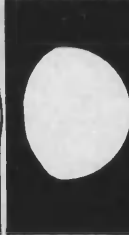

asleep in the middle of the night
going to school
coming home from school
watching evening T



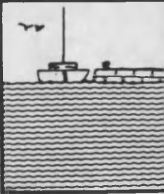
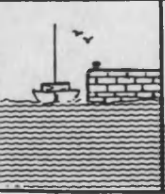
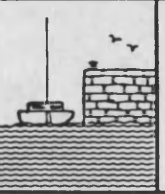
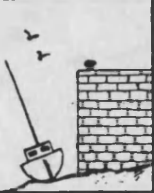
20) It is cold in the winter because the North Pole tilts away from the Sun at this time of the year.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

21) Tick the shape the person will see the moon make.

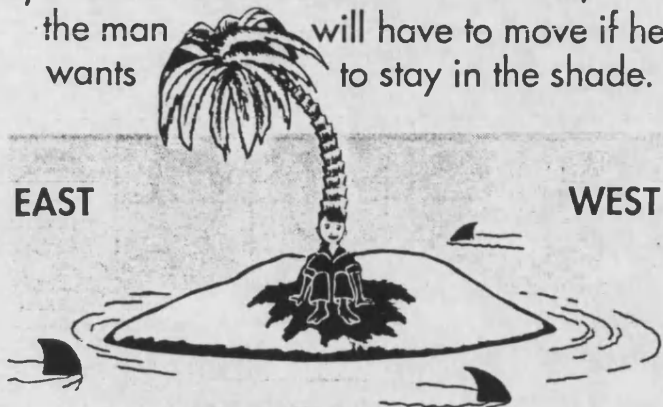
				
A	B	C	D	E

22) Tick the drawing which shows how the boat will look twelve hours later.

			
A	B	C	



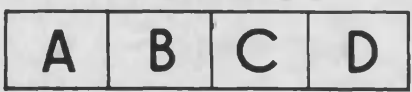
23) Draw an arrow to show which way the man will have to move if he wants to stay in the shade.



24) This is a drawing of sunset.

I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

25) Which drawing compares the real size of the Sun and Earth best?



26) The Moon sometimes makes this shape in the night sky.

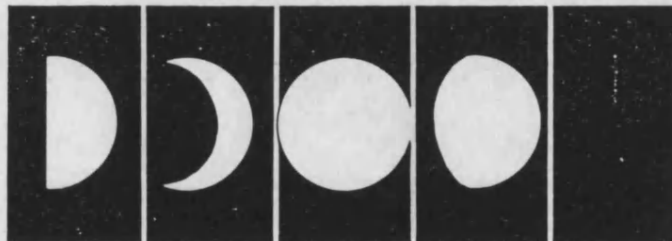
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong



27) The Moon can sometimes be seen during the day.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

28) Tick the shape the person will see the moon make.



29) What do you think makes the tide go in and out?

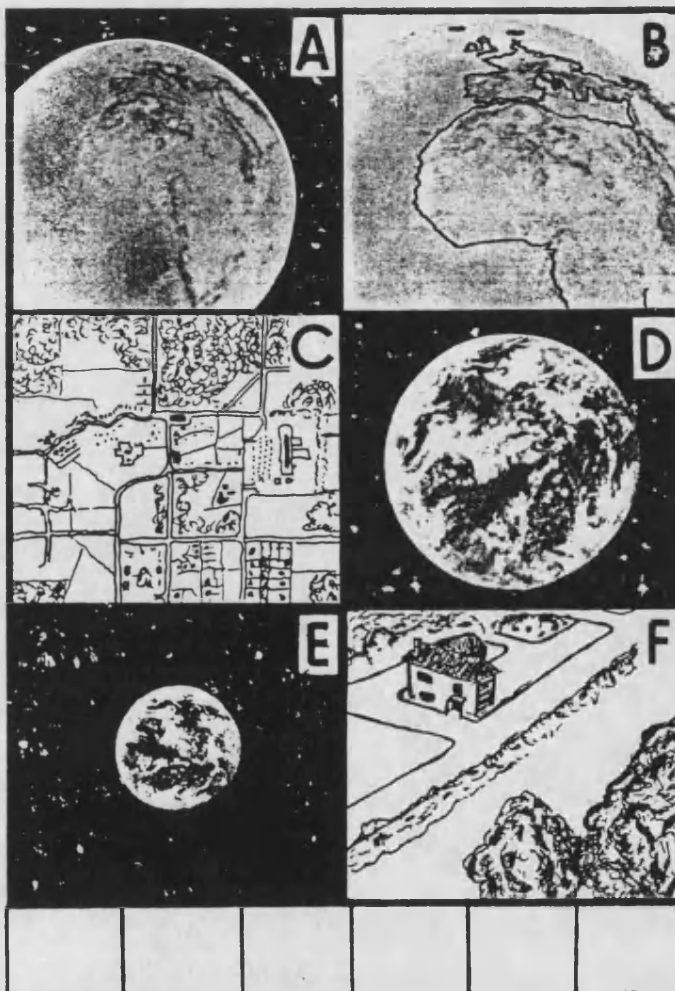
A	B	C	D
---	---	---	---

30) The Moon changes its shape from half to full to crescent because parts of it get covered by clouds.

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong



31) Put the spaceman's view in order.



32) The Moon never makes this shape in the night sky.

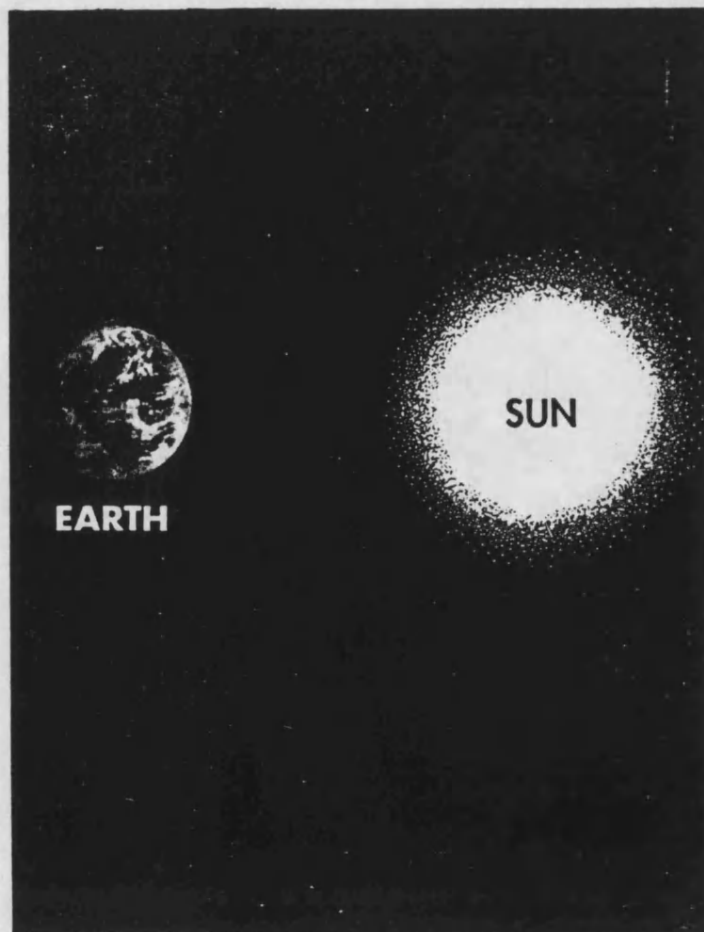




33) The half moon weighs less than the fullmoon

				
I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

34) Draw in where you think the stars are.





35) The moon appears to change its shape because we see different amounts of the illuminated half from the Earth.

I know it is true	I think it is true	I am not sure	I think it is wrong	I know it is wrong

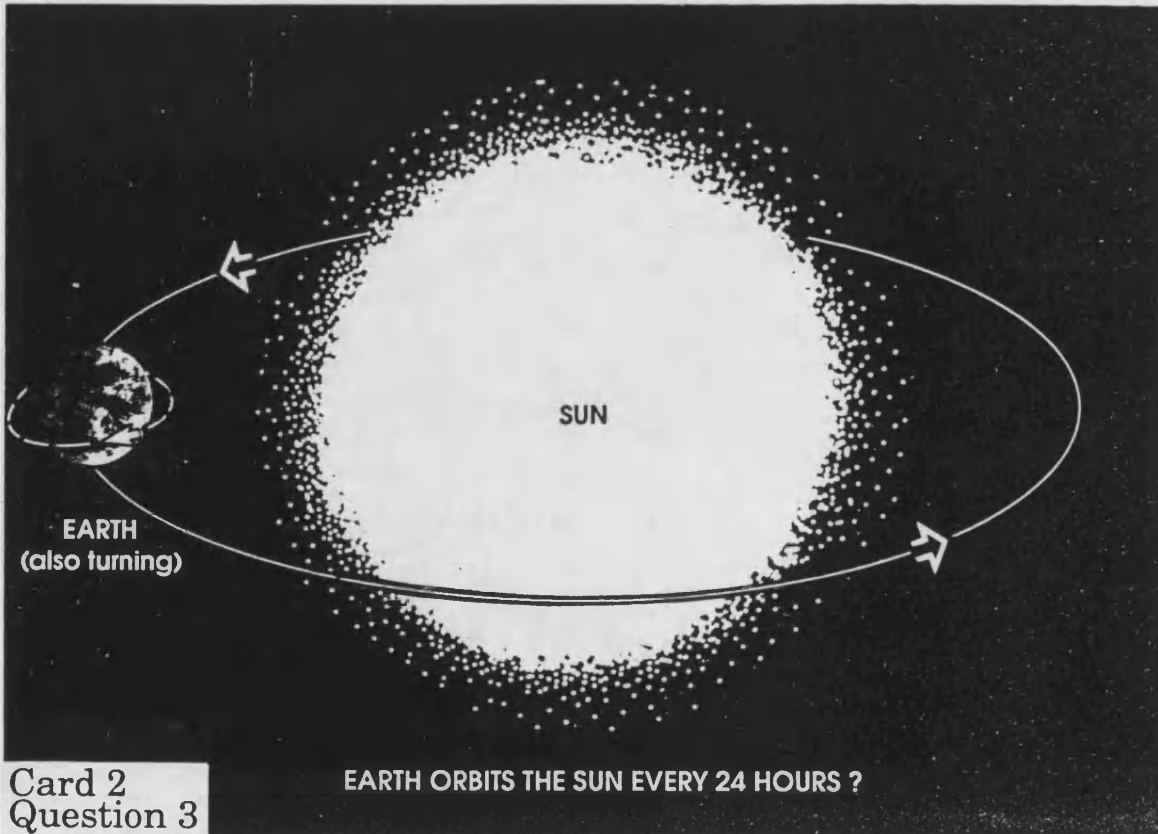
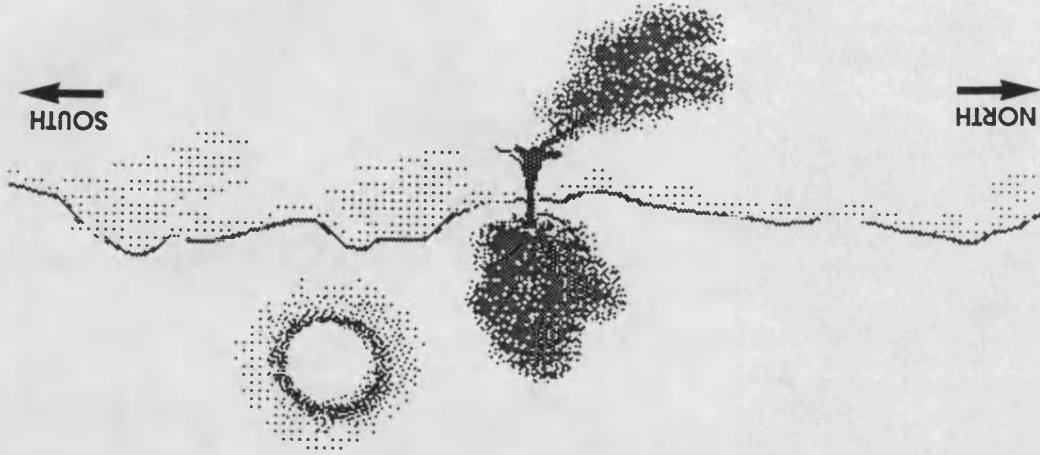
36) The Moon changes its shape throughout a month because different amounts of the Earth's shadow falls on the Moon's surface.

The Earth in Space

Masters for Photocopying



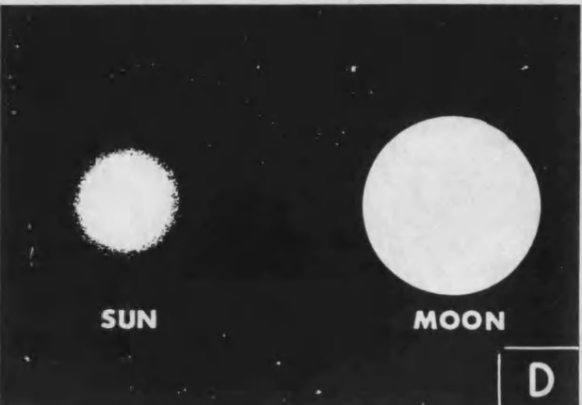
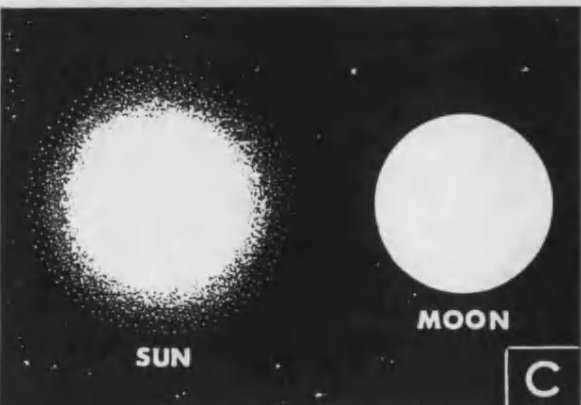
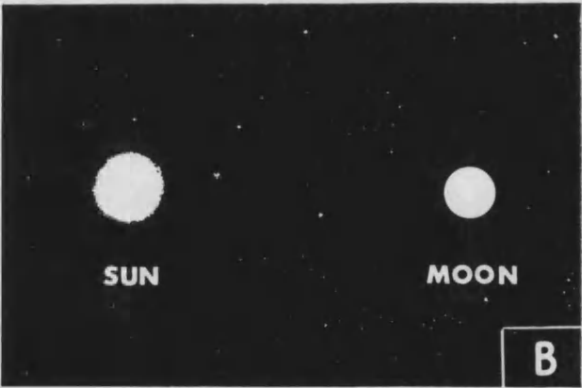
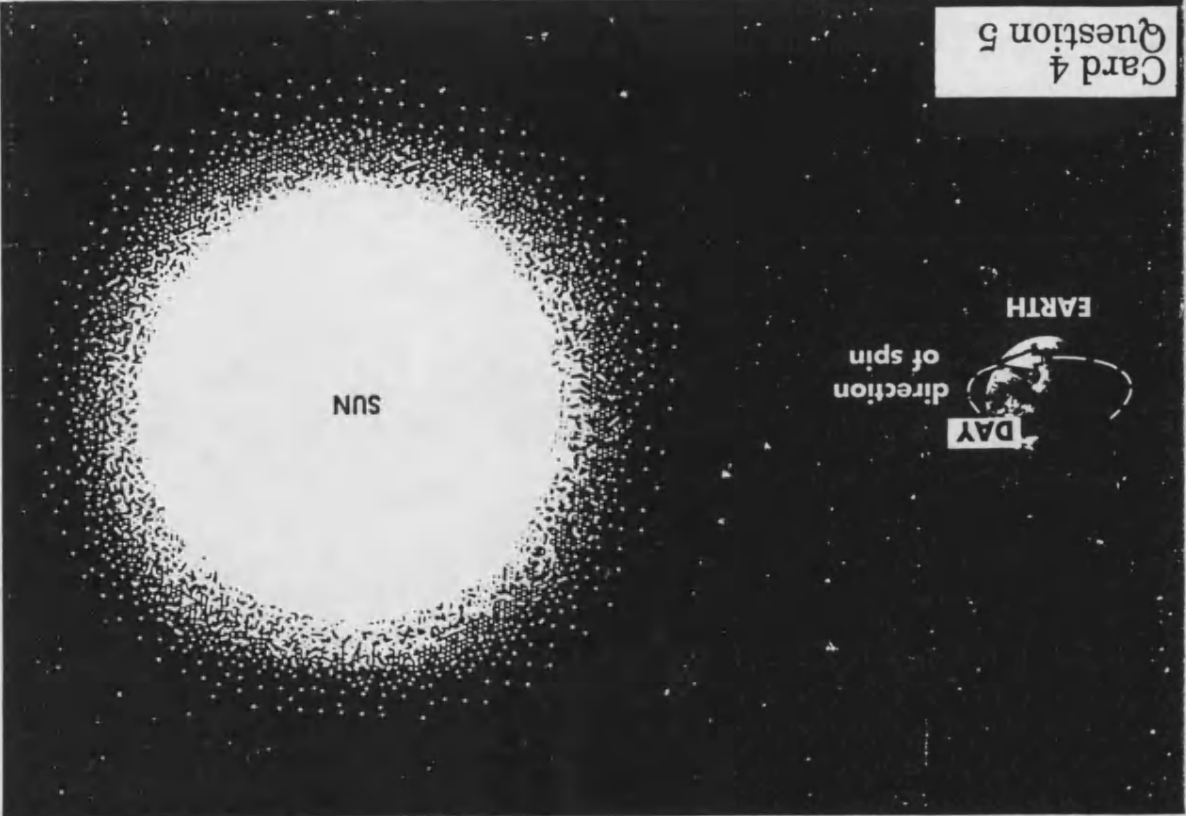
Card 1
Question 2



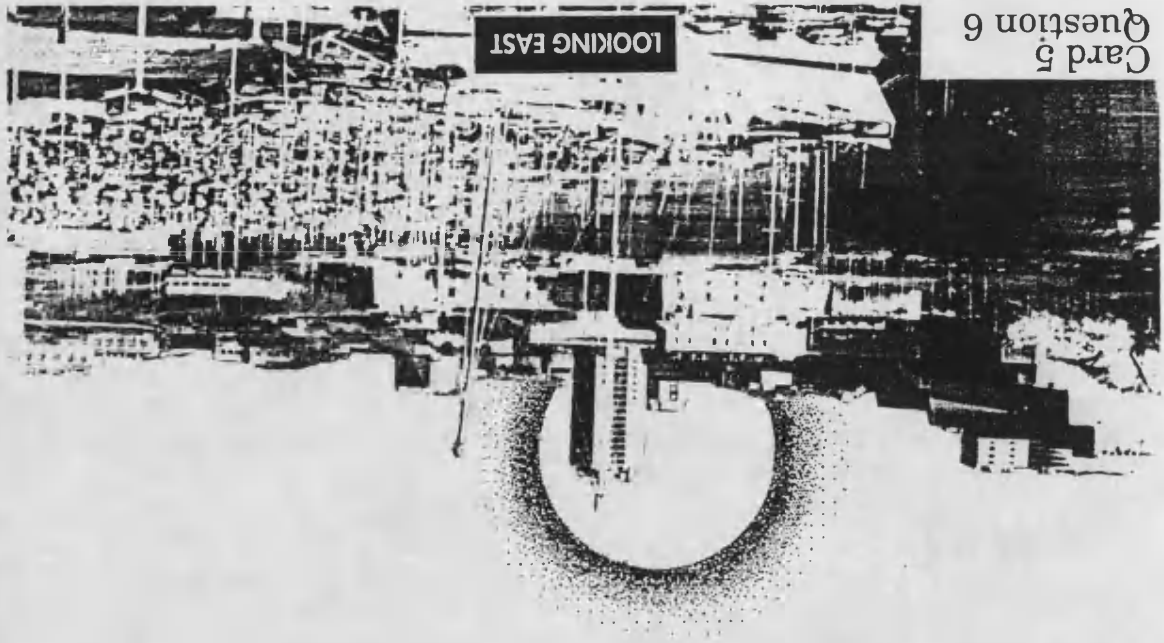
Card 2
Question 3

EARTH ORBITS THE SUN EVERY 24 HOURS ?

Card 4
Question 5



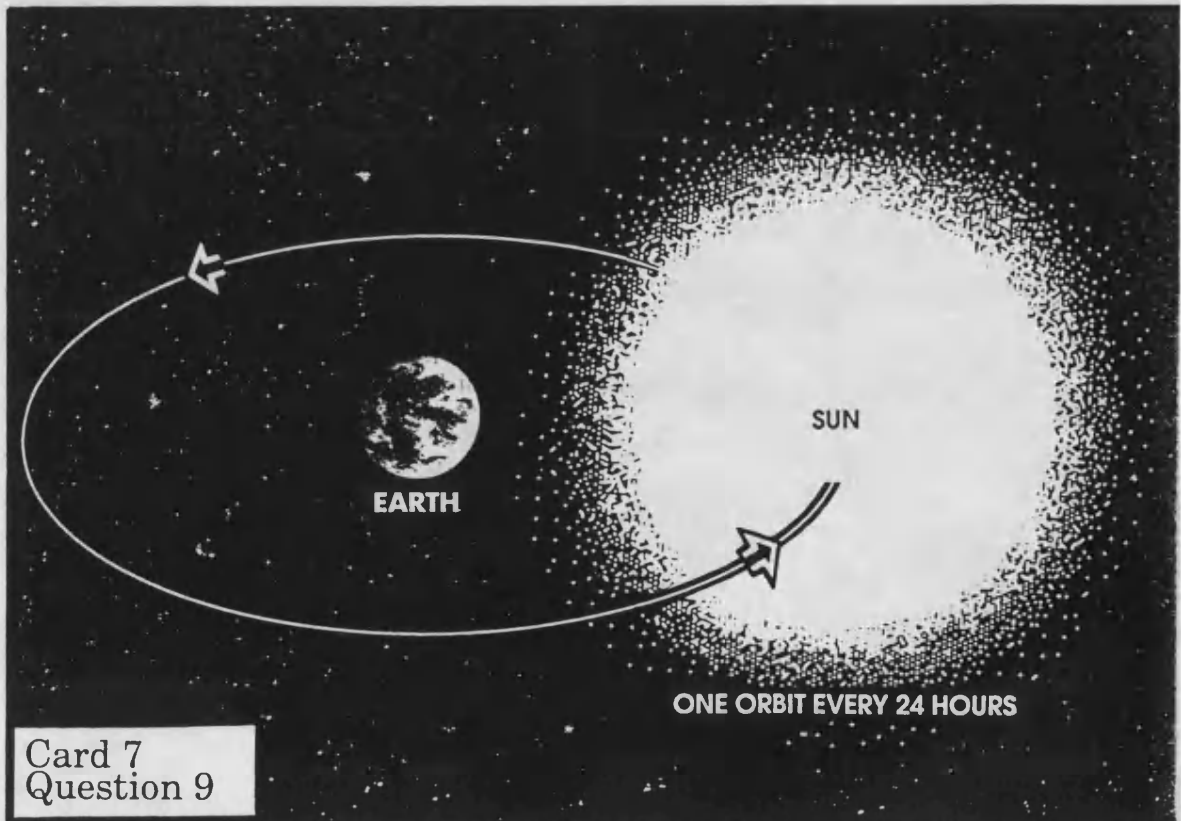
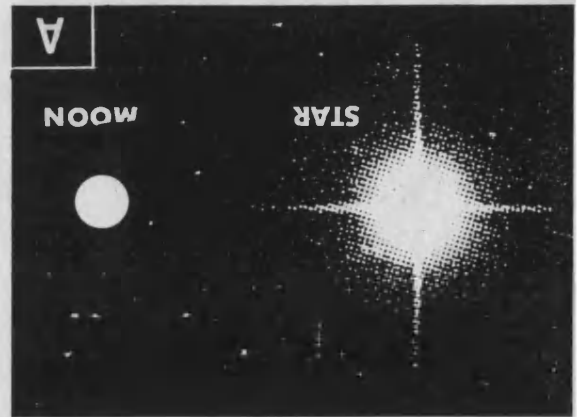
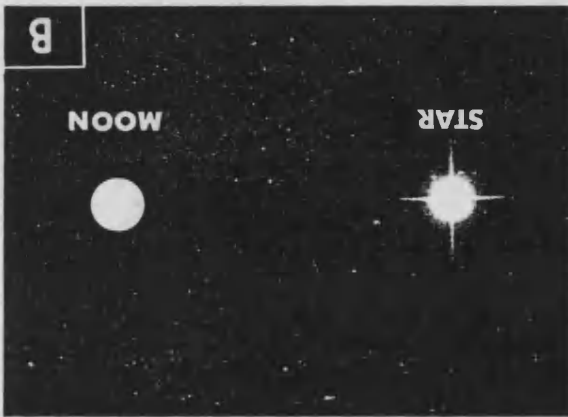
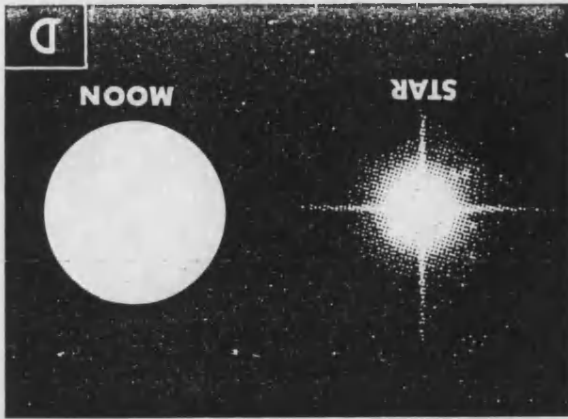
Card 3
Question 4



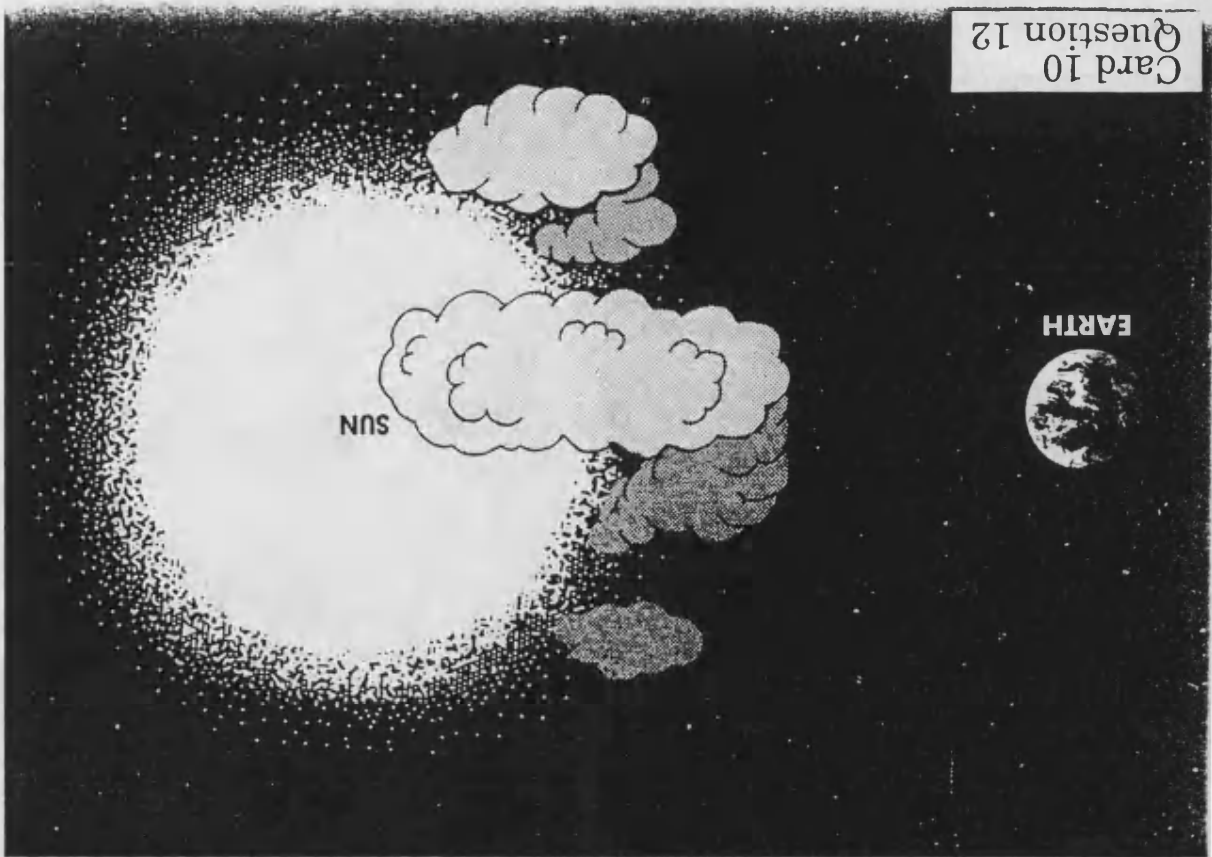
Card 5
Question 6



Card 6
Question 8

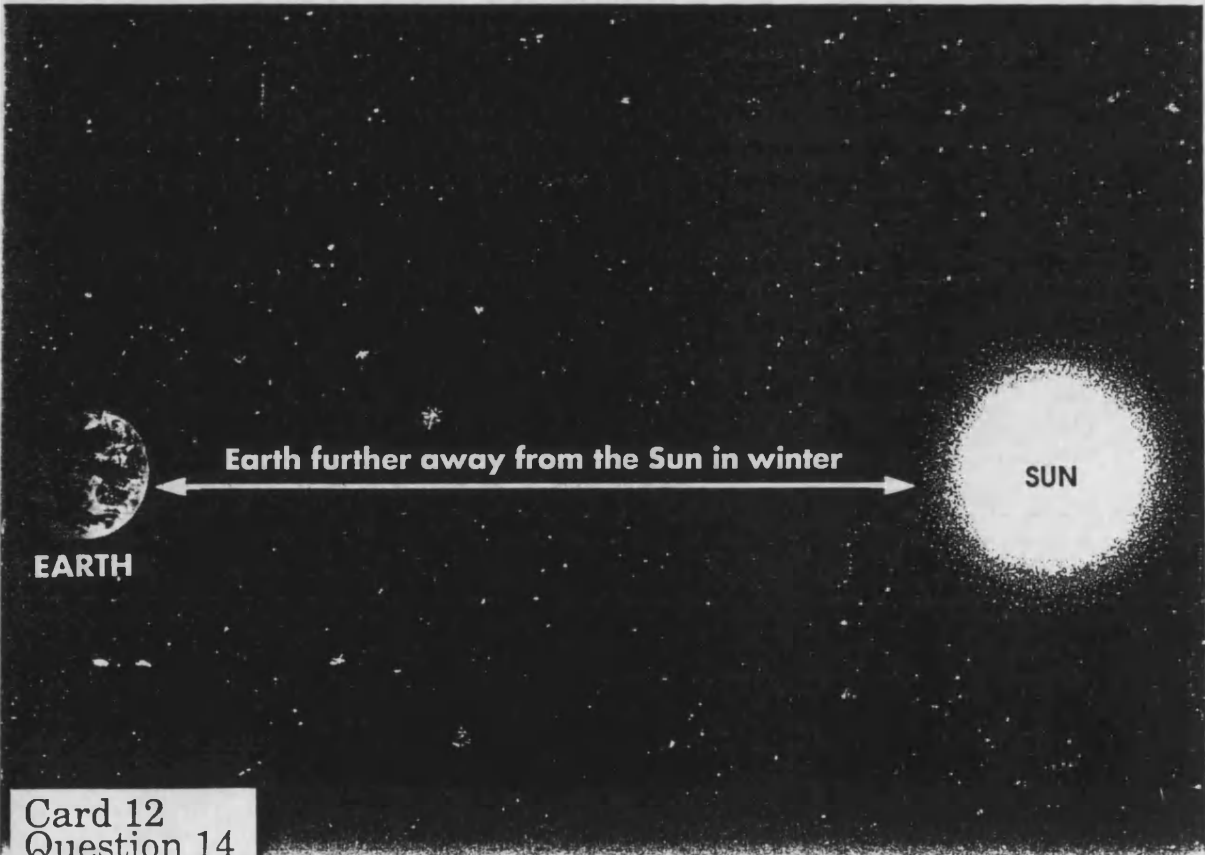
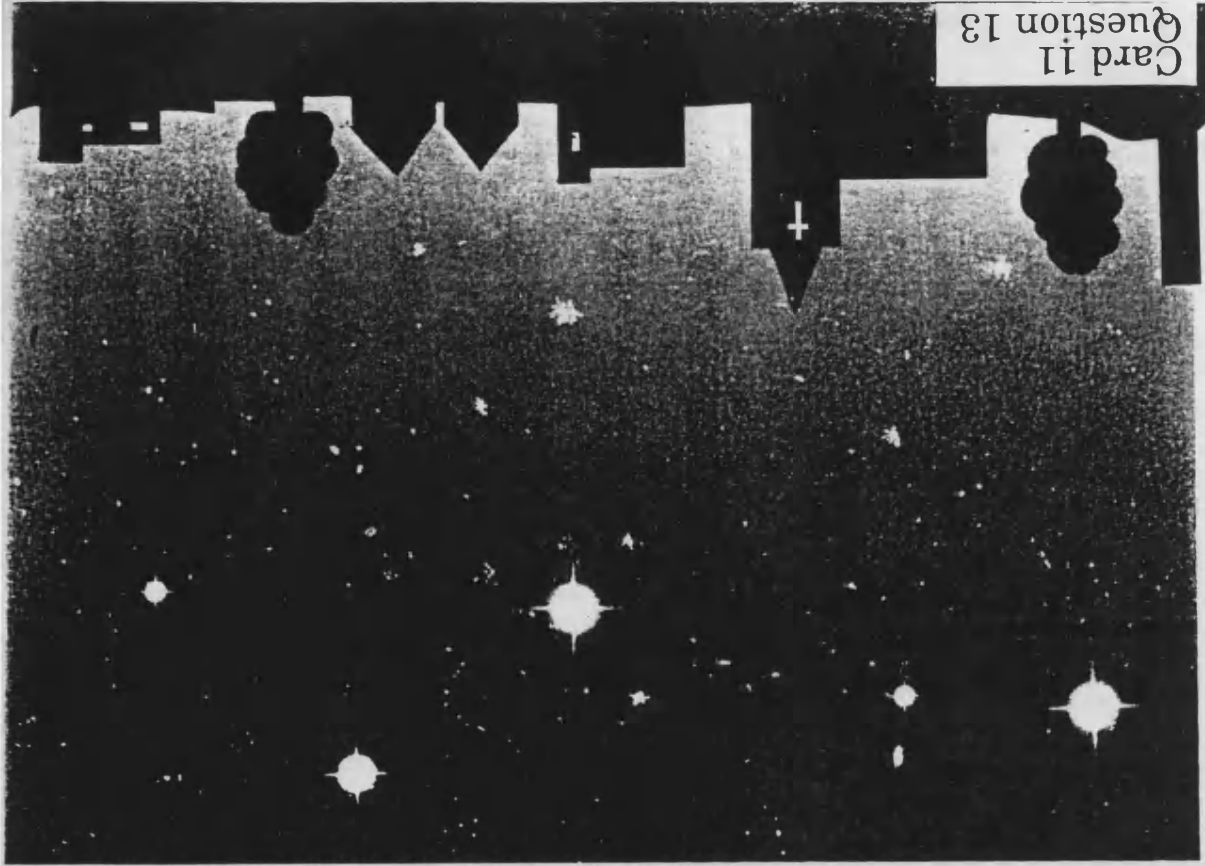


Card 10
Question 12



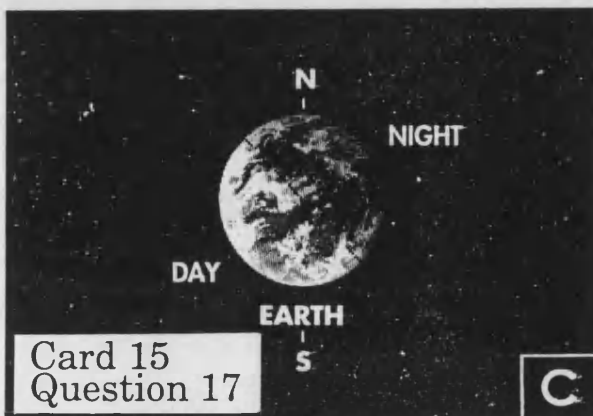
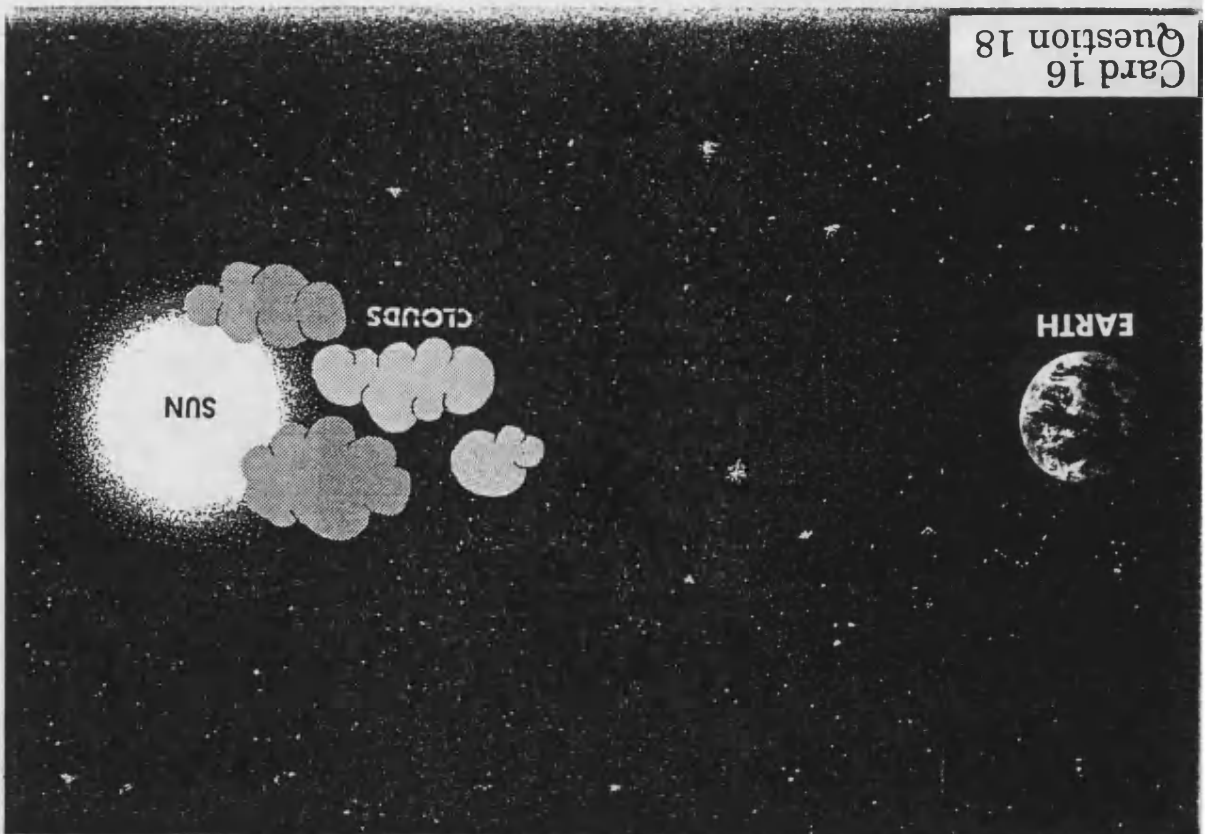
Card 9
Question 11

Card 11
Question 13



Card 12
Question 14

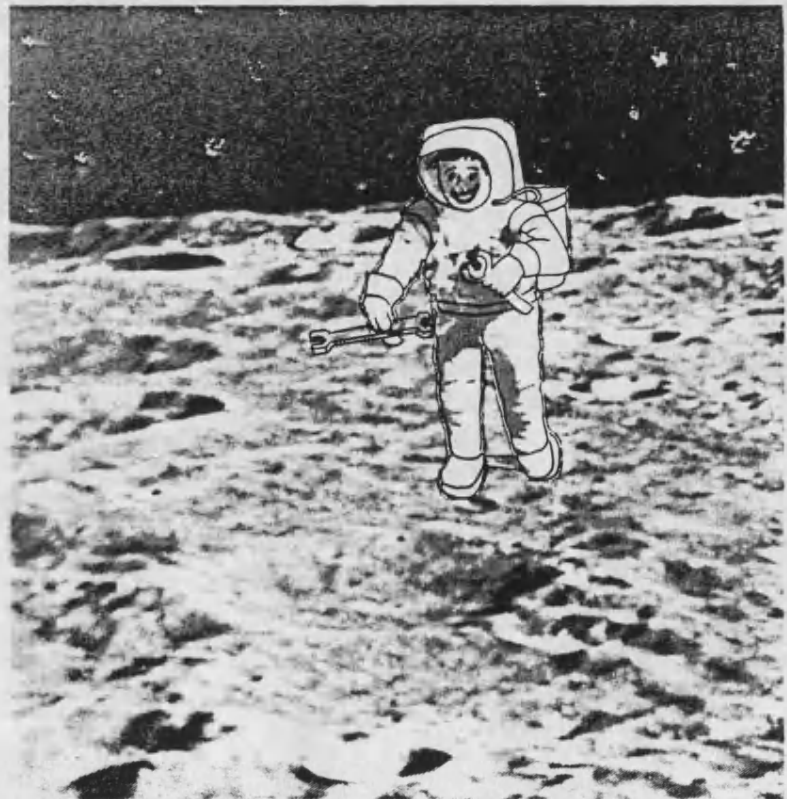
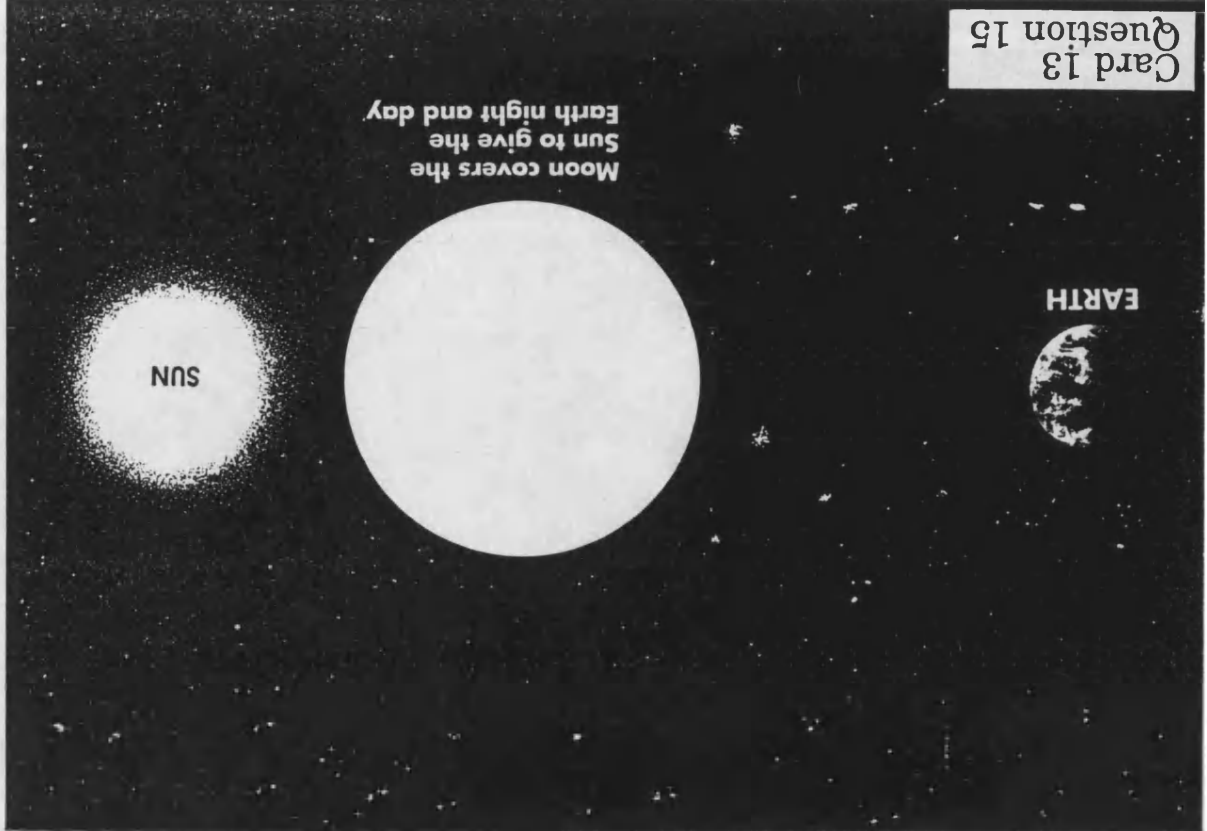
Card 16
Question 18



Card 15
Question 17

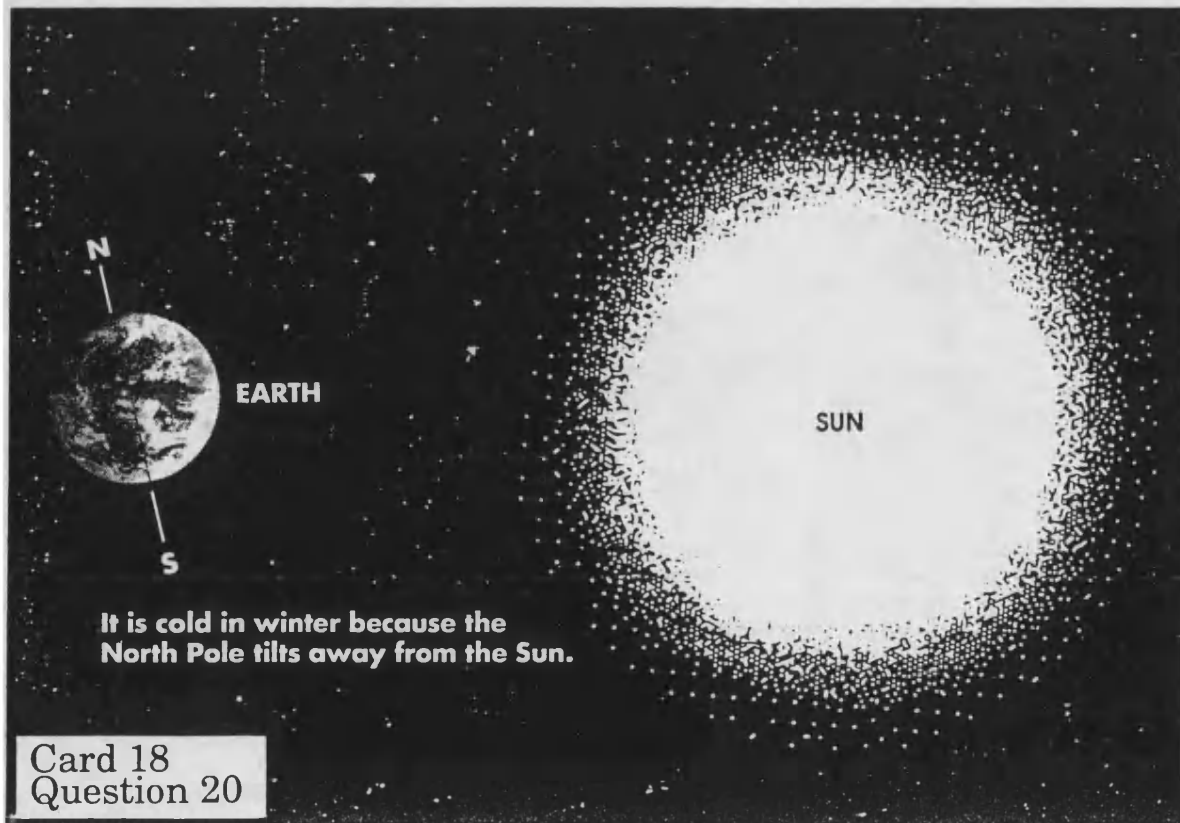
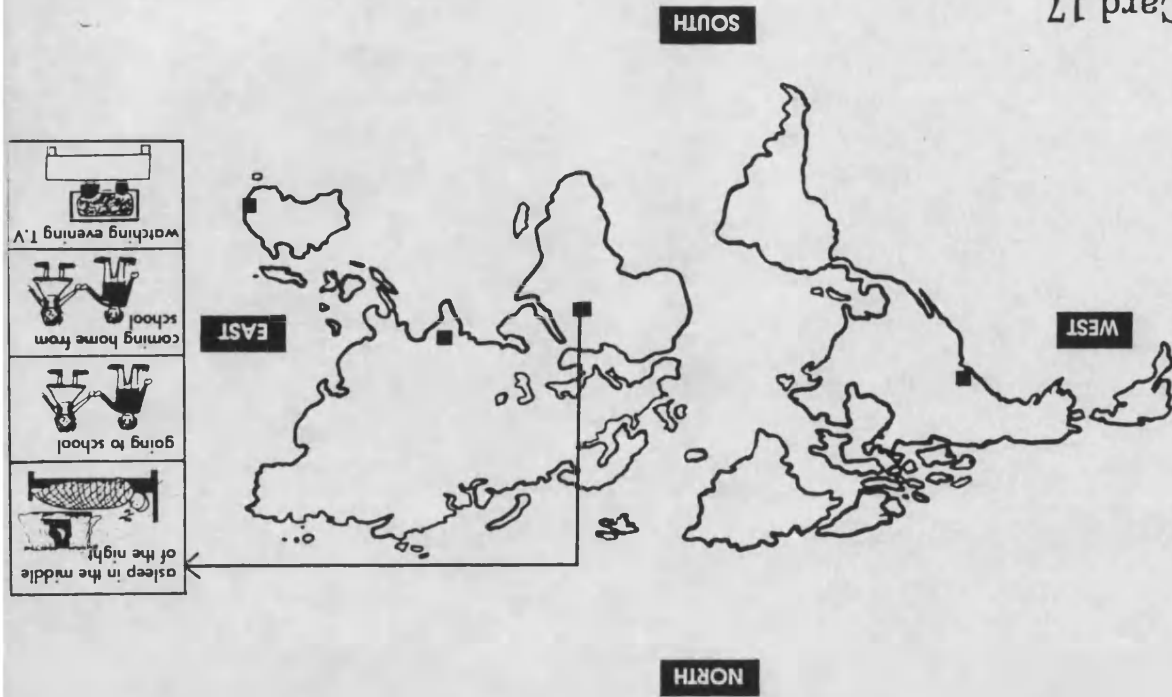


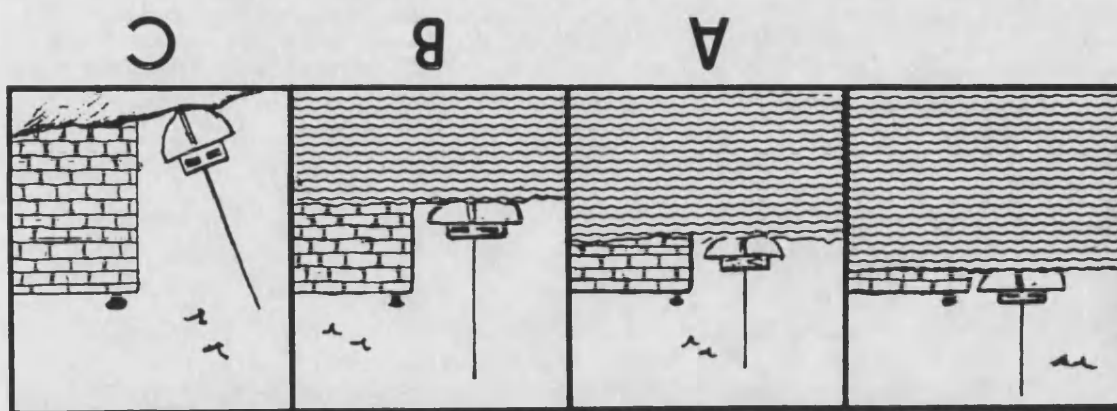
Card 13
Question 15



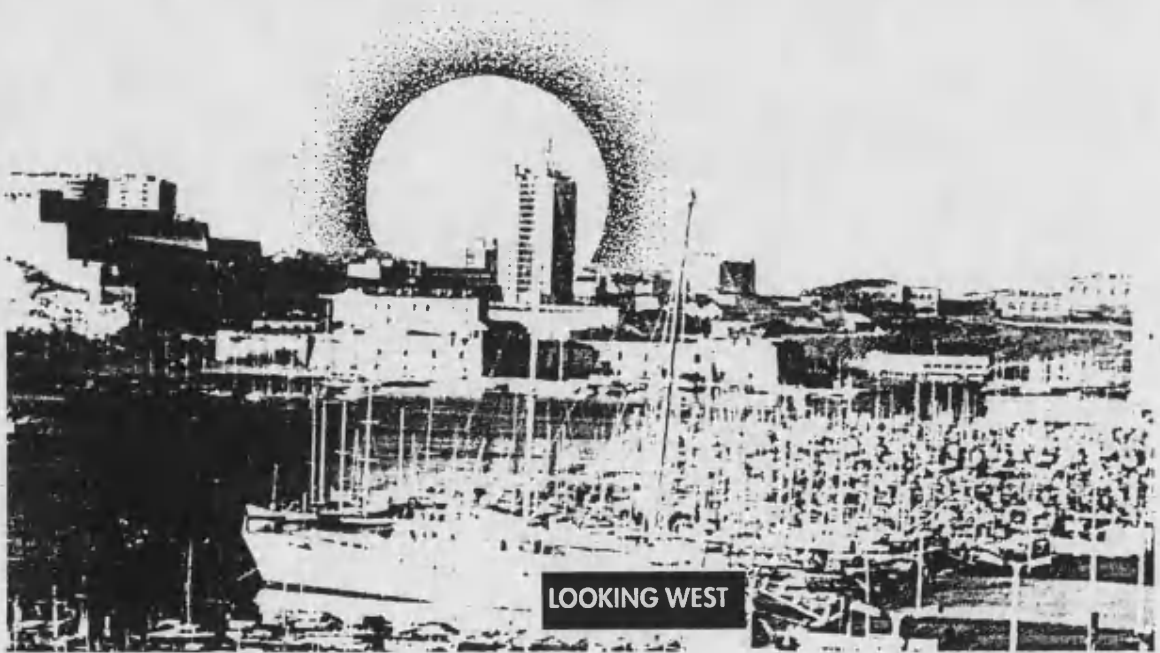
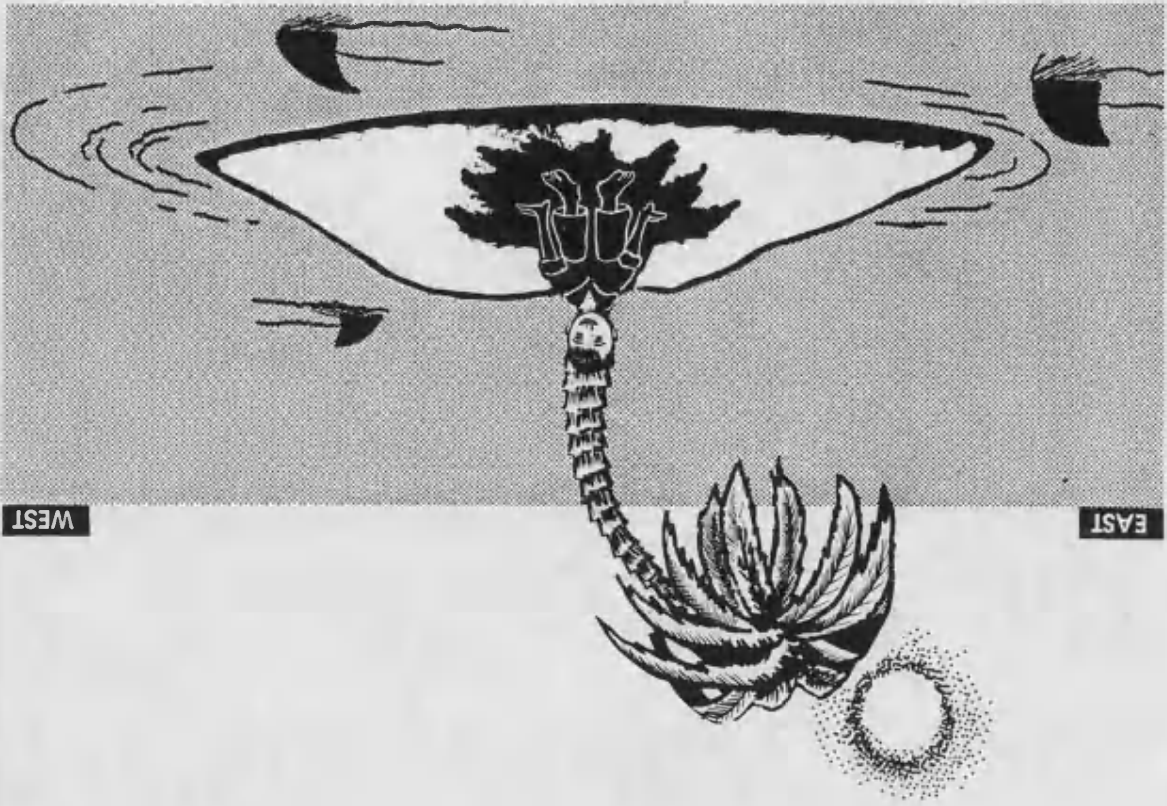
Card 14
Question 16

Card 17
Question 19



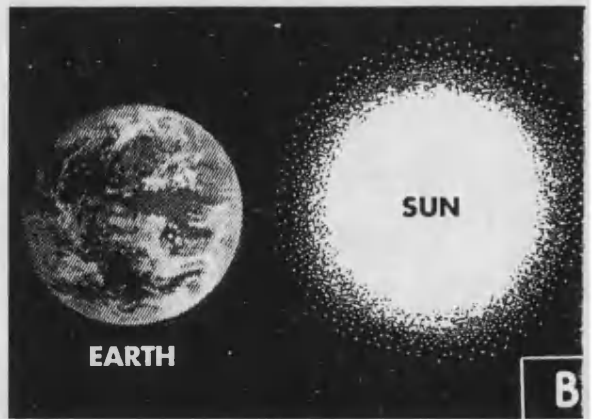
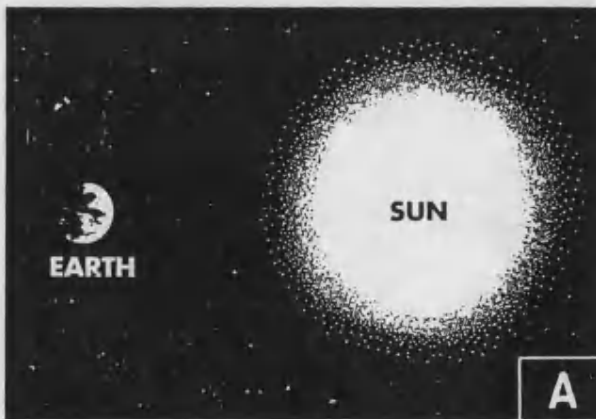
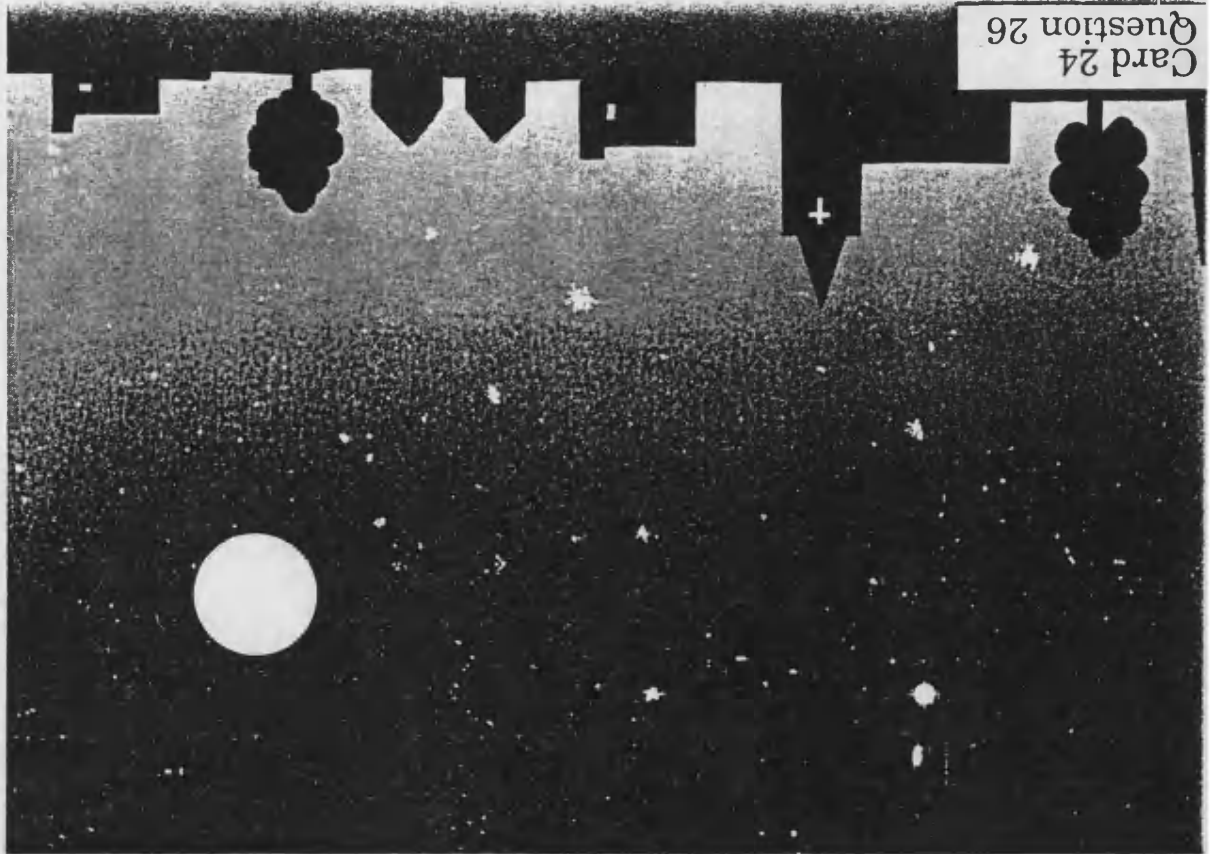


Card 21
Question 23



Card 22
Question 24

Card 24
Question 26

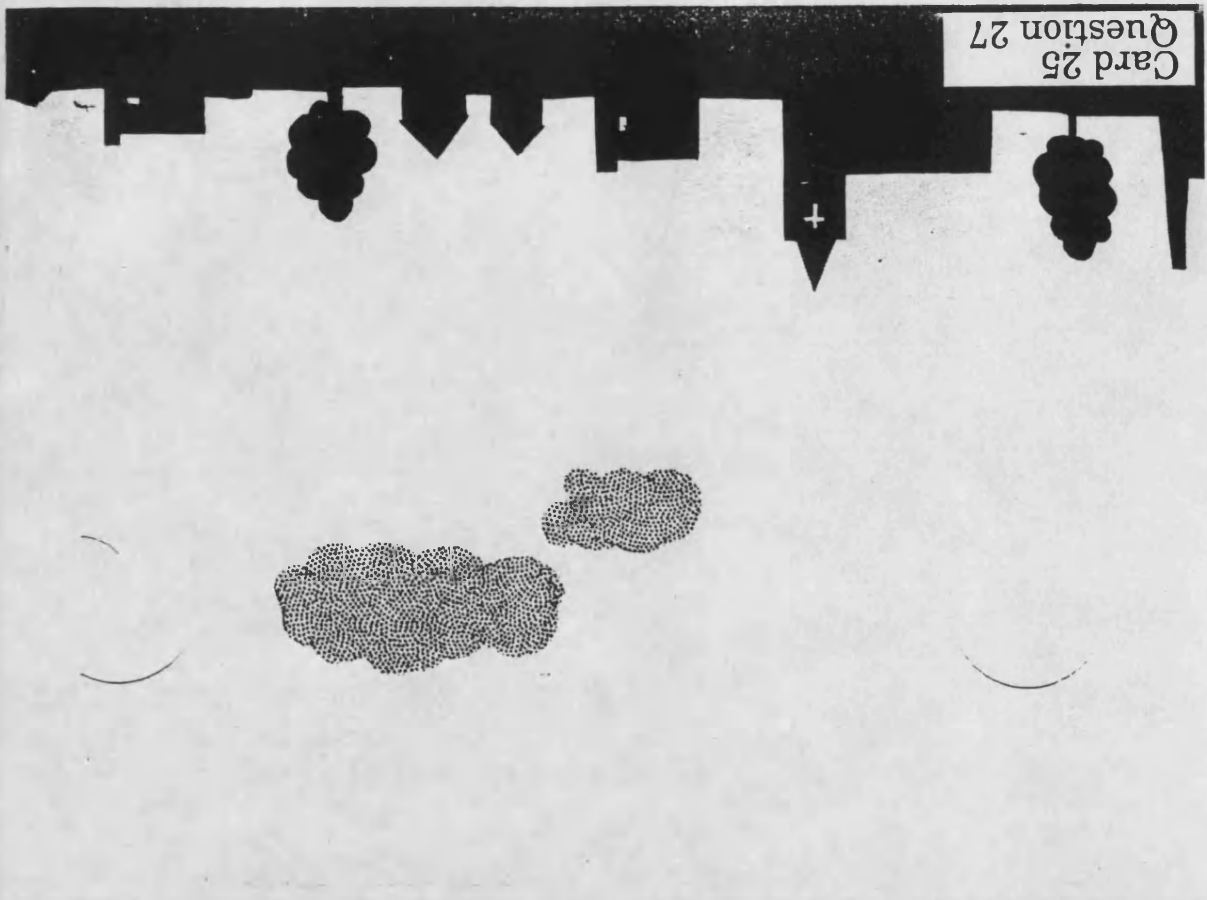


Card 23
Question 25

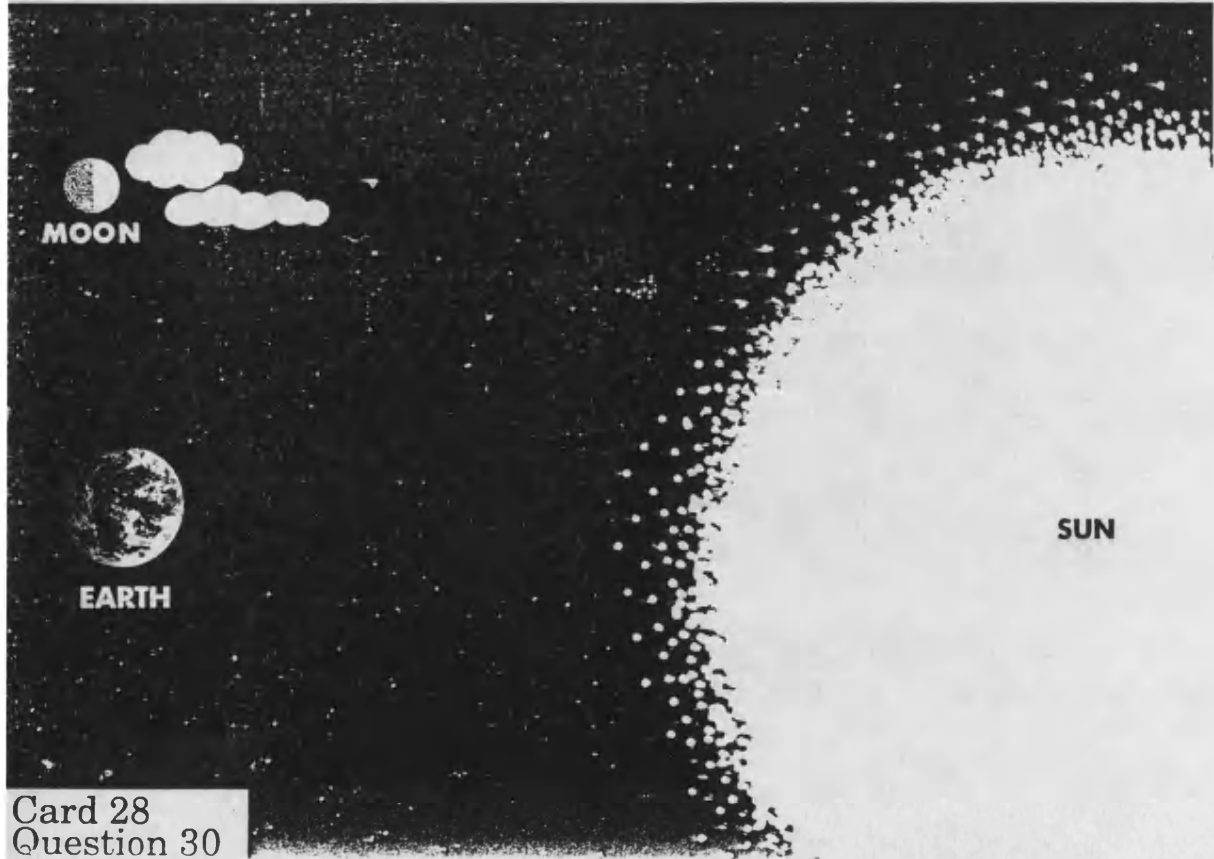
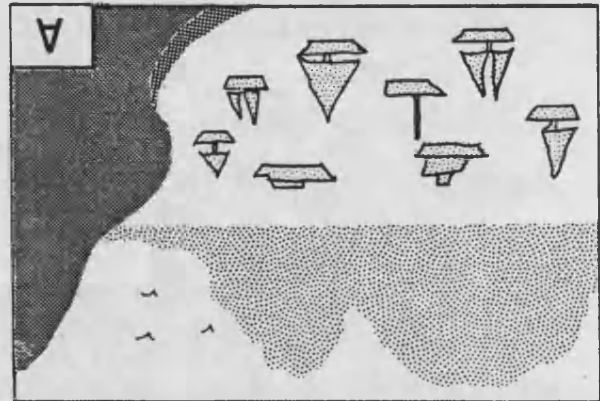
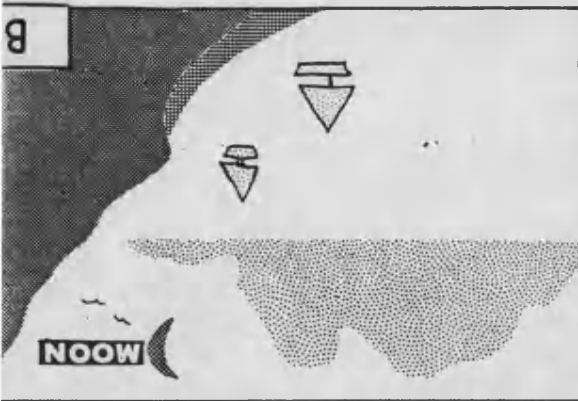
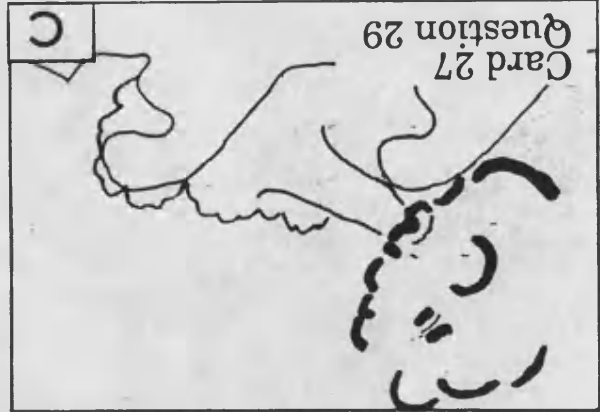
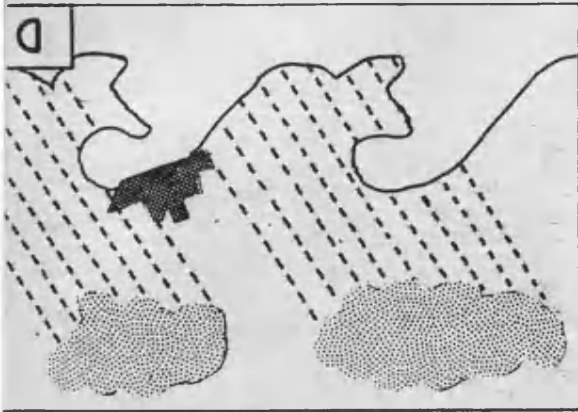
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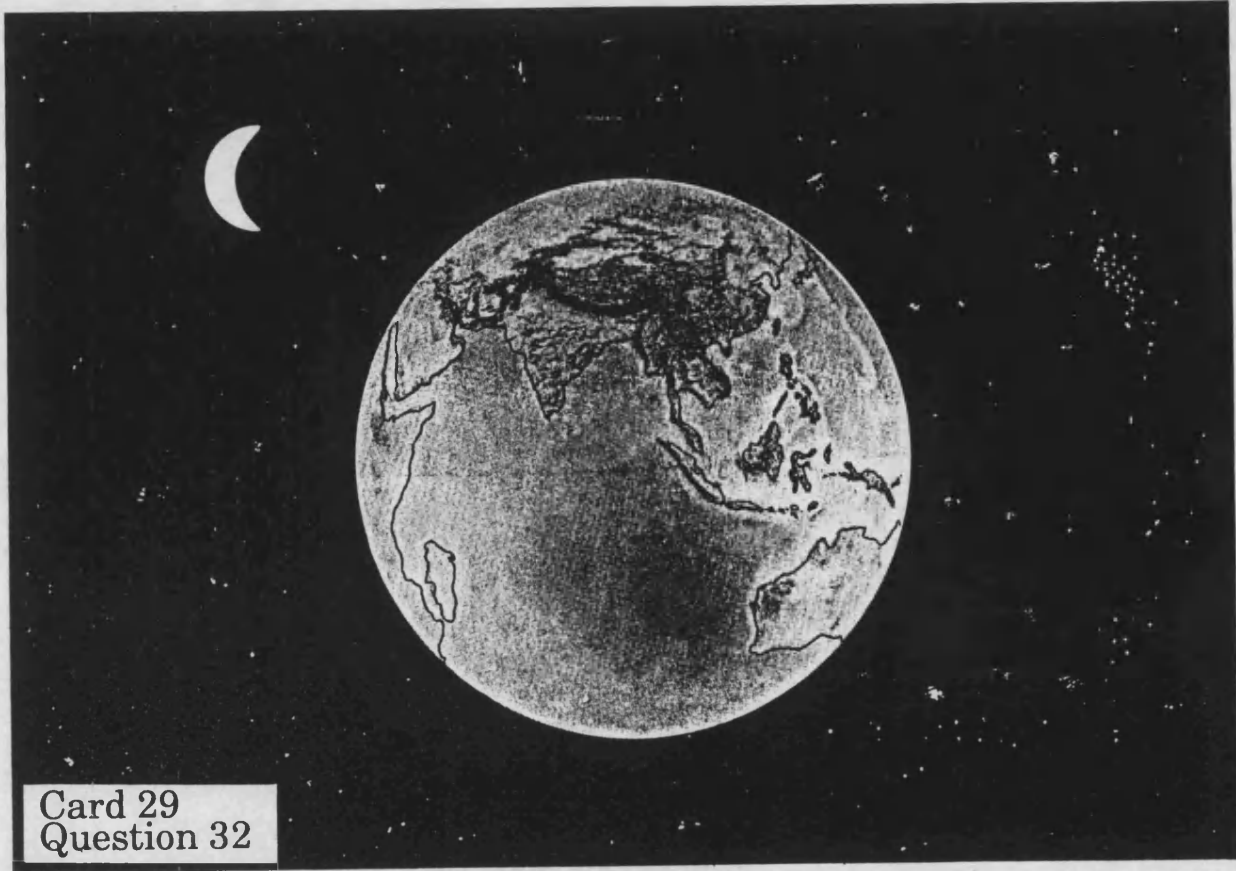
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Card 25
Question 27



Card 26
Question 28





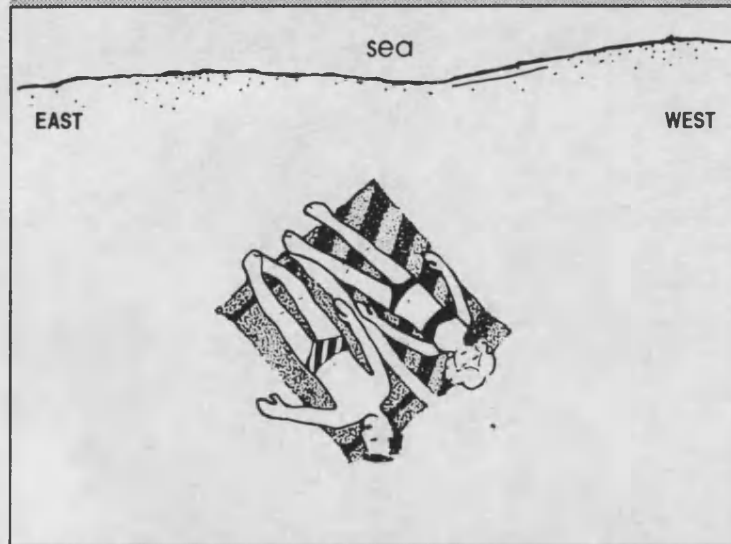
Card 29
Question 32

The Sun and Time : Predicting the Sun's movement ②

The Simpsons like to sunbathe when they are by the sea . . .

The picture shows them at 10 am. If they wish to face the Sun throughout the day, in which direction will they have to move?

Draw them in 3 different positions they should move to during the day if they wish to get maximum tanning from the Sun.



What warning would you give to the Simpsons?

Our hero is trapped on a desert island . . .

The palm tree will give the only shade.
Draw a large arrow pointing in the direction he will have to move if he is to remain in the shade.



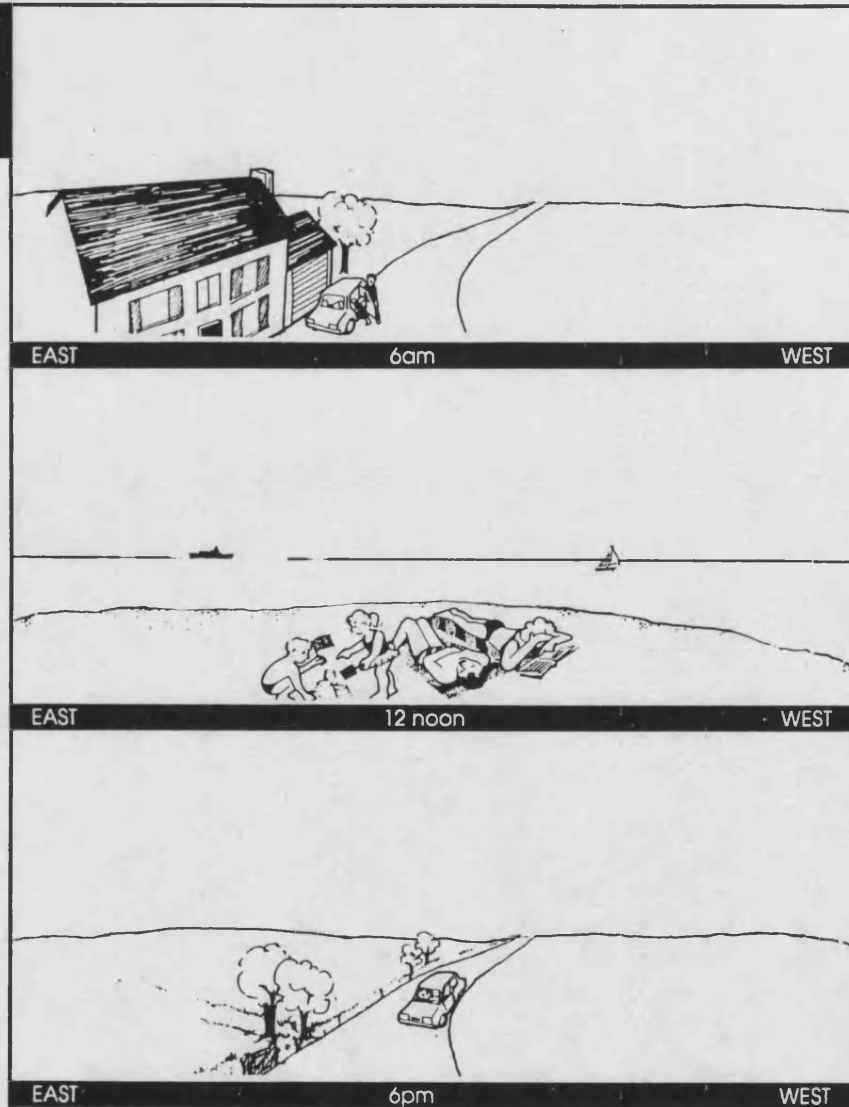
The Sun and Time :

Predicting the Sun's movement ①

One bright Sunday morning the Simpsons got up early and drove to the sea ...

The three drawings show them at different times of the day.

Although the Sun shone throughout the day it has not been drawn on any of the pictures. Look at the time at the bottom of each picture and then draw in where you think the Sun should be.



Scale Answer Sheet



THIS SHEET MAY BE PHOTOCOPIED

SUN	ball 2 feet in diameter
MERCURY	mustard seed 82 feet away
VENUS	pea 142 feet away
EARTH	pea 215 feet away
MARS	large pin head 327 feet away
JUPITER	orange 0.25 mile away
SATURN	orange 0.4 mile away
URANUS	plum 0.75 mile away
NEPTUNE	cherry 1.25 miles away
PLUTO	pin head 1.5 miles away

On this scale:

The Moon would be a pin head
6 inches from the Earth.

Alpha Centauri, the nearest
star to the Sun would be a
2 foot diameter ball 10 000
miles away (in Australia).

The Andromeda Galaxy,
the nearest galaxy to our own,
would be 5 000 million miles
away. Remember, this is using
our scale!

APPENDIX XIII

EVALUATION OF TEACHING MATERIAL

EVALUATION OF ASTRONOMY UNITS

for info. Written by an Avon Head of Science

<u>CRITERON</u>	<u>comments</u>
the aims underpinning the unit explicitly stated?	Yes in teacher's guide (although most is ^{miss})
there congruence between the ,teaching strategies, student s and content?	By and large
the aims underpinning the unit feasible to realise in practice?	Not all topics could be covered in the likely amount of time available
these desirable aims?	Yes
<u>Content</u> the content require prior ledge of the field by teachers?	Not really
teachers likely to have that ledge?	—
the content require prior ledge of the field by pupils?	No
pupils likely to have that ledge?	—
the content as presented relating to teachers/pupils?	Design needs improving
the content feasible to teach practice?	Most
it desirable that this content should be taught?	Most

<u>Question</u>	<u>Comments</u>
the media of communication appropriate for the intended audience?	Yes
the language level appropriate for the intended audience?	Just - may be too early.
the mode of presentation consistent with the:	Yes
<u>aims</u>	Yes
<u>learning theories</u>	Yes
<u>teaching strategies</u>	Maybe
feasible to use the product as presented, in practice?	No / Redesign / Spelling corrector / look no longer
not desirable to use the product as presented?	↑
<u>Resource Implications</u>	
the implications of implementing the curriculum as spelled out in terms of time?	No
the resource implications feasible in practice?	Yes

COMMENTS

A compendium of interesting possibilities. Too much for the amount of time likely to be available for a topic such as this; however teachers can select those activities they feel most appropriate for their groups. Some better ideas of questionable validity/practicality/complexity.

(R)

Level E of A first Practical Astronomy by John Baxter.

Copy available in DRAFT only at this stage.

The materials as supplied are in two parts, a student guide and Teacher's notes. Both are described as being in draft form but there is no indication of when final copies will be released.

Criterion one

There are no records or references as to whether the texts have been trialled within the classroom situation, but most of the activities are of a sort which are commonly used within schools. The product is, however, feasible for use within classrooms, using only a few items of apparatus, all of which are commonly available. The presentation of the product ought to be suitable for a range of students and should encourage students to become actively involved.

Criterion two

There are no assessment procedures within the package, although it would be easy to use some of the activities for assessing certain criteria, such as, manipulative ability, graphicacy, and devising experiments. The product makes no attempt to enhance the participation of either girls or students with special educational needs. There is a limited attempt to introduce multicultural themes but there is room for improvement. I was disappointed to see that the one diagram of a scientist was of the standard stereotype, a diagram which could be changed in the re-print. Given that the package is for 11 to 13 year olds, the language level is rather high in some places and could be adjusted in the final copy. All other criteria within this area are met.

Criterion three

The aspects of this criterion are all fully met.

Criterion four

There are several typographical errors in the text, which I hope will be eliminated in the final text, otherwise, the materials are technically accurate and represent up-to-date thinking in this area.

Paul Carpenter
22 February 1988

Summary for directory

This package of a teacher's guide and pupils manual would be an excellent addition to the resources of any science department, opening up the field of astronomy for pupils of ages eleven to thirteen. The 'process' approach is to be commended, as is the aim to 'start where the pupils are'. There are a number of good examples of practical work and a wealth of ideas for further work.

PAC

APPENDIX XIV

SPREADING LIGHT ACTIVITY

SPREADING LIGHT ACTIVITY

This activity was designed to support and develop the seasons activity (see appendix xii). Teachers involved in the teaching material trials considered that there is a need for a practical demonstration/ activity which shows that as the angle of incidence of light from the Sun decreases from 90° , the same amount of light is spread over a greater surface area, therefore, effectively diluting the amount of light energy reaching a particular point on the Earth.

ACTIVITY

Teachers' Notes

Pupils will have carried out the seasons activity and will have challenged their notions on the cause of the seasons. In all probability the most common idea was that during the winter the Sun is further away from the Earth. After using the seasons model pupils will begin to challenge their original notion, but research has shown that they frequently attempt to salvage some of their original idea in their new explanation for the seasons. They end up with a hybrid view, a mix between their original notion and the evidence they have seen from using the seasons model. The following activity and OHT is intended to build upon pupils' developing ideas about the cause of the seasons.

PUPILS' SHEET

The Seasons; An Extra Activity

Information

By now you will have made the seasons model and you are probably having to change your ideas about what causes the seasons. Use the seasons model again' and Make the Earth orbit around the Sun. Look at what happens to the angle of the Earth's axis as it orbits the Sun. Now place a small pin in your model Earth just about where you think England is. Imagine that you are standing where you have placed the pin. Orbit the Earth around the Sun until the Sun is most overhead. What season will this be ? Now move the pin so that it is in the winter position. Is the Sun as high in the sky ?

ACTIVITY

You Will Need

one bench lamp.
a large sheet of squared paper.
a thermometer.

This is What You Do

Imagine that the bench lamp is the Sun. Lay the squared paper flat onto the bench. Put the lamp on top of the paper and fix it so that it is about 15 cms. from the paper. Without changing the height of the lamp, position it so that when it is switched on it lights up as few squares as possible. Write down how many squares were lit up. Now place the thermometer so that the bulb is on the centre square which is lit up. Leave it there for 2 mins. Write down the temperature.

Now position the lamp so that as many squares as possible are lit up. Write down the number. Remember, you can not alter the height of the lamp. Find out the temperature of the centre square. Write down the temperature.

Things To Think About

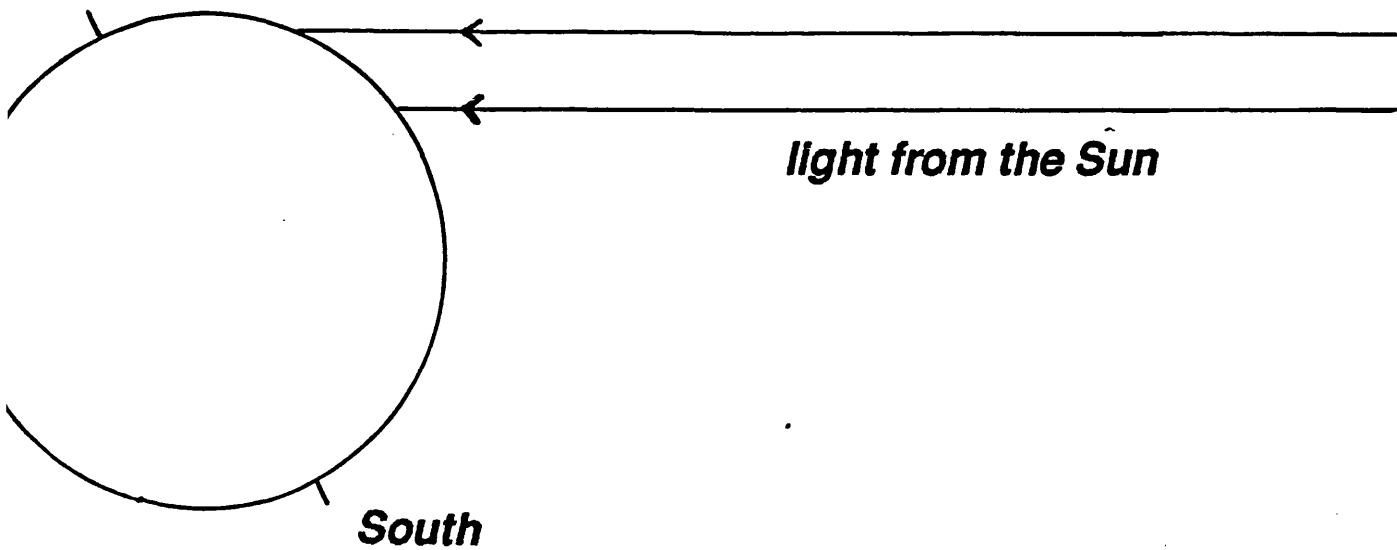
What happened to the temperature when you spread the light over a large surface? Which lamp position was most like the Sun during the summer?

Now look at the OHT your teacher has placed on the screen. What do you notice about the rays of light as they pass through the Earth's atmosphere during the summer? How are they different during the winter?

Ask your teacher if you can do the "Lights on Your Bike" activity. You may be able to explain why we get more hours of daylight during the summer.

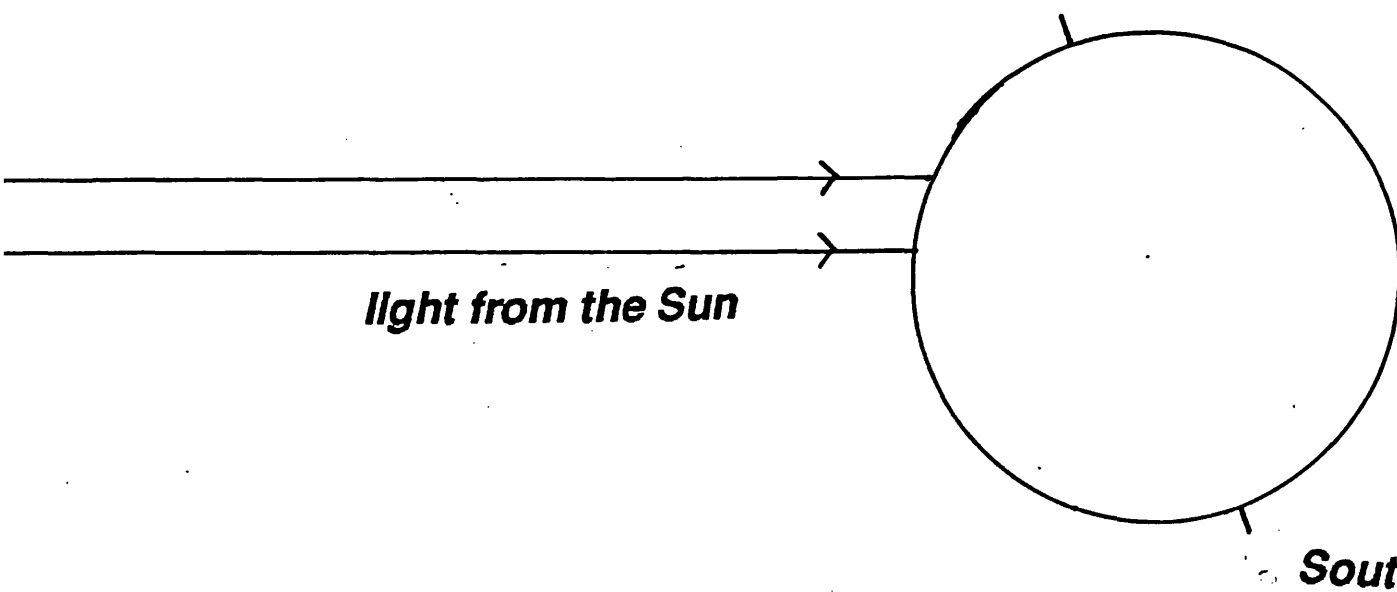
Winter In the Northern hemisphere

North



light from the Sun

North



light from the Sun

Summer In the Northern hemisphere

APPENDIX XV

UNRELATED t TEST

UNRELATED 't' TEST

This test was applied to those areas of the surveys in order to determine the probability that any difference between two conditions (test retest) is significant.

The unrelated 't' test inspects the amount of difference between the two means taking into account the variation of scores in the two conditions.

Flow chart for calculating unrelated 't'

Adapted from
Heyes et al 1986

1. Square each subjects' score
2. Add up the scores in condition A (A)
3. Add up the squares of the scores in condition A (A²)
4. Add up the scores in condition B (B)
5. Add up the squares of the scores in condition B (B²)
6. Find the means of the scores in conditions A and B (A) (B)

$$A - B$$

t =

Where Na and Nb = numbers in conditions A and B respectively.

Calculate degrees of freedom (df) (see Appendix VII) from:

$$df = (Na - 1) + (Nb - 1)$$

The 't' value was then looked up from Elementary Statistics Tables (Neave 1979).

As with chi square, any difference in scores was only considered significant when p was 5% or less.

APPENDIX XVI

PUPILS' END OF MODULES QUESTIONNAIRE

YEAR III END OF MODULES QUESTIONNAIRE

NAME _____ GROUP _____

You have now completed all of the year three science modules. We would like to know which modules you enjoyed the most, and which ones you think will help you in the world of work.

(1) Below is a list of the science modules you have studied this year. In the spaces on the right place the modules in order; the one you enjoyed most first, the one you least enjoyed last.

- PHYSICS _____
- CHEMISTRY _____
- ASTRONOMY _____
- TECHNOLOGY _____
- BIOLOGY _____

(2) Which of the modules do you think are the most help to you in the world of work? Place them in order; the most helpful first, the least helpful last.

- PHYSICS _____
- CHEMISTRY _____
- ASTRONOMY _____
- TECHNOLOGY _____
- BIOLOGY _____

APPENDIX XVII

NUSSBAUM'S COMPARISON SETS OF BASIC
STATEMENTS CHARACTERISTIC OF VARIOUS
PHILOSOPHICAL VIEWS

EMPIRICISM	KANT	POPPER	LAKATOS	TOULMIN	KUIN
Knowledge is only that which has been <u>proven or confirmed</u> .	Knowledge grows when logic liberates us from systematic error.	Theories are bold speculation, creatively constructed.		Knowledge is non-provable and non-confirmable.	
Impartial and patient observations result in generalizations (hypotheses) which are confirmed (i.e. made into laws and theories) by induction.	In proving knowledge about the phenomena, we apply conceptual structures which are universal, <u>a priori</u> categories.	A theory can be disproved (falsified) by testing it against counter-evidence using deductive logic.	Theories are non-disprovable. Logically, a fact can never falsify a theory. A theory can always be saved by proposing a suitable set of auxiliary hypotheses.		
Objective observations and inductive procedures constitute the scientific method.	Systematic application of <u>a priori</u> categories on experimental data is the scientific method.	Falsification is the scientific method for rejecting theories.	A theory is not rejected by its falsification, but only in the context of a comparison with rival theories, using research fruitfulness as the criterion.	Conceptual systems change as individual concepts change their meaning in socio-historical processes and by rational acts (which are not necessarily logical); analogical to 'ecological change' occurring in population of concepts.	Theory-choice is a community decision, influenced by <u>shared</u> professional, social, and psychological values, rather than by rules of choice.
Knowledge is accumulated inductively.	We construct reality by our inner <u>a priori</u> conceptual structures, which in turn constitute the framework for our perception of the world.	Falsification uses crucial experiments all the time.	There is no crucial experiment and no instant rejection.	There is no crucial experiment.	There is no crucial experiment.
The scientific method guarantees progress towards (probable) truth.	There is only one kind of logic and therefore only one kind of geometry. Newtonian physics is the apex of cognitive activity.	Conceptual changes are mini revolutions occurring all the time. Thus, they are evolutionary.	Conceptual change is evolutionary.	There is no crucial experiment.	Conceptual change (paradigm shift) is revolutionary, like a Gestalt shift. It occurs in rare moments of crisis.
	There is only one kind of logic and therefore only one kind of geometry. Newtonian physics is the apex of cognitive activity.	Succession of scientific theories is genuine progress, even in an absolute sense.	Progress occurs when a rival research programme proposes a more fruitful 'problem shift'	Conceptual change is evolutionary.	There is no communication between two paradigms.
	Scientific progress approximates truth (regarding the world of phenomena)			Progress is similar to biological adaptation.	Progress is a relative notion.

Comparison of sets of basic statements characteristic of various philosophical views.

APPENDIX XVIII

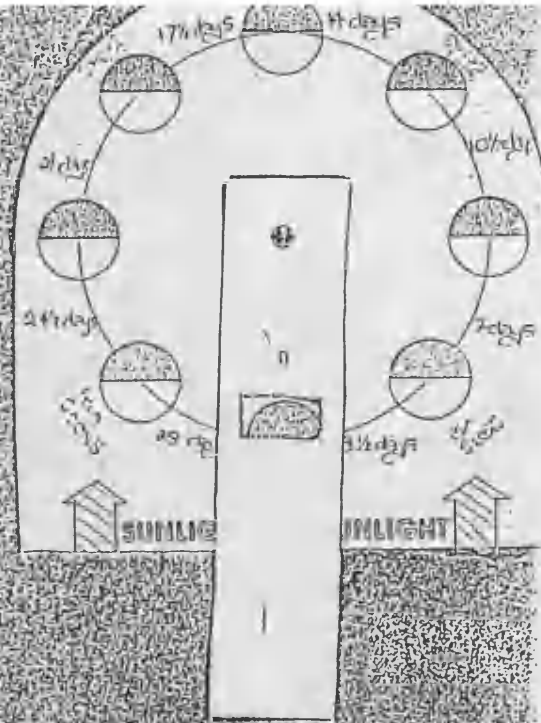
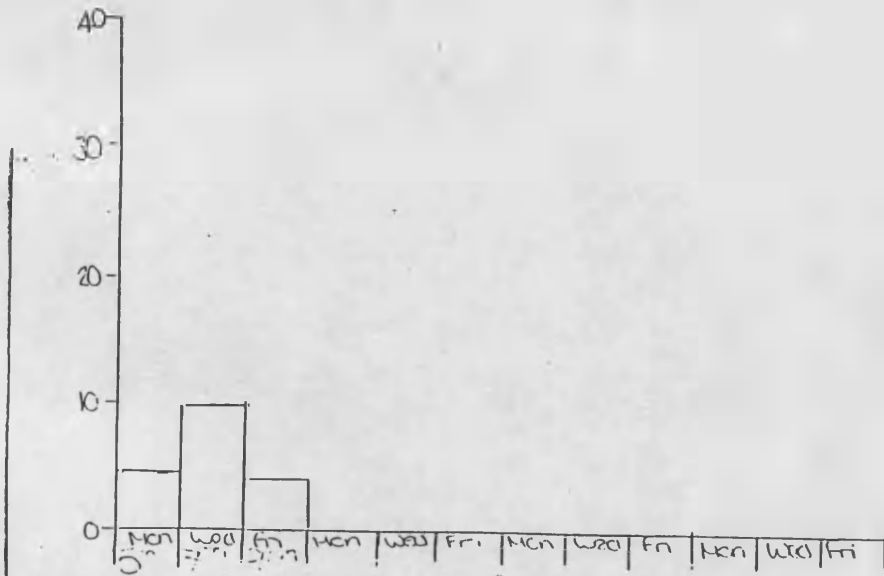
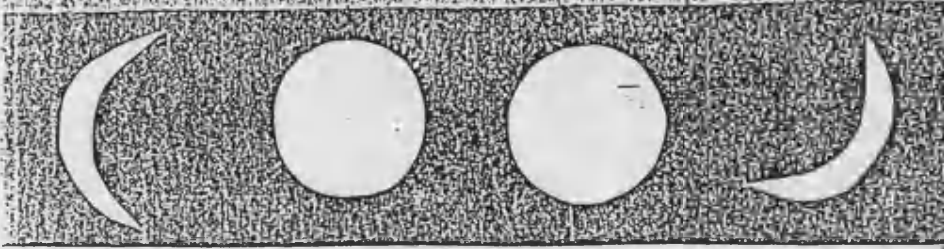
EXAMPLES OF PUPILS' WORK:

Seasons

Moon and Seeds

PROBIAM

We are doing an experiment to see if seeds grow better if they are planted at a full moon.



MOON AND SEEDS SUPERSTITION
 In the past, many people thought that any seeds planted during the time of a full moon would grow better.

Materials

- Seeds
- Cotton wool
- Containers

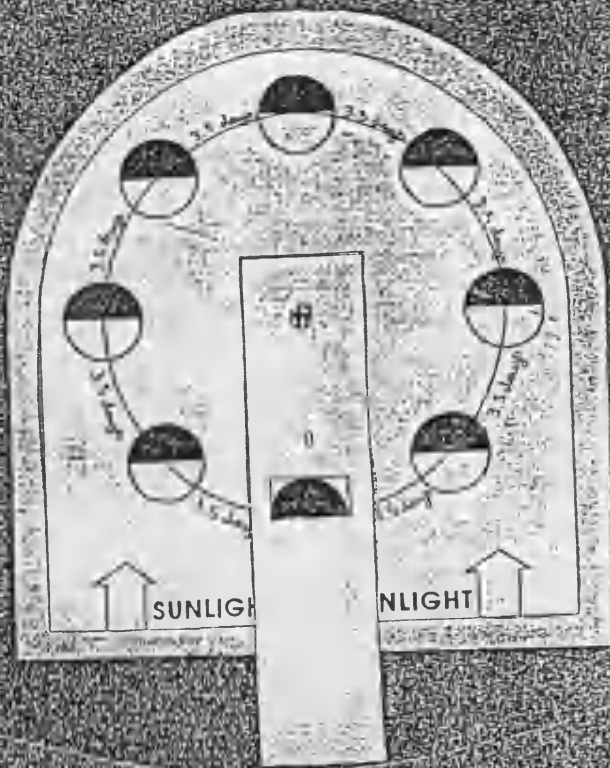
Method

Our group's method is to plant up to ten seeds in four seasons during the moon phase, ten each week. We will see if the germination of the seeds differs according to the phase of the moon. The superstition goes that the seeds will germinate best when the moon is at its fullest.

MOON

BEANS

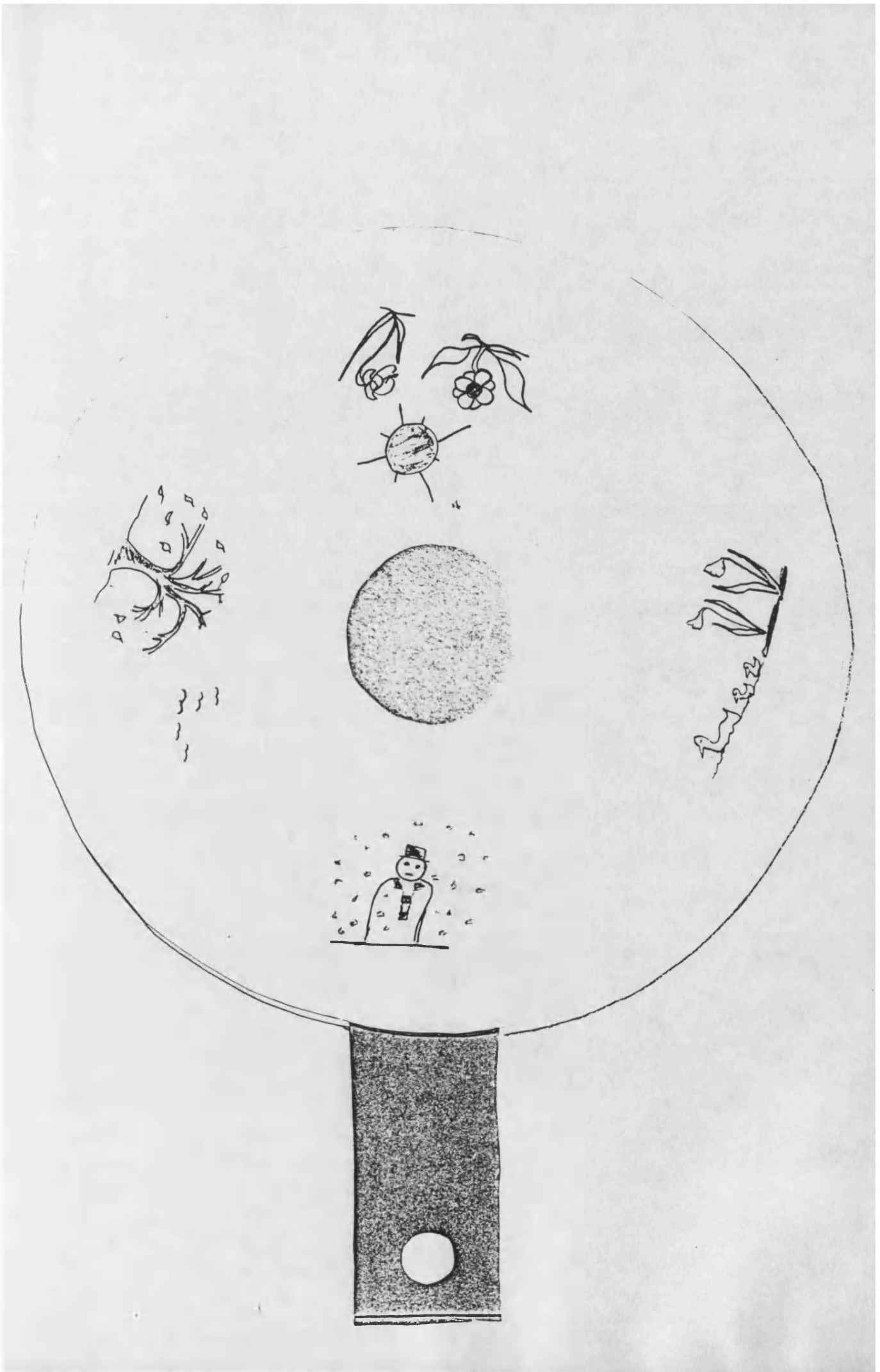
MOON PHASE	DATE	AMOUNT GERMINATED	HEIGHT
☾ ☽ ○ ○	1st Feb	10	2cm
	2nd Feb	8	3cm
	5th Feb	9	0.7cm
	3rd Feb	10	2cm
○ ○	2nd Feb	7	2.8cm
	8th Feb	9	10.9cm



MOON AND SEEDS

Design Brief

In the past many people thought that seeds planted during the full moon would grow better.
Our group is going to test this theory and see if it works.



APPENDIX XIX

SECOND DRAFT OF ASTRONOMY ENGLISH

CROSS CURRICULAR MATERIAL

SCIENCE / ENGLISH CROSS CURRICULAR PROJECT

This is a second draft of a project presently undergoing trials at Court Fields Community school. The project is intended to develop the cross curricular potential which exists between English and science curricula, and to develop the use of science as a medium for narrative writing.

All documents related to the project included in this appendix are in a raw state, and should be read as a first draft. At present (Feb.1991) weekly meetings between the teachers involved in the project are taking place and the final product will, in all probability, differ considerably from this draft.

An application has been made for a 'COPUS' grant to finance the further development of this product.

I am indebted to Mr. B.Stannard,(co writer) Head of English at Court Fields Community school for permission to include this draft in the thesis.

(i) COPUS is the Committee on the public understanding of science. Grant forms are available through the Royal Society, London.

NOTES FOR TEACHERS

It is intended that teachers make themselves familiar with all material to be presented to the pupils, and that they are familiar with the aims of both departments.

Aims of Science Department

To demonstrate that ideas in science have changed through out history and that these changes have often been resisted. To show that the invention of a new technique (in this case the telescope) gives new evidence which initiates, or supports, a change in the established view.

Aims of the English Department

To use drama structures as a means of exploring scientific ideas and their impact on society.

To provide a range of contexts, purposes and audiences for writing, speaking and listening.

To help students understand the differences in language used in creation myths and scientific descriptions of the world.

Teaching Sequence

(i) Week one: English department will work on the "Imaginary Worlds". Science Department: Earth in Space , Pupil Activity Booklet, challenging their ideas.

(ii) Week two: English department working on "Creation Myths" Science department: What do you know about the Earth in space?

(iii) Week three: English department: Introducing the Conflict Thesis. Science department: Working on the card A and B activities of the cross curricular pack.

(ix) Week four: Both departments working on the Copernicus and Galileo sheets; activities not tied to a particular department.

Drama and role play potential to be explored by both departments.

Teachers' Background Reading

RLDU 'The Earth In Space' pp 6-10. The Coming of Age in the Milky Way. T.Ferris. (1988) The Sleep Walkers. A.Kostler (1957). Narrative in Science Education. Strobe. P. (1989).

Look carefully at the picture below.

Make a list of words which could be used to describe this world.

What feelings does the picture evoke in you?

What other things come to mind?



Your teacher will ask you to describe your world to the rest of the class. Try to describe it *as if you were an inhabitant* of this world. Be prepared to answer questions.

The questions you were asked may have helped you to clarify your ideas about this world. Write a description of what it is like to live here. Where and how do people live? What kind of work is there to do?

CREATION STORY

The people who live in this world would have a story to explain the beginning of their world. This type of story is called a Creation Myth. In your group make up the story the people of this land would tell to explain how things began. It should be appropriate to the land and should take account of and explain its natural features (e.g. the land, the sky, the wind, fire, rain etc.), and how the creatures were made.

Tell your story to the rest of the class.

SCIENCE AND SOCIETY CONFLICT THESIS SIMULATION

Simulation - where the central features of reality are replicated with the aim of helping participants understand that reality.

It is very important that throughout the whole scheme teachers invite students to decide on things themselves. It is essential that students have ownership of their ideas since they need a vested interest in them. There does not have to be universal agreement with or even commitment to the ideas since we are trying to simulate an actual historical situation. All students' responses are therefore valid. This scheme of work demands a high degree of negotiation with the students although the structure is determined by the teacher throughout.

CREATION MYTHS

The students should read several creation myths from different cultures, particularly those which are obviously influenced by environment such as the Norse, Amerindian, Egyptian, Eskimo, and African. Students should then be able to see that the sequence of events and the nature of creation in these stories are determined by the particular geographical context in which they are set, e.g. desert, Arctic wastes, wetlands, a mountain range.

The class should be divided into groups of about four or five students per group. Each group is given a picture of an imaginary/fantasy world. Groups brainstorm words, feelings, ideas engendered by the pictures.

Each group in turn describes its world to the rest of the class (without revealing the picture). The other students in the class are encouraged to ask questions about the world. The group describing the picture should answer as if they were inhabitants of the world. This should help to build up their belief in

Groups might now be asked to work on their worlds in more detail and to provide information about climate, flora and fauna, geographical features, means of subsistence, habitation and so on. At this stage students should concentrate on the physical features of their worlds.

Each group should now invent a creation myth to explain the origin of their world. It should take into account the geographical features, weather, living features and so on as decided in 3 above.

The myths should then be related to the rest of the class.

An alternative here would be to give all the groups the same picture. They could follow activities 2, 4 and 5 as described above. As different myths will have been invented, groups might challenge other groups about the validity of their mythological explanation of the origin of the world.

INTRODUCING THE CONFLICT THESIS

the following activities it is assumed that the students are familiar with scientific description of the evolution of life on Earth.

Divide the class into two groups as before. All groups are given the same lecture. The groups prepare a creation myth to explain the origin of the world. One group, however, will be given a different brief. They should prepare a 'scientific', rational explanation of the origin of the world. They might need help from the teacher to prepare this.

The groups working on the mythological explanations should present their theories to the rest of the group and one story/worldview should be agreed upon and accepted as the established view.

It doesn't matter if there is not universal agreement as this can be explored later.

Groups now work on inventing a history, culture and religion for the people to live in this world. They should decide how society is organised and the laws which govern the land. These laws should be religious in nature and should derive from the essential worldview already agreed upon. They should elect from among themselves those who will govern them according to the 'Law'. What will they do with people who disagree with the official explanation of the origin of the world is? (It is very important that students are clear about this last issue).

At a suitable stage in the work the 'scientific' group should be allowed to present their alternative explanation to the rest of the class.

How will the 'Establishment' react?

Will the 'scientists' be able to persuade the 'Authorities' and the rest of the people?

Will the theory be adopted?

How will the 'Authorities' deal with the 'heretics'?

What changes will need to be made?

What will the heretics do? Recant? Stick to their theories?

The form for the presentation of these theories needs to be carefully selected. Perhaps a court/hearing could be set up by the 'Authorities' to examine the 'heretics', in much the same way as the Church examined Galileo. In this way the person with a vested interest in the established worldview will be in control at all stages. Although this is a 'rigged' situation with obvious bias to the 'Authorities' it is exactly what pertained in Galileo's time. The fairness or otherwise of the 'trial' can be examined later.

JOURNALS

It is essential that throughout this exercise individuals should record in a learning journal their thoughts and feelings. Students should reflect on the changes - intellectual and emotional - that they went through :

What do you believe?

When did you change your mind, at what point were you persuaded to do so? Why?

What new evidence did you have to take into account?

Do you believe one thing privately but say something else publicly?

BRIEFING

A quantity of time needs to be set aside for discussion of all the above. Both sets of students should share their ideas, thoughts and feelings with the rest of the class. Perhaps some of the 'establishment' were persuaded by the 'scientists'. Perhaps some of the 'scientists' doubted whether they were right or not.

At this point it is obvious that an exploration of the Conflict Thesis and the Clean Revolution could be introduced.

KNOWLEDGE ABOUT LANGUAGE

From the English point of view an exploration of the language used by the groups would be very useful.

Students could examine the written descriptions of the origin of the worlds produced by the various groups : the 'scientific' and the 'mythopoeic'. What sort of words were used? Is there any difference in the way the groups described the world? Is one more 'accurate' than another? Is a technical vocabulary employed by the 'scientists'? Is there an equivalent in the mythological explanation (e.g. of metaphorical language or symbolism)?

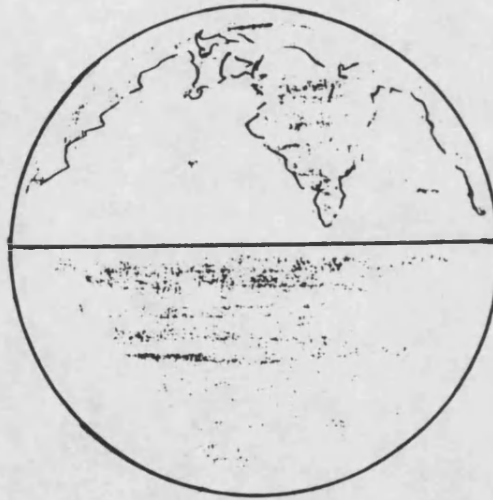
As an interesting additional exercise each version of the origin of the world should be written in language appropriate to the other version, i.e. the 'mythological' explanation could be written in objective, 'scientific' language, and the 'scientific' version in language more appropriate to a story. Does this make any difference to the way the stories are perceived?

These are very complex issues and need to be carefully introduced.

SUN



EQUATOR



EARTH

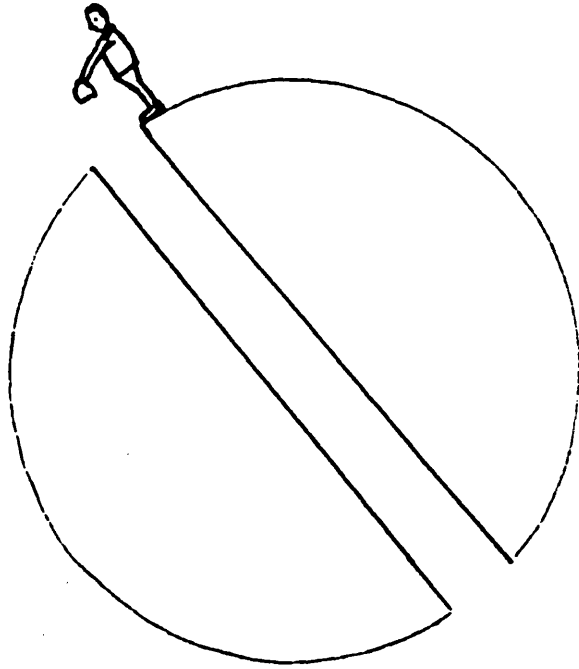
Between the 7th and 11th centuries AD many people believed that the world was round, but they did not think that anyone could live South of the equator.

Some argued that it was impossible to live at the bottom of the round world because rain and snow does not fall upwards, and people are not able to walk with their feet above their heads.

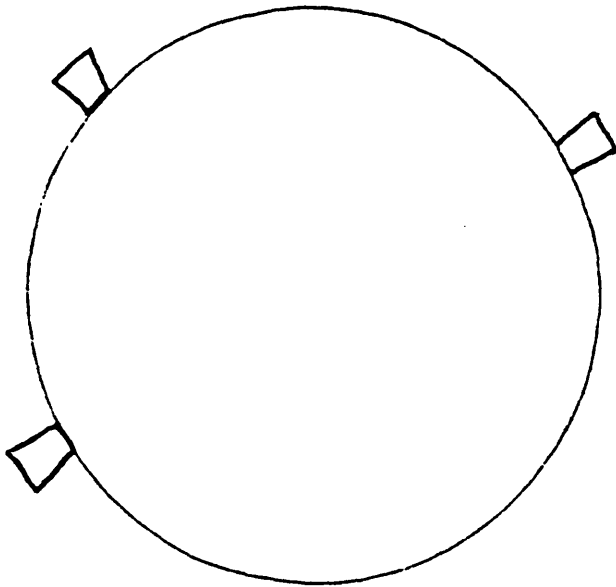
THIS IS WHAT YOU DO

Write about some modern pieces of evidence which show that ancient the ideas about people not living south of the equator are wrong.

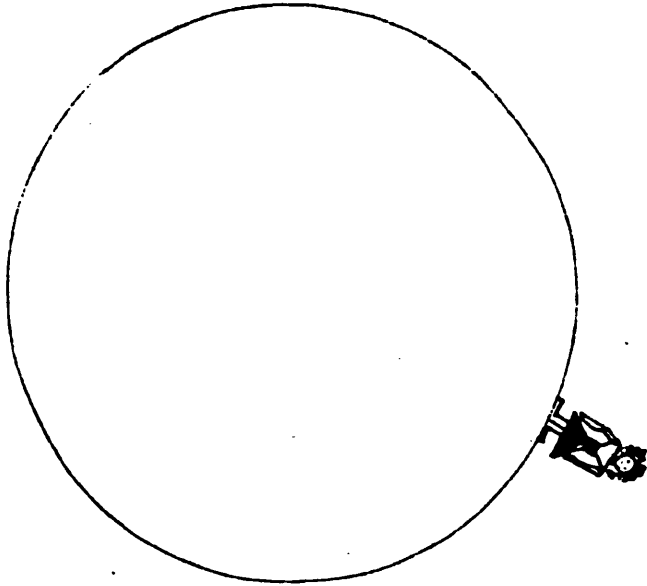
Now complete the activity sheets on gravity.



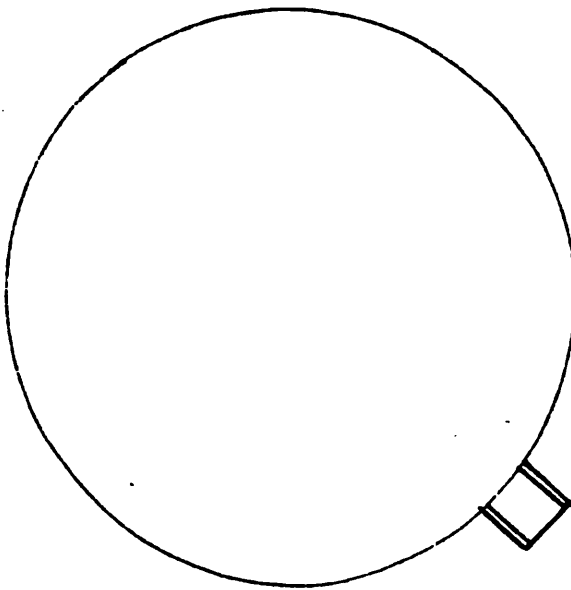
(3) Draw arrows to show which way the stone will fall if the boy lets it fall down the hole drilled through the Earth.



(4) The drawing shows three drinking glasses on the Earth. Draw lines to show the water level if each glass is half filled with water.



Draw arrows to show which way is UP for the girl standing on the Earth.



(6) Draw a person hanging from the bar by their legs.

WHY DID PEOPLE BELIEVE IN THESE IDEAS ?

Look at cards A and B again. The people who believed in these ideas were not stupid. Many of the people who taught these ideas were highly respected and intelligent people.

What Do You Think ?

Write about the things that you think made people believe in these ideas.

Have You Ever Had To Change Your Ideas ?

Think about an ideas you had about astronomy when you were younger. How did you have to change these ideas ?

Information sheet No.1

COPERNICUS AND GALILEO

By the 11 th. century AD. most people accepted that the Earth is round, but they thought that it was placed at the centre of the solar system. They claimed that God made the Earth, Sun, Moon and stars and placed people on the Earth. Humans, they said, were God's special creation, so he was bound to place them in the very centre of His Universe. They thought that the Sun, planets and stars circled around the Earth once every day.

No one dared to challenge this theory, for if they did, they would probably be placed in prison, tortured, or even executed for saying that the Earth is not at the centre of the solar system.

In 1543 Nicholas Copernicus, a Polish churchman, published a book in which he claimed that the Sun is placed at the centre of the solar system, not the Earth. He supported his claim by using some complicated mathematics as evidence for his theory. Very few people could understand his mathematics, so his theory went almost unnoticed for about one hundred years.

You may wonder what happened to Copernicus for daring to write such things. The answer is nothing. He was a very ill old man when his book was published and died before any action could be taken against him. You could say that his timing was perfect.

The Invention Of The Telescope

In 1609 a Dutchman, Hans Lippershey, invented the first telescope, but his instrument was not very good. Galileo, probably one of the most famous scientists ever, made improvements to Lippershey's design and produced a high quality telescope.

Galileo looked at the Moon and planets through his telescope. He saw mountains and craters on the Moon, and noticed that there are moons which orbit the planet Jupiter.

By making careful observations through his telescope,

Galileo found evidence which supported the theory which Copernicus had published seventy years earlier. Galileo was an outspoken man and was not afraid to let people know that he believed that the Sun is at the centre of the solar system. He invited priests to look through his telescope, but many refused for fear of what they may see.

It was not long before the Pope called Galileo to Rome to face trial for teaching that the Earth is not at the centre of the solar system. Although he was not tortured, as is often claimed, he was forced to "curse and detest" the theory that the Sun is at the centre of the solar system, and swore never to teach or write about the theory again. He was placed under house arrest and died in 1642, one hundred years after Copernicus first published the sun centred theory.



READ INFORMATION SHEET No.1

Now look at the drawing above and then answer the questions.

- (1) What do you think the drawing shows ?
- (2) Why is the group of people standing away from the telescope ?
- (3) What do you think these people are saying to each other ?
Write down their conversation.
- (5) What other invention which magnifies things has changed our ideas ?
Write about how this instrument has changed the way we think about nature.

APPENDIX XX

TEACHERS' RESPONSES TO INSET



CHILDREN'S LEARNING IN SCIENCE PROJECT

Centre for Studies in Science and Mathematics Education
The University, Leeds LS2 9JT
Telephone 0532 431751 Direct line 334675/334678

Mr. J. Baxter,
Kingsley Close
Salmington,
Taunton
Somerset.

5. 3. 90.

Dear John,

Phil asked me to send you a mixed batch of
comments from the 'Earth in Space' workshops from
Training the Trainers' and the secondary short course.
At long last here they are! Apologies for the
delay.

Yours sincerely,

Thelma Wightman

Training The Trainers Nov '89

Further comments: ... The area which is at present causing concern and consideration for myself because of the lack of understanding which science teachers in general do not have and are not aware of not having!

1.1.11

Further comments: ... Excellent presentation. Uncovered ~~many~~ ^{much} of my misunderstanding.

John Baxter used the development (through history / through children's understanding) of ideas to a good advantage. He provided sound understanding to many of the issues. An excellent INSET session was outlined which I will attempt with colleagues.

Highlighted my ~~own~~ weaknesses in this area - but was grateful to discover that others too were as weak or even weaker! (Had quite a shock when I looked at the correct answer to the card sort lab. - I had let myself be convinced by others that I was wrong when I was right - and vice versa!)

Food for thought / an area in which I need to develop confidence in putting over the ideas. The presentation has shown me a way forward.

Training For Trainers Nov '89

activity a or repetitive.

I'm not sure where it's left or where
with advanced publicity for a forthcoming
publication.

Further comments: Interesting to see how both
primary and secondary advisory teachers
have a lack / misconception of knowledge.
That some secondary teachers could
not see the cross-curricula links or
how this could be incorporated in an
integrated approach to science. I feel
more time could have been spent on identifying
how astronomy could be integrated. More practical
activities and samples of children's work were needed.

Activity

Further comments: Another way of opening up a workshop session -
could use it in a modified form but would have to be sure of
own knowledge of facts!! Children's ideas were less useful - I was
uneasy about interpretation of children's responses.

Shows how ignorant I am, but not in a
threatening way. I felt my mind drifting
though, and feeling sleepy - yet the speaker
was good - was the session too long? Or
was it just too much food and drink?? Or
lack of a break, fresh air, ??

Training The Trainers. Nov '89

Further comments:

It high lighted my inadequacies - lack of understanding
At primary level because of the difficulties in producing
books or experience of children. I would tend to leave topics
until the last year of primary education. The subject seems
to be too abstract for most pupils other than in terms of a list of facts.

Further comments: A very valuable session, about an AT which
we have done little for so far. Good material, well
presented, worked on & summarised. Very useful
for Hilary to share her plan of an INSET session
with primary teachers using this material.

Further comments: ... This activity made me very aware
of my own lack of knowledge within this
A.T.T. - and also of the real need for teacher
support. I was interested to hear that we
might possibly contemplate not teaching this
A.T. at Key Stage 1 / however Key Stage 2 - I have
personally been concerned at the lack of
concrete evidence which it is impossible to
provide.

Further comments: I learned more facts which will
hopefully give me greater ability to discuss this AT
- more than that I had the opportunity to explore
my own ideas and fit in the new info. where I
needed it - where it made sense to me. I can also
imagine using these ideas again in my own work
with teachers. Many primary teachers want more
scientific understanding to enable them to work
successfully with their pupils. Interesting to see individ

Training Pt Trainers Nov '89.

Further comments: ... Very helpful for sorting out my own concepts & misapprehensions.
Excellent material for use in courses with teachers.

I liked the card method of exploring ideas, it was interesting to see the children work and the methods used to elicit their understanding.

Further comments: ... As a head of a science dept in a comprehensive school I was surprised how unclear I and other participants were on AT16.
Most worthwhile focusing on children's perceptions at various ages.

Secondary short course Oct 89

Further comments: ... Basically recapped theme of the overall course. A useful reference was given for use by teachers.

Interesting approach to a new subject area. Good opportunity to talk through ideas.

Further comments: ... A totally new area - useful info about teaching package available.

Further comments: ... Great provoked a lot of thoughts + doubts.

Further comments: ... Basically recapped theme of the overall course. A useful reference was given for use by teachers.

Secondary short course Oct 89

Further comments:
..... What is so new about 'starting
..... where the children are' + 'having a class
..... with very different amounts of previous knowledge
..... on every subject' ?! ?

Further comments:
..... Some useful material here to help with A.T.16,

Further comments:
..... A totally new area - useful info about teaching
..... package available

Further comments:
..... More time was needed to look at the next step

APPENDIX XXI

COMMUNICATION WITH ROYAL
ASTRONOMICAL SOCIETY

TELEGRAMS:
URANOMETRY LONDON
FAX:
01-494 0166

ROYAL ASTRONOMICAL SOCIETY
BURLINGTON HOUSE
LONDON, W1V 0NL

TELEPHONE:
01-734 4582
01-734 3307

PLEASE REPLY TO:—
ASTRONOMY CENTRE
PHYSICS BUILDING
UNIVERSITY OF SUSSEX
FALMER, BRIGHTON
BN1 9QH

24 September 1990

Mr J H Baxter
8 Kingsley Close
Galmington
Taunton
Somerset

Dear Mr Baxter

QJ paper N177R

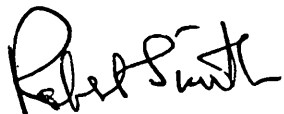
Many thanks for your recent letter and for the enclosed original drawings and histograms.

Your insertions and corrections to the text of the paper are fine, and the paper has now been accepted for publication. Unfortunately, the diagrams required too much work on them for me to be able to get them ready in time for last week's press deadline, so I am afraid that the paper will not appear until our 1991 June issue. You should receive proofs in February.

Since I was not able to meet the current deadline, the diagrams have had to take second place to more pressing commitments at work. However, when I have managed to produce a suitable version I shall send you a copy.

I hope that your back continues to improve and I am sorry that you had to do these diagrams so quickly, without reaping the benefit. But I did need the original drawings in any case, so you have certainly not wasted your effort.

Yours sincerely



R C Smith

cc: Mr J Randall, RAS; Professor G H A Cole

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The National Curriculum: A Challenge for Astronomers

*John H. Baxter**

8 Kingsley Close, Galmington, Taunton, Somerset TA1 4LQ

(Received 1990 January 12; in revised form 1990 September 14)

SUMMARY

In this paper I describe the present position of astronomy education in secondary schools and the concerns felt by teachers towards teaching basic astronomy. The general features of childrens' untutored ideas on the easily observed astronomical events are identified and astronomers' attention is drawn towards the need for child-centred teaching materials which use topics from astronomy to support important ideas in the three main sciences.

1 INTRODUCTION

It is 16 years since Lintern-Ball's (1972) survey of astronomy education in British schools revealed a short-fall in provision. During the intervening years our understanding of the Universe, exploitation of space and the science curriculum have undergone considerable change. As part of a Ph.D. thesis on the role of astronomy in the school science curriculum, a research programme was carried out to discover the present position of astronomy education, pupils' untutored understanding of the easily observed astronomical events and opinions and concerns of science teachers towards teaching basic astronomy. Although the data were collected before the position of astronomy within the National Curriculum (1989) was finalized, the findings give an insight into the task facing those responsible for the introduction of Attainment Target 16 (The Earth in Space) into the school science curriculum.

2. METHODS OF INVESTIGATION

Postal questionnaires were used to gather data on the position of astronomy in secondary schools and opinions and concerns of teachers towards teaching the subject. In order that the questions and statements which made up the questionnaires reflected the range of opinions and views of practising teachers, rather than the researcher's bias, a collection of statements from informal interviews was made. The interviews were held with teachers who visited the Secondary Science Curriculum Review stand during the Association for Science Education's York 1985-86 AGM. The most recurrent statements were used to construct two questionnaires, which were sent to: (i) heads of departments (HODs) to discover the present state of astronomy education and their opinions on including astronomy in the science curriculum; or (ii) assistant science teachers to discover their opinions

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TABLE I

Responses to questionnaires sent to schools. Total returns: 32.8 per cent

School type	Number sent	Frequency	Number of returns	Frequency
Comprehensive				
Mixed	315	0.789	106	0.809
Girls	12	0.030	6	0.046
Boys	10	0.025	3	0.023
Sec. Modern				
Mixed	31	0.077	7	0.053
Grammar				
Mixed	12	0.030	4	0.030
Girls	10	0.025	3	0.023
Boys	9	0.022	2	0.015
	399	0.999	131	0.999

and concerns on teaching basic astronomy. Astronomy was defined as those events which are easily observed from Earth and which feature in the lives of most people, e.g. Sun rise and set, phases of the Moon, tides and gravity.

A random selection of 399 secondary schools was made from the *Schools Handbook* (1985 edition) and on 1986 June 24 one HOD and three science teachers' questionnaires were sent out to each school. The randomly selected schools divided into seven distinct types. Table I shows the number of HOD questionnaires sent to each school type and the number of useable returns received. Responses were coded, entered onto punch cards and then transferred to a 'Delta Plus' data base (available from Minerva Software, Exeter).

A major factor deciding the low level of returns was the political situation prevailing at the time questionnaires were sent. There had been an on-going pay dispute and teachers were preparing for what many felt was the premature introduction of GCSE courses. However, although the returns were lower than hoped for, the 131 returning schools represent the astronomy education of 111 729 pupils.

3 RESULTS

Almost half of the returning schools cover some aspects of basic astronomy in their science curriculum, but none allocated it a particular slot on the timetable. This is a higher exposure to astronomy than that found by Lintern-Ball (1972), and goes some way towards supporting the findings of Gold (1976) who claimed to have observed considerable enthusiasm for the subject. However, the picture of astronomy education becomes less rosy when we take into consideration the HODs' responses to question 3: Are you satisfied with your present provision for astronomy education?

3.1 HODs' concerns

Of all the returning HODs, only 21 per cent registered satisfaction with their present provision. Over two-thirds of those from schools covering some aspects of astronomy claimed that they are dissatisfied with the way it is

TABLE II

HODs' attitudes to provision of astronomy education in schools

School type	Astronomy covered	Number satisfied	Astronomy not covered	Number satisfied
Comprehensive				
Mixed	57	19	49	4
Girls	2	0	4	0
Boys	1	0	2	0
Sec. Modern				
Mixed	1	1	6	1
Grammar				
Mixed	0	0	4	0
Girls	1	1	2	2
Boys	0	0	2	0
Totals ($n = 131$)	62	21	69	7
% of sample	47.3	33.9	52.7	10.1

TABLE III

HODs' responses (131 schools) to statement 24 in the questionnaire: 'In general, pupils leaving the fifth year have a satisfactory knowledge of basic astronomy'

Opinion	Strong agreement	Agreement	Unsure	Disagreement	Strong disagreement
Score	2	8	25	22	74
% of sample	1.5	6.1	19.0	16.8	56.5

covered and 89 per cent from schools where astronomy does not feature registered dissatisfaction with their present lack of provision (Table II). HODs' opinions of their school leavers' knowledge of basic astronomy is further evidence that there is a short-fall in astronomy education (Table III).

Only two of the HODs from schools where astronomy features ticked the agreement side of the scale. Responses to statement 23 suggest that this apparent short-fall starts in the junior schools (Table IV). Fifty per cent of the HODs think there is a shortage of suitable teaching material and 65 per cent expressed a positive interest in materials which use topics from astronomy as support material for important concepts in the three main sciences.

All returning HODs consider astronomy should feature in the science curriculum but, at the time the surveys were sent out, they placed it low in priority for a place on the timetable.

3.2 Teachers' concerns

Eighteen per cent (216) of the teachers returned responses to their questionnaire. This low level of response was expected as returns depended on their HODs passing the questionnaires on to them.

A lack of subject knowledge was the major concern of 60 per cent, and 82 per cent claimed that their training had failed to give them the necessary background to teach basic astronomy. Although teachers of physics

TABLE IV

HODs' responses (131 schools) to statement 23 in the questionnaire: 'In general, pupils entering our first year have a satisfactory knowledge of basic astronomy'

Opinion	Strong agreement	Agreement	Unsure	Disagreement	Strong disagreement
Score	2	4	34	25	66
% of sample	1.5	3.0	25.9	19.0	50.4

TABLE V

Percentage of sample (of 216 teachers) confident to teach astronomy

Subject	% Confident
Physics	55
Chemistry	51
Biology	35

TABLE VI

Percentage of sample (of 216 teachers) interested in astronomy support material

Subject	% Interested
Physics	83.3
Chemistry	68.08
Biology	45.6

registered the greatest confidence, 45 per cent considered that they did not have the necessary background to teach basic astronomy with confidence (Table V). This result confirms Butt's (1985) concern that although it is commonly thought that teachers of physics are *ipso facto* teachers of astronomy, they are not necessarily trained, or confident, to do so.

Seventy one per cent of the teachers showed a positive interest in teaching materials which used areas from astronomy as support material for important concepts in their subject specialism (Table VI).

The great majority of both HODs and science teachers (89.2 per cent) consider that they will need in-service training if they are to teach basic astronomy with confidence.

3.3 Childrens' ideas on astronomy

Childrens' 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 children aged between 9 and 16 years was taken from pupils attending a comprehensive school in the south-west of England (having a full spectrum of abilities, HMI 1989) and its four main feeder junior schools. Apart from planet Earth topics typical of secondary school geography, astronomy does not feature in the curriculum of these schools. Therefore, most notions held by pupils represent personal constructs, or are the product of informal education.

TABLE VII
Breakdown of pupils in interview group

Age group (years)	9-10	11-12	13-14	15-16	Totals
Girls	3	2	2	3	10
Boys	2	3	3	2	10
					20

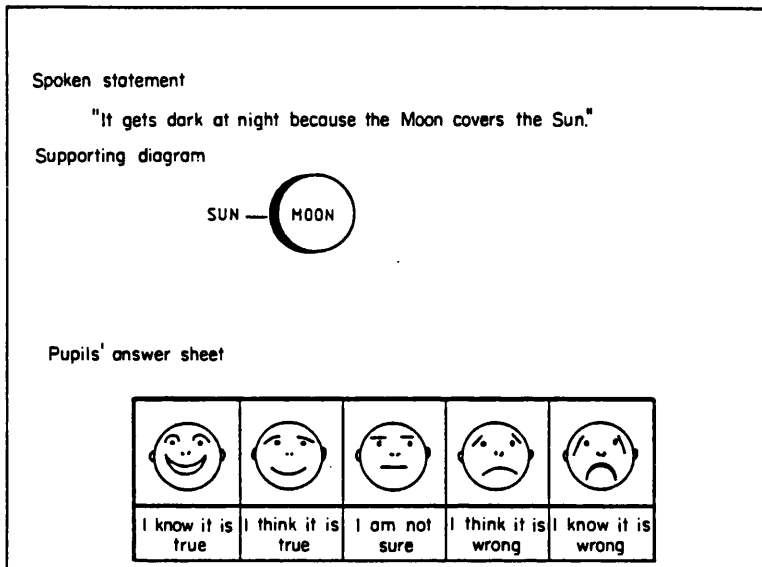


FIG. 1. Example of the way in which ideas were presented to the children, and of how they were asked to respond.

A two-stage process of data collection was used. First, a sample of twenty pupils aged between 9 and 16 years were interviewed about their theories concerning the four domains. These pupils covered the full range of abilities based on their teachers' judgements (Table VII). The commonly occurring ideas used by these pupils were identified from the diagrams and explanations given, and were used to construct an astronomy conceptual survey instrument. This comprised a series of statements with supporting diagrams; pupils responded to the statements and their accompanying diagrams by placing a tick on the face which represented their view (Harty & Beall 1984) (Fig. 1). Thus, pupils' reading and writing skills would not influence their astronomy score. The test was presented to 48 boys and 52 girls (Table VIII).

Pupils were given practice questions to familiarize them with the method of recording their answers and were told that the statements were a collection of peoples' ideas, some correct, others incorrect. They were reassured that the test was not a formal school test but that the researcher was interested in their ideas. The test was then administered in silence to groups of ten pupils at a time.

TABLE VIII
Breakdown of pupils who were tested

Age range (years)	9-10	11-12	13-14	15-16	
Girls	12	10	15	15	
Boys	9	17	11	11	
Totals	21	27	26	26	100

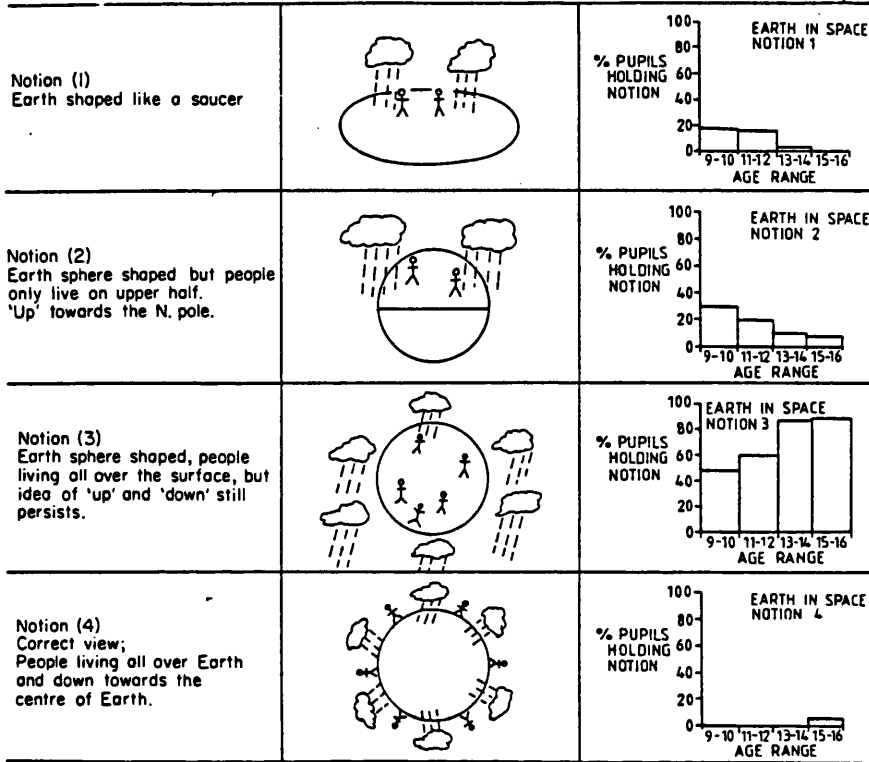


FIG. 2. Children's notions on The Earth in Space. For each notion is shown a summary of the spoken statement, a typical drawing illustrating the notion and a histogram showing the percentage of pupils holding the notion in each of the age ranges 9-10, 11-12, 13-14 and 15-16 yr.

Pupils' ideas on planet Earth and gravity fell into four distinct notions (Fig. 2). The four notions uncovered were similar to those first proposed by Nussbaum (1979), the most popular idea being that of a round Earth but with notions of vertical up and down still persisting. It is notable how few pupils, even in the older age group, use notion 4, the accepted view. -

Pupils' ideas on day and night fell into six distinct types (Fig. 3). Support for the more naive notions decline with age but they are not necessarily exchanged for the accepted view.

Four alternative ideas on the cause of the Moon's phases were elicited, all

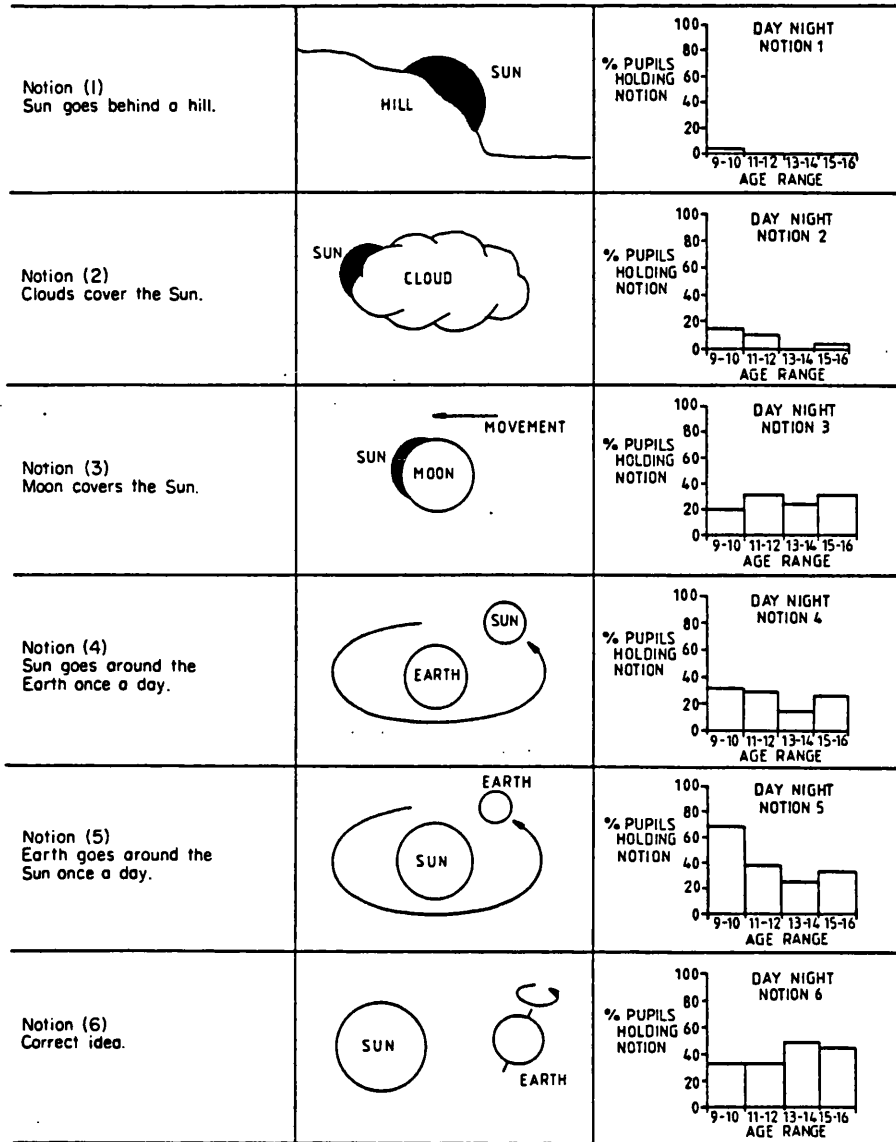


FIG. 3. Children's notions on Day and Night, displayed as in Fig. 2.

of which involve an object either obscuring part of the Moon or casting a shadow on its surface (Fig. 4).

Rather like childrens' notions on day and night, their early ideas on the seasons involve near and familiar objects. Older children appear to replace these more naive ideas with notions which involve the astral bodies moving their position. At first this movement is 'up', 'down' or across, later these ideas are replaced by orbital motion (Fig. 5).

Although the surface features of the ideas children use to explain the easily

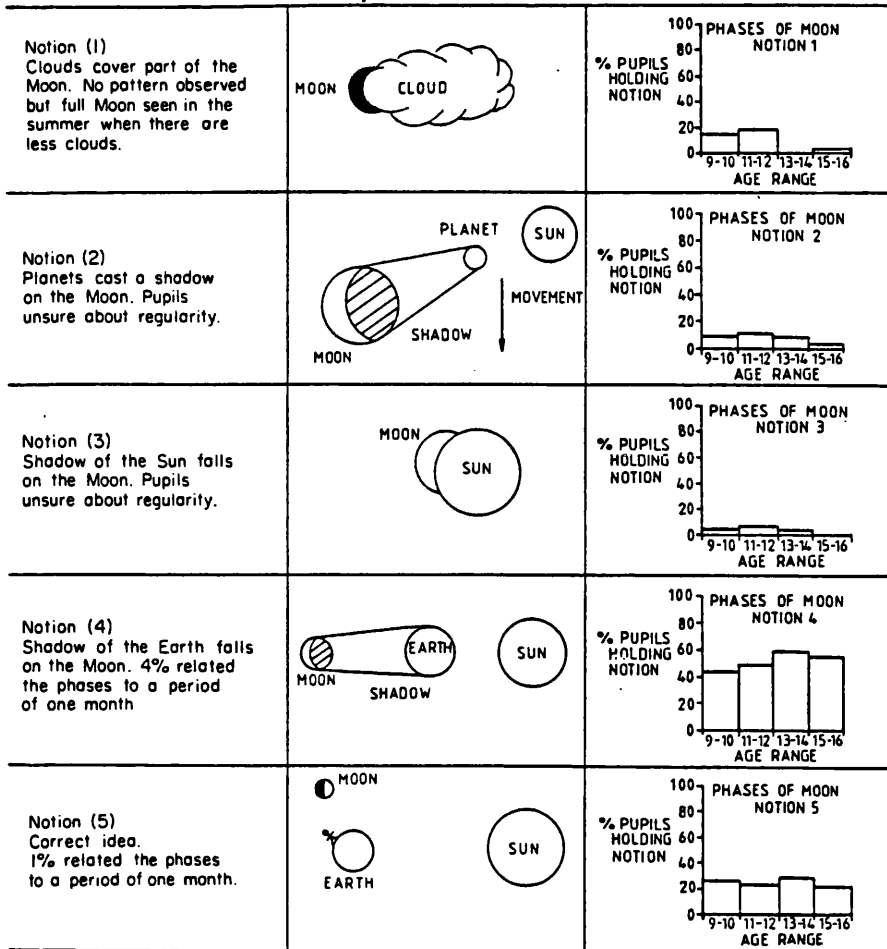


FIG. 4. Children's notions on The Phases of the Moon, displayed as in Fig. 2.

observed astronomical events are variable, a four-phase developmental pattern in the underlying conceptual operations which underpin the responses can be identified.

Phase (i). Earth static, frequently drawn saucer-shaped, north = 'up', south = 'down'. Any changes in astral bodies caused by familiar and near objects.

Phase (ii). Earth round, naive view of 'up' and 'down' still persists. Earth central and commonly thought of as static. Astral bodies can move to cause observed phenomena but their movement is frequently represented as horizontal or vertical.

Phase (iii). The same notions about Earth and gravity still persist, but astral bodies are now seen to move in orbits which are frequently drawn Earth centred.

Phase (iv). The present heliocentric view with its associated ideas.

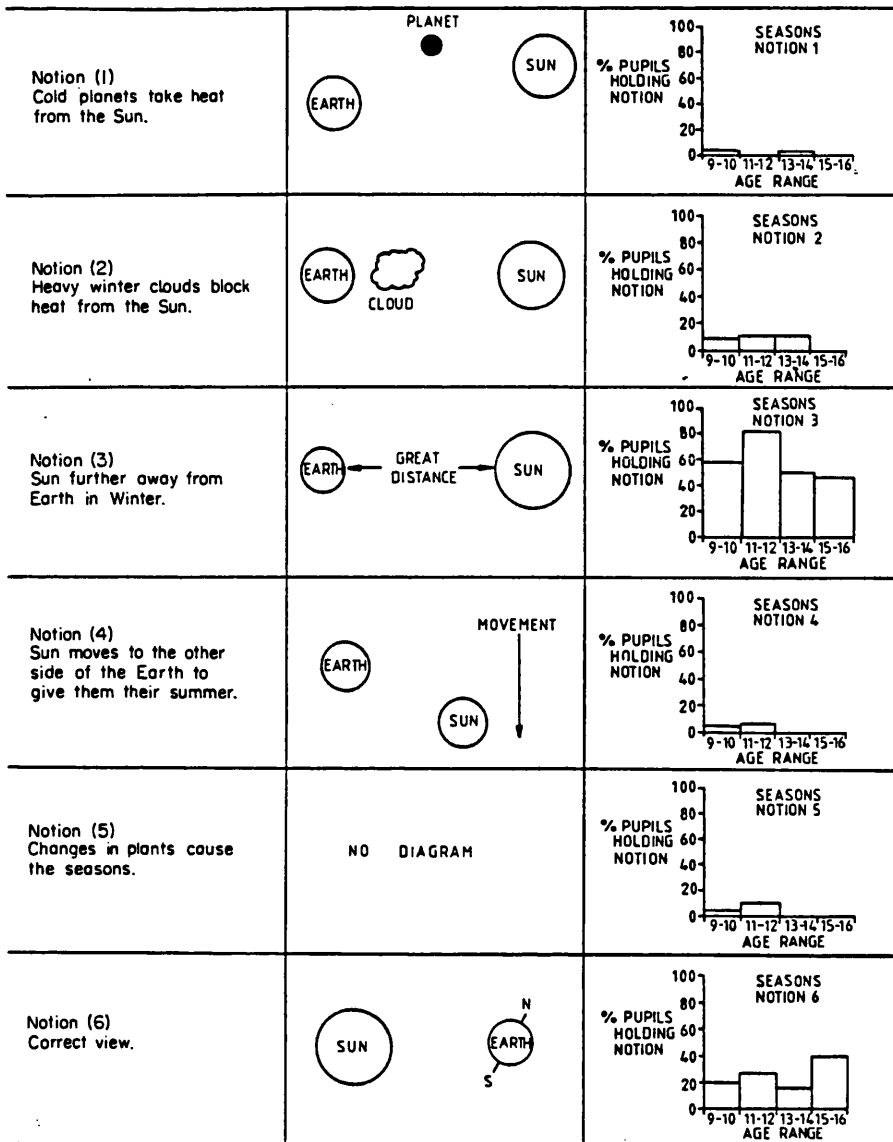


FIG. 5. Children's notions on The Seasons, displayed as in Fig. 2.

4. DISCUSSION

The findings from the postal surveys do not speak well for astronomy education in schools or of the preparedness of many teachers to undertake the astronomy content of the National Curriculum. This confirms Butt's (1985) concern that teachers are ill-prepared to embark on introducing astronomy, a problem which Gold (1985) likens to that of the 'chicken and egg': teacher-training institutions give no instruction in astronomy because there is no demand from schools for teachers with this particular skill.

Clearly, now that astronomy features in the National Curriculum, this situation cannot continue. While in-service training may prove to be a temporary measure, the long-term solution lies with the teacher-training institutions. However, given that the lecturers' background is similar to that of practising teachers, it is unlikely that they are any more confident to teach the subject than the teachers themselves.

There are two levels at which the RAS's Education Committee could operate to facilitate the successful introduction of the National Curriculum's astronomy content.

(i) To work in close liaison with teacher-training establishments to produce an astronomy module aimed at trainee teachers, thereby addressing a hitherto unfulfilled need of student teachers.

(ii) There is concern about the shortage of suitable teaching material. Teachers are particularly receptive to astronomy materials which support their own subject discipline. If we are to focus on the potential of this approach, astronomers need to link with biologists, chemists and physicists to produce astronomy teaching material which can be used as support material for important ideas in the three main sciences. Stoneman (1972), *Space Biology*, and Slater & Thompson (1987), *Where Do Chemicals Come From?* have demonstrated the potential of this approach and make good exemplars of this method of introducing astronomy into the curriculum.

Astronomy in the National Curriculum need not be confined to Attainment Target 16, it will probably be the most relevant vehicle through which to approach aspects of Attainment Target 17, The Nature of Science. In the same way that McCloskey (1983) has shown for motion, pupils' understanding of basic astronomy appears to pass through phases of perception which reflect the history of man's understanding of planet Earth in space. Teaching materials which draw on the history of man's changing view of the solar system will be particularly relevant as many pupils hold ideas astronomers have abandoned long ago.

In all probability, good amounts of these types of material are already in existence in the form of ideas, models or one-off exercises which have not been developed commercially. I propose that the RAS, possibly in conjunction with the Association for Astronomy Education, publicize the need which exists for this type of material, and at the same time set up a central resource of astronomy teaching materials on the lines of Sunal & Demchik's (1984) astronomy materials network resource guide.

Materials for these types of initiative should not be prepared in isolation from the untutored ideas pupils may bring with them into their lessons. Driver & Oldham (1986) have suggested that pupils' ideas can act as a spring-board for the design of teaching strategies. If we accept the view that pupils are not passive recipients of learning material but that learning involves a change in the pupil's conception and for this to occur they must become actively involved (Driver 1987; Duit 1987), then a knowledge of pupils' untutored ideas becomes paramount. Such initial conceptions form a starting point from which pupils can test ideas and modify them should they not hold good in the light of their new experiences.

For the first time since the inception of compulsory education, astronomy is to feature in the science curriculum of almost all pupils. If we are to avoid

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a passive 'facts/regurgitation of facts' teaching strategy which will – as Moore (1976) predicts of school astronomy – kill the subject, then a new approach to writing teaching material needs to be taken. They should start with the pupils' ideas and actively involve them in the learning process. Where possible, pupils should be given the opportunity to clarify their own notions and be encouraged to challenge them using the scientific process of:

IDEA → TEST → RESULTS → CONCLUSION

The National Curriculum, although not without its opponents, has given astronomers their first opportunity to show that astronomy can take its place in the main stream of science education. But resources must be mobilized quickly, for any future reappraisal may well remove astronomy from the science syllabus and many of our pupils will be deprived of an opportunity to emerge from their pre-Copernican world view.

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APPENDIX XXII

S.S.C.R. EVALUATION

Western Hemisphere

S | S SECONDARY SCIENCE
C | R CURRICULUM REVIEW

A General Framework for the Development of
the Products of a Curriculum Review

Gene R. Smith
and
John H. Brubaker

This paper is essentially an invitation to members of working groups and others around the country to participate in the evaluation of the products of the Review. By and large we envisage that for working groups this will take the form of trials at the level of participants' own classrooms (Empirical product evaluation). However, we recognise the advisability of evaluating products at a variety of other levels (Intrinsic product evaluation). This paper does several things. It proposes a basic framework which sets out the various levels at which product evaluation can take place. In addition it sets out who we envisage would assume responsibility for initiating and implementing product evaluation at these various levels. Then it summarises the suggestions put forward in the first two sections in the form of a flowchart of the idealized pattern of events.

Finally we feel it would be useful for working groups to know in advance the evaluative criteria which the Central Team will use in order to judge the eventual products of the Review in 1986. So the final section lists these criteria. This list might well be a useful tool in helping working groups to come to some view of the evaluative criteria against which they themselves might wish to judge the effectiveness of their own products in their own classrooms.

Four Technical Terms

Empirical Product Evaluation - evaluation carried out in participants' own classrooms (i.e. trials); addresses issues of feasibility; does the product achieve its aims in classrooms?

Intrinsic Product Evaluation - evaluation carried out away from classrooms ('armchair evaluation') addresses issues of desirability; are the aims of the product desirable?

Formative Evaluation - feeds back judgements in order to modify and improve a product.

Summative Evaluation - provides judgements upon a completed product.

A General Framework for the Evaluation of the Products of Local Working Groups

1. What is the basic framework within which working groups will evaluate their product?

Organisationally we are proposing a multi-level programme of product evaluation. This will involve as far as possible ALL working groups participating at Level [A]. In addition the products of some groups could also be evaluated at levels [B] or [C] or [D]. All products will again be evaluated at national level [E]. The levels we are proposing are:

Level [A] All products subject to empirical evaluation within and by working group

Level [B] Products of some working groups submitted for intrinsic evaluation between working groups

Level [C] Products of some working groups submitted for intrinsic evaluation at regional level

Level [D] Additionally some products can be submitted for intrinsic evaluation by external groups or agencies

Level [E] All products submitted for intrinsic evaluation at national level

Categories [A] to [C] above involve cross-evaluation within the Review and are hierarchical in conceptualisation. Category [D], however, can operate at any level, for example:

- [i] a local working group may wish to refer an examination and assessment scheme to an examination board for critical comment;
- [ii] a regional conference that has "shredded" a set of curriculum materials on applied science may wish to refer those proposals to a group of local industrialists for comment;

- [iii] a local working group may ask colleagues in a department of education to prepare a critique of their proposals prior to final writing up;
- [iv] the Central Team may refer a proposal for a core physics course to the Institute of Physics or the Royal Society for detailed scrutiny and comment;
- [v] a publisher may be asked to advise on the format and layout of a set of worksheets.

What we are suggesting in essence is that prior to our receipt of group products in 1986 (or indeed before then), we would wish them to have been exposed to some form of evaluation. This statement in turn carries with it the implication that some working groups should be prepared to send their product to others in the system (both inside and outside the Review) for their appraisal. By the same token another implication is that some working groups are likely to receive products from other groups within the Review, working on a similar topic or theme. Although this sort of activity is already occurring the momentum of this exchange of curriculum 'merchandise' around the system is likely to increase as 1986 approaches.

The ideal evaluative situation would be one in which the product of a working group could be subject to formal evaluation at three points from three different sources (i.e. a form of triangulation). These three evaluative points of the triangle would ideally be constituted from three of the levels already mentioned, that is

- [a] the working groups itself
- either { [b] another group working on a similar topic
- { [c] a regional grouping of participants
- { [d] a group with specialist expertise, within or outside the Review
- [e] the Central team

2. Who takes responsibility for initiating and implementing product evaluation at the various levels?

Level [A] - Empirical product evaluation by working groups themselves

It seems to us to be entirely within the philosophy of the Review that responsibility for initiating evaluative activity at this level should rest with working groups themselves. We

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suggest, however, that this is done in consultation with the Regional Project Leader, so that the fact that product evaluation is taking place can be recorded centrally.

Levels [B], [C] and [D] - Intrinsic product evaluation by others within and outside the Review

Because of their wider contacts it seems to us that Regional Project Leaders should take responsibility for initiating product evaluation at these levels; of course this would be done in consultation with groups which generated the material. Again it would be recorded centrally.

Level [E] - Intrinsic product evaluation at national level

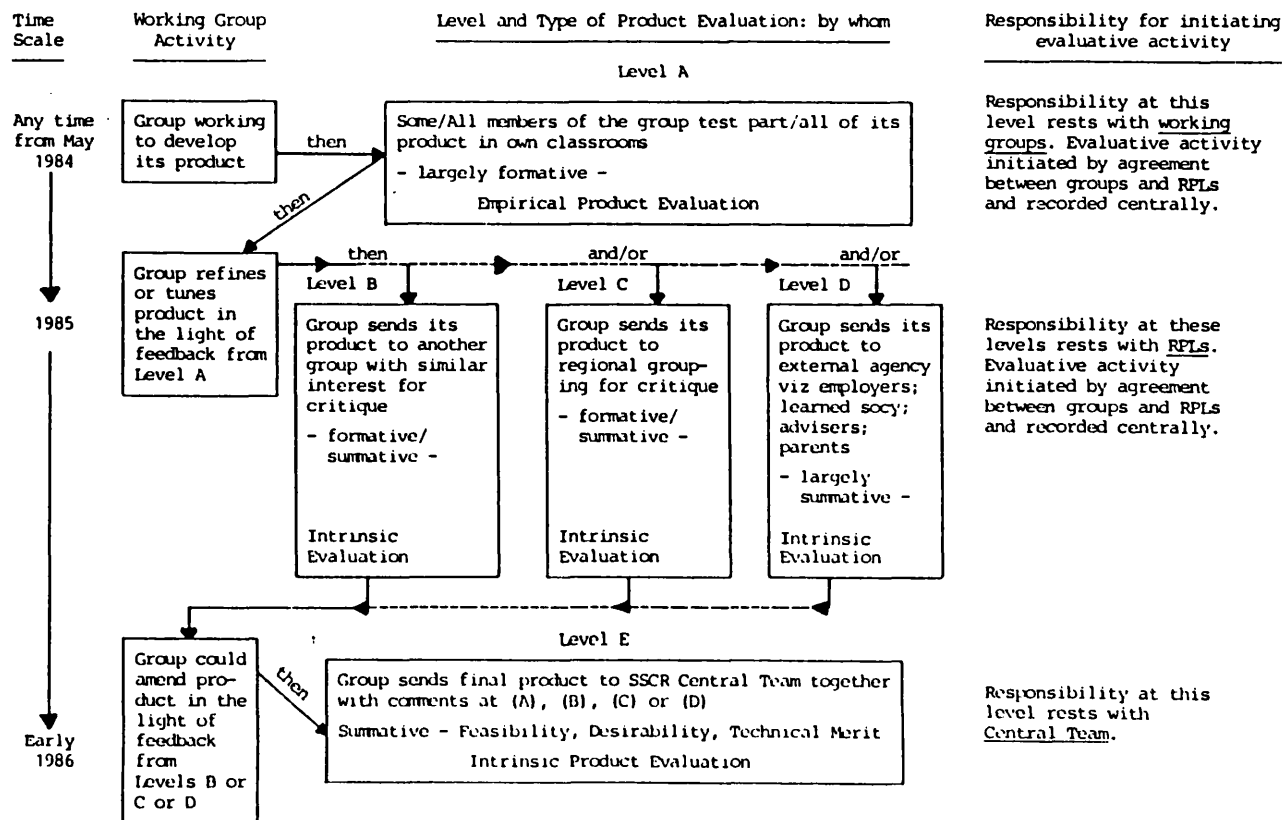
Responsibility for product evaluation at this level rests with the Central Team.


What criteria will the Central Team use in order to judge products in 1986?

Before we lay out the criteria which we will eventually use in 1986 we would like to make an important point. We do see the crucial importance of enabling and allowing each working group to generate and state its own criteria for both empirical and intrinsic evaluation. Within the general context of the evaluative criteria of the Central Team we feel that it is important that groups should stake out for themselves their own perceptions of what they have done, of what they have sought to achieve and the contextual constraints under which they have operated. This background we feel should be explicitly spelt out for any group called upon to critique a product, as should details such as who the writers are, why they have generated this product, what were their aims, how they feel about their work, who the intended audience is seen to be and how they see their product being used. We would expect that the working brief negotiated between the 'internal group' and the SSCR to be a useful tool in helping to decide the most appropriate criteria. What we feel we must avoid at all costs are situations in which products, from whatever source, are evaluated against unspecified or inappropriate criteria. Thus we feel that any 'external' agency that critiques a group product should

- [i] take note of the overall (and Central Team) criteria
- [ii] take note of the internal group criteria

FLOWCHART SUGGESTING IDEAL PRACTICAL STEPS IN THE EVALUATION OF THE PRODUCT OF A LOCAL WORKING GROUP



- 
- [iii] establish its own criteria
 - [iv] form a balanced judgement accordingly.

3. About the Criteria

Our initial response towards formulating criteria which we thought would be helpful at all levels [A to E] of product evaluation was to produce a rather free ranging set of criteria/questions. This list was organised under such obvious headings as 'criteria about aims of the product', 'criteria about the content of the product', etc.

However, when we discussed this list with several coordinators and convenors, they suggested that although they saw it to be helpful in thinking about the evaluation of product, they had two reservations. First, they felt that from the point of view of the Central Team there was probably an hierarchy of importance implicit in the list. Moreover they felt that if indeed this was the case, then working groups would need to know about it, and the Central Team ought to make the hierarchy explicit. Second, there was a suggestion that the original form in which we had framed the criteria - as questions - meant that technically speaking they were not criteria at all.

So we took the list back to the drawing board in order to attempt to derive those criteria which we (the Central Team) saw to be fundamental. In addition we recast each question as criterion against which some aspect of a product could be evaluated. We have included here both the first rather free wheeling list and the second hierarchical listing. We have done this because we feel that some groups may wish to select empirical or intrinsic criteria from the original list in order better to match their needs in judging the quality of their product. At the same time we have taken upon ourselves (at Level E) the task of evaluating the final product [taking into account product evaluation at preceding levels] and we wanted all involved in product evaluation to be aware of the criteria we will use to accomplish this task.



Overall Criteria for Product Evaluation

Criteria about the aims of the product

Is the product compatible with the broad aim of increasing educational opportunity?

Are the aims underpinning the product explicitly stated?

Are there aims implied which are not explicitly stated?

Is there congruence between the aims, teaching strategies, student tasks and content?

Is there conflict between the aims, teaching strategies, student tasks and content?

Are the aims congruent with alternative approaches to similar content currently found in schools?

Are the aims in conflict with alternative approaches to similar content currently found in schools?

Are the aims underpinning the product feasible to realise in practice?

Are these desirable aims?

How do the aims of the product meet the aims of the Review as spelled out in para 4.2 of Science Education 11-16.

Criteria about the content of the product

Does the content of the product reflect up-to-date thinking about the chosen topic area?

Is the content technically accurate?

Does the content require prior knowledge of the field by teachers?

Are teachers likely to have that knowledge?

Does the content require prior knowledge of the field by students?

Are pupils likely to have that prior knowledge?



Is the content as presented stimulating to teachers/students?

To what extent are methods of inquiry, forms of evidence and types of justification representative of the field of study?

What image of the subject area is explicitly communicated by the content?

What image of the subject area is implicitly communicated by the content?

Is the content feasible to teach in practice?

Is it desirable that this content should be taught?

Criteria about the audience for the product

Is the target audience for the product specified in terms of age?

Is the target audience for the product specified in terms of perceived ability?

Does the product meet the needs of the most able students?

Does the product meet the needs of the average student?

Does the product meet the needs of the less able student?

Does the product make any special provision or create specific problems for girls?

Does the product make any special provision to meet the needs of cultural minorities?

Does the product make any special provision for students with special needs?

Does the product implicitly or explicitly erect stereotypes?

Is there an appropriate match between the reading age of the intended audience and the product?

Is the product generalisable beyond the specified audience?

Is it feasible to use the product with the specified audience in practice?



Is it desirable to use the product with the specified audience?

Criteria about teaching and learning

Is there a specifically stated theory of learning within the product?

Is there an implied theory of learning within the product?

Is the way in which the product is organised compatible with that theory?

Does the way in which the product is organised reflect students' cognitive growth?

Is provision made for extension material for faster working students?

Is provision made for extension material for slower working students?

Are specific forms of classroom organisation explicitly recommended (group work, whole class teaching, individual learning)?

Are forms of classroom organisation implicit but unstated?

Are specific teaching strategies recommended?

Are teaching strategies consistent with aims, target audience, learning theories, classroom organisation?

Are the teaching strategies (explicit or implicit) feasible in practice?

Are the teaching strategies (explicit or implicit) desirable?

Criteria about presentation of the product

Is the media of communication appropriate for the intended audience?

Is the language level appropriate for the intended audience?

Are illustrations and diagrams clear and unambiguous?

Do the illustrations and diagrams convey the same image as the text?

Are student activities and tasks sufficiently varied?

Is provision made for specific extension tasks, e.g. homework/self directed study?

Is the terminology and/or symbol system common or esoteric: does it help or hinder understanding?

Is the product adequately sectioned, content listed, paginated, indexed?

Does the product allow teachers and learners to be flexible in their approach?

What explicit and implicit values can be detected via the presentation?

Is the mode of presentation consistent with the aims, learning theories and teaching strategies?

Is it feasible to use the product as presented, in practice?

Is it desirable to use the product as presented?

Criteria about student assessment

Do the recommended assessment procedures match the aims, content, teaching strategies?

Have the recommended assessment strategies adversely or restrictively dictated content or teaching strategies?

What criteria are recommended for marking students' work?

Are recommended assessment procedures largely formative/largely summative?

Are there adequate means of reporting assessments to students?

Are there adequate means of reporting assessments to wider audiences [e.g. parents, employers]?

Are assessment procedures consistent with the explicit/implicit learning theory?

Do assessment procedures purport to measure recognition, recall of knowledge, application of knowledge, conceptual understanding, development of skills and development of capability?

Is it feasible to use the recommended assessment procedures in practice?

Are the recommended assessment procedures desirable?

Criteria about resource implications/costs

Are the cost implications of implementing the curriculum package spelled out in terms of:-

Teacher numbers?

Teacher time?

Timetabling?

Facilities/equipment/printed resources/a.v.?

Cost per student?

Administration?

In service/retraining?

Are the resource implications feasible in practice?

Are the resource implications desirable?

4. The Criteria which the Central Team will use to Evaluate Product

In terms of organisation, the fundamental criterion appears on the left of each page: on the right hand side are those criteria which we feel amplify aspects of the fundamental criterion.

Criterion 1 is the criterion which pertains most directly to empirical evaluation at level [A] (within and by working groups). Criterion 2-4 are largely concerned with intrinsic evaluation at levels [B] and [E]. Of course criteria 2-4 ought to be helpful to working groups in terms of helping them structure and refine their product.



Criterion 1

The product must have been tested as feasible to implement in practice

The aims of the product ought as far as is possible to be tested in the classroom

The content ought as far as is possible to be tested in the classroom

The product ought as far as is possible to be tested in the classroom with the intended audience

The recommended teaching strategies ought as far as is possible to be tested in the classroom

The presentation of the product ought as far as is possible to be tested in the classroom

The recommended assessment procedures ought as far as is possible to be tested in the classroom

The recommended procedures for reporting assessments to others (parents, employers) ought as far as is possible to be tested

The feasibility of the product in the classroom in terms of teachers' prior knowledge ought as far as is possible to be tested

The resource implications of the product in classrooms ought as far as is possible to be tested



Criterion 2

The product must be compatible with the Central Team's view of increasing educational opportunity

There ought to be recommended assessment and reporting procedures included and, whether summative or formative, these ought to match the aims, content and teaching strategies

The product ought to identify the needs of and make special provision for enhancing the participation of girls

The product ought to be varied and stimulating to both teachers and students

The product ought to make special provision for the expression of cultural diversity

The product ought to make special provision for students with special needs

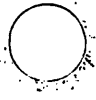
The product ought not (implicitly or explicitly) to erect undesirable stereotypes

The way in which the product is organised ought to facilitate students' cognitive growth

Provision ought to be made in the product for extending pupils up to and beyond some minimum entitlement

The product (including diagrams) ought to be appropriate, clear and unambiguous with respect to the intended audience

The language in the product ought to be accessible by the intended audience



Criterion 3

The product must be coherent in terms of internal structure and, externally, consistent with the aims as specified in Science Education 11-16. The approach to learning (that is either implicit or explicit in the product) must be consistent with the views of learning as articulated by the Central Team

The product aims ought to be explicitly stated

There ought to be congruence between aims, teaching strategies, student tasks, content and assessment procedures

Any recommended assessment procedures ought not adversely or restrictively to dictate teaching strategies or content

The product ought to be contingent upon and consistent with the prior knowledge of the learner

The audience for the product ought to be specified

The methods of classroom organisation and the teaching strategies envisaged for the product ought to be specified

Any illustrations ought to convey the same image as the text

The product ought to be sensibly edited in terms of adequate sectioning, content listing and pagination

Criterion 4

The product must reflect thinking about the chosen topic area

The Product ought to be technically accurate

The methods of inquiry, forms of evidence and types of justification ought to be representative of the field of study

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APPENDIX XXIII

QUESTIONNAIRE TO AMATEUR
ASTRONOMICAL SOCIETIES

University of Bath

Claverton Down
Bath BA2 7AY

Secretary and Registrar
R M Mawditt

Tel: (0225) 61244
Telex 449097

Senior Assistant Registrar
G G O'Brien

BAXTER. School of Education. University of Bath

1987

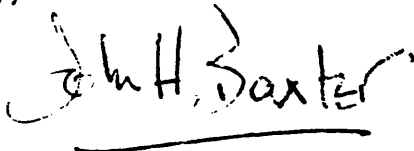
Dear Sir/Madam,

At Bath University we are researching into the role of astronomy in the school science curriculum.

We are particularly interested in the part amateur astronomical groups may play in promoting astronomy education, and will be most grateful if you will complete and return the enclosed questionnaire.

Many thanks in anticipation of your help.

Yours sincerely,



John H. Baxter

JOHN H. BAXTER.

Encl: 1 questionnaire
1 S.A.E.

4. Do you have any members who would be willing to assist schools in respect of astronomy education?

YES



In what way do you consider you can help?

NO



Is there any particular reason why not?

5. Do you consider basic astronomy should feature in the school science curriculum?

YES



Why should it be included?

NO



Why should it not be included?

6. How do you rate the average persons knowledge of basic astronomy?

EXCELLENT	
GOOD	
FAIR	
POOR	
ALMOST NIL	

7. In your opinion, how can the general public be made more aware of basic astronomy?

Thank you for completing this questionnaire. Please tick the box below if you wish to be notified of our findings.