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Learners' conceptions about astronomical concepts related to the sun and the earth

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CHAPTER 4

RESULTS ANALYSIS

This chapter gives an item-by-item analysis of results obtained from the questionnaires. The first part (section 4.1) gives results obtained from the pilot study while the second part (section 4.2) gives a detailed analysis of learners' responses from the main study.

4.1. PILOT RESULTS[*]

This section gives a general view of responses given by learners during the pilot study. Forty one learners answered the diagnostic questionnaire at this stage.

4.1.1. Question 1: Date of the December Solstice

Learners could not predict the date of the location shown in the diagram. Most of them (37%) chose dates in June, ranging from the 1st to the 31st, some giving days, *e.g.* Monday and Sunday. Some reasons given for the predictions were, among others, that June is the middle of the year, June is winter, and that the Sun travels in the sky. Others (24%) chose some dates in September; the most common reason being that the Sun gets back to make spring, or that it is the beginning of summer. The rest chose dates in February, March and May, with only two choosing dates in December (25th and 31st).

Very few (10%) gave the correct angle of the Sun's rays at noon at location C, *i.e.* 90^{o}. They however gave unscientific reasons for their choice, *e.g.* the Moon is almost full, and the Sun is on the equator at noon. The rest chose other angles *i.e.* 50^{o} (27%), 30^{o} (22%) and 75^{o} (12%). Several reasons were given: Sun rays are received by the equator; C is lower than the equator; Sun rises from the east/north, *etc.*

[*] Refer to Appendix 1 for the questionnaire

4.1.2. Question 2: Alignment of the Earth and the Sun during Equinoxes

Learners could not draw a scientifically acceptable alignment of the Earth and the Sun during equinoxes. Twenty one percent drew a circle without labels, with a vertical line drawn down the centre to divide the circle into 2 semi-circles, with lines of latitude shown in some diagrams. The Sun is not shown by these learners. Seventeen percent drew diagrams similar to the ones just explained, but shaded half of the diagram. In many diagrams, the shaded part is labeled night, the un-shaded part day. These diagrams too do not show the Sun. Fifteen percent of learners drew the Sun in a position above the equator as shown in Figure 4.1 below. One learner drew the Moon, slightly larger than the Sun, on the opposite side of the Sun.

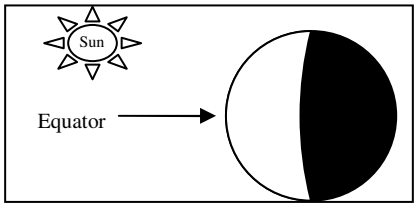


FIGURE 4.1: Earth-Sun relationship during equinoxes (model 1)

Only ten percent of learners drew the Earth with the Sun overhead the equator at noon as shown in Figure 4.2 below. The axis of the Earth is not tilted in these diagrams.

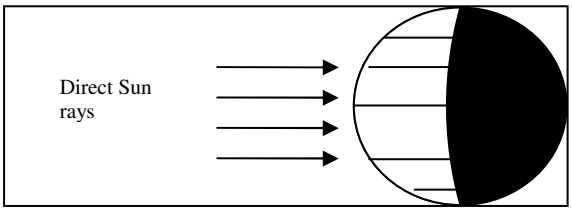


FIGURE 4.2: Earth-Sun relationship during equinoxes (model 2)

4.1.3. Question 3: Temperature Difference Between Summer and Winter

Several explanations were given as to why summer is hotter than winter in a given place. Twenty seven percent of responses implied that summer is meant to be hot while winter is meant to be cold. Forty one percent of learners related seasonal change to physical features of the Sun, *e.g.* the Sun is hotter in summer than in winter, summer Sun is hotter than winter Sun, the Sun is further away in winter than in summer, and that there is no Sun in winter while there is more Sun in summer. These responses are similar to those reported in the literature, *e.g.* the distance model (2.2.3), uneven radiation of the Sun (2.2.5.), and different heating capacities of the Sun (2.2.6), as reported in chapter 2.

Seventeen percent of learners related seasonal change to geographical features around the place, *e.g.* altitude, absence of seas, presence of firms and trees, and geographical location: being near a hot province. Ten percent related seasonal change to weather: Moon produces snow in winter, there is more rain in winter, there is a lot of cold wind in winter, the sky is blue in summer, and that the Sun is closed by clouds in winter. Other learners related seasonal change to the rising of the Sun, *e.g.* the rising direction (NE and East), and the time of Sun rise, *e.g.* the Sun rises earlier in summer than in winter.

4.1.4. Question 4: Overhead Sun at Noon

Learners were unable to state that the Sun is never (directly) overhead at noon in Benoni, a place located south of the tropic of Capricorn. Thirty two percent gave a season in which the Sun is overhead: summer or winter while twenty seven percent gave months: September, July and January. Thirty three percent gave a time of day as a response (despite a clue given in the question that the Sun would be overhead at noon), *e.g.* 6 pm, 1 o'clock and 5 o'clock.

4.1.5. Question 5: Daily Movement of the Sun

Only 22% of learners gave a scientifically acceptable explanation of the cause of day and night, *i.e.* the spinning of the Earth on its axis. Other responses showed that learners had some organistic worldviews. For example 51% of learners said that the Sun moves and disappears to cause day and night. Examples of learners' responses are: "*it disappears here to shine in another place*", "*it disappears underground to become the Moon*" and

"*it disappears in the clouds at night*". Twelve percent of learners said that the Sun moves to fulfill the needs of humans, *e.g.* to allow humans to sleep and to work. Other learners (15%) gave naïve responses, *e.g.* time (or God) causes day and night. This response is similar to one found by Fleer (1997) who studied four-to-eight year olds in Australia. Mechanistic worldviews were not found in this question.

4.1.6. Question 6: The Moon during the Day

Only 10% of learners said that the Moon can be seen during the day. Sixty nine percent said that the Moon cannot be seen during the day: 37% said that the Moon does not appear during the day, 10% said that the Moon remains in the dark, 10% said that the Moon is covered (by clouds or the Sun), and 12% said that the Moon changes size, *i.e.* it becomes smaller. Most of the responses showed that learners had an organistic worldview, *e.g.* "*the Moon stands firmly in the dark*", while others showed that learners had a mechanistic worldview, *e.g.* "*the Moon cannot be seen because of powerful light of the Sun*".

4.1.7. Question 7: The Cause of the Leap Years

Learners could not give a scientifically acceptable explanation for the cause of seasons. Forty four percent of learners said that the extra day in the fourth year is caused by the leap year, but they did not explain how this happens. Twenty nine percent said that an extra day has to be added once after forty four years, and they also did not explain why this happens. Seventeen percent of learners gave other scientifically unacceptable reasons, *e.g.* Moon eclipses cause this extra day.

4.1.8. Question 8: The Cause of Different Seasons in the two Hemispheres

Two percent of learners used the wobbling Earth model (discussed in section 2.2.4) to answer this question. They said that the Earth's axis turns towards the Sun in summer and away from the Sun in winter. Fourteen percent of learners said that weather elements are responsible for different seasons in the two hemispheres, *e.g.* rain, dryness and snow. Twenty percent said that the southern hemisphere is nearer to the Sun, and receives more radiation than the northern hemisphere. Fourteen percent of learners said that the two

hemispheres have to experience different seasons because they are different, *e.g.* one being higher than the other. Other (irrelevant) responses, given by 22% of learners are that: people need different temperatures, the Earth is round, the "*world needs different economic status*", and that rotation of the Earth causes different seasons in the two hemispheres.

4.1.9. Question 9: The Change in the Position of Sunrise from Season to Season

Learners were unable to describe how the rising and setting points of the Sun change from one solstice to another, *i.e.* they could not state that sunrise moves towards the South after the June solstice and moves towards the North after the December solstice. Fifteen percent described how time changes for sunrise and sunset, *e.g.* Sun rises early in summer and sets later than in winter, and that seasons change from time to time. Another 15% described temperature change from one solstice to another, *e.g.* winter is colder than summer. Ten percent mentioned direction, but gave scientifically unacceptable responses, *e.g.* the Sun rises from the west and sets in the east, it rises from the north and sets in the south, and that it "*goes with weather to different directions*". Thirty nine percent of learners did not respond to this question.

4.1.10. Question 10: Changing the Tilt of the Earth's Axis

For question 10a, only 12% of learners said that seasons would not change if the Earth's axis were not tilted. Twenty percent said that temperatures would be either too high or too low, but they did not give further explanation. Seven percent of learners said that seasons would change every day, or that they would be as they are today. About half of the learners did not answer this question.

For question 10b, none of the learners stated that the Earth would receive the same amount of heat energy from the Sun. Forty one percent suggested places that would be hottest, *e.g.* northern hemisphere and Africa. Other alternative responses are that the west direction would be hottest (7% of learners), and that there would be no sunrise and

sunset (5% of learners). Seven percent said that the equator would be the hottest part of the Earth. Fifty one percent of the learners did not answer this question.

As discussed in section 3.3.6, the questionnaire was modified and then administered to the main study group, made up of 60 learners in two classrooms, and gave the following results.

*4.2. MAIN STUDY RESULTS**

This section gives analysis of results obtained from the main study. The analysis indicates the learners that gave each response.

4.2.1. Question 1: Apparent Daily Movement of the Sun

Only 9 learners said that the Sun seems to move because of the Earth's movement. The rest gave other responses, *e.g.* movement of the Sun, and response to human and other needs. The following discussion shows the responses given by learners.

Movement of the Earth: Learners 5, 8, 16, 19, 28, 30, 45, 48 & 57.

These learners said that the Sun seems to move because of the Earth's movement. Five of them did not describe this movement, but just said that the Earth moves, as Learner 16 stated that "*… when we look at the Sun we see that the Sun move, no the Sun is not move the thing that move is the Earth and when it moves, it moves slowly*". The other four learners described the Earth's movement as rotation, as Learner 30 stated that the "*Sun doesn't move its just the rotation of the Earth*". None of these learners mentioned the Earth's axis.

* Refer to Appendix 2 for the questionnaire

Movement of the Earth and the Sun: Learners 17, 18, 29, 34 & 58.

These learners gave responses that imply that both the Sun and the Earth move. A typical example of these responses is that "… *the world moves round and round and the Sun moves to other places to give light*" (Learner 58).

Movement of the Sun: Learners 9, 11, 22, 23 & 46.

The responses given by these learners imply that the Sun actually moves. A typical example of these responses is that "*each and everyone knows that the Sun rise in the east and travels across the sky to the overseas*" (Learner 11). This response is almost similar to the responses given by some eight-and-eleven year olds studied by Sharp (1996) and some prospective teachers studied by Parker and Heywood (1998), who said that the Earth is stationary, and that the Sun revolves around the Earth to make day and night (discussed in section 2.1.5).

Shape of the Earth/Sun: Learners 26, 7 & 55.

These learners stated that either the shape of the Earth or the shape of the Sun is responsible for the apparent motion of the Sun, *e.g.* "*because the Sun is like the ball*" (Learner 55).

Time has to change: Learners 1, 3, 6, 12, 13, 20, 21, 25, 35, 36 & 53.

These learners said that the Sun moves to show different times of day, *e.g.* morning and afternoon, and day and night. A typical response is one given by Learner 21, who said that "*the Sun move in the sky each day for separation of days*".

Response to human and other needs

The responses given by learners in this category show an organistic worldview, *i.e.* they believe that the Sun moves to fulfill certain needs/purposes, as organisms usually do. The following discussion outlines these needs.

To give light: Learners 10, 37, 38, 39, 40, 41, 42, 51, 59 & 60.

These learners said that the Sun moves in the sky to give light energy on Earth because humans do not need complete darkness. An example of these responses is that "*the Sun seems to move in the sky each day so that it gives light to Earth. If there was no Sun the Earth would be dark*" (Learner 60).

To allow people to rest: Learners 24, 27, 31, 32, 49 & 50.

Responses given by these learners imply that the Sun appears and then disappears to allow humans to rest and sleep. Learner 31 stated that "*we need night so that we can make our mind rest, that is why the Sun move in the sky each day, from East to West*".

To shine in other places: Learners 47, 52 & 54.

These learners said that the Sun moves in the sky to shine in other places because other people need to experience day and night. A typical response given by Learner 54 is that "*because we are in South Africa and is monning in another country is night, and all of us need the Sun. We are supposed to share it*".

To provide plants with light: Learners 14 & 15.

These learners stated that during the day plants need the Sun for photosynthesis. Learner 14 stated that "…*we need Sun during the day so dat the plants can photosynthesize from the Sun…*"

These animate conceptions are similar to conceptions given by four-to-eight year olds studied by Fleer (1997) in Australia, eight and eleven year olds studied by Sharp (1996) in the U.K., and secondary students studied by Bakas & Mikropolous (2003) in Greece (discussed in section 2.1.3).

Unclear responses: Learners 2, 33, 44 & 56.

These learners gave responses that do not make sense, *e.g.* "*the Sun's rays to move in the sky each day because the Earth will be the Sun seems to move in the sky each day. The people have look the Sun each day*" (Learner 56).

Learners 4 & 43 did not respond to the question.

General overview: The majority of learners believe that the Sun actually moves in the sky, and/or that it moves to fulfill certain human needs. Very few gave a scientifically acceptable response.

4.2.2. Question 2: Temperature Difference between Summer and Winter

Only four learners gave scientifically acceptable responses to this question, *i.e.* that summer is hot because of more direct Sun's rays and a longer duration of day time, and that winter is cold because of less direct Sun's rays and a shorter duration of day time. The rest said that changes in the features of the Sun, and in the weather, are responsible for this temperature difference. Learners' ideas are discussed below.

Scientific ideas: Learners 5, 6, 19 & 59.

Three of these learners (5, 6 & 59) said that summer is hotter than winter because days are longer in summer than in winter, while Learner 19 said that summer is hotter because "*in winter the Sun rays indirectly and in summer it rays directly*".

Changing features of the Sun

Learners in this category said that summer is hotter than winter because the Sun radiates less energy in winter, moves away from the Earth or disappears in winter. The following discussion gives details of these ideas.

Changing distances between the Earth and the Sun: Learners 16, 18, 21, 26 & 28.

Responses given by these learners imply that the Sun moves closer to the Earth in summer and further away in winter. An example of these responses is one given by Learner 18, who said that "… *the Sun in winter is very far away … but in summer the Sun is too hot because of the Sun are near in the ground*". This conception was also

found by Parker and Heywood (1998) who studied pre-service and in-service training teachers in the U.K (Discussed in section 2.2.3). The response does not explain why the southern hemisphere has winter when the northern hemisphere has summer, but as is to be seen in question 7, many learners from this study do not know why the southern hemisphere has summer when the northern hemisphere has winter.

The Sun radiates more energy in summer: Learners 35, 48, 49, 50, 53, 57, 58 & 60.
These learners said that summer is hotter than winter because the Sun radiates more energy in summer than winter. An example of these responses is that "… *the Sun in summer is very hot and the Sun in winter is very cold*" (Learner 53). This conception was also given by the ten and eleven year olds studied by Sharp (1996) in the U.K (discussed in section 2.2.6).

No Sun in winter: Learners 12, 25 & 55.
A common response given by these learners is that summer is hotter than winter because there is Sun in summer and no Sun in winter, as stated by Learner 12: "… *because in winter there is no Sun but in summer there is Sun*". A more elaborate response would help to clarify what learners mean when they say there is no Sun in winter.

Plants grow in summer: Learners 7, 8, 13, 14, 22, 31, 33 & 54.
These learners stated that summer is hot because it is a growing season, *i.e.* it is time for plantation. An example of these responses is that summer "*is a period whereby things happen, example grown of fruits & vegetables and it is a good season for plantation, winter is a season whereby plantations don't take place*" (Learner 7). These learners have given the effect of summer, *i.e.* growing season, not the cause of high temperature in summer.

Change in weather conditions:
Learners in this category mentioned weather elements, *e.g.* wind, temperature, rainfall, clouds and snow as causes of different temperatures in summer and winter. The following discussion elaborates on this conception.

Effect of temperature: Learners 15, 20 & 51.

These learners said that temperature is constant in summer (always hot), and that temperature changes in winter. A typical response is that "*summer is hotter than winter because winter is always cold and the weather is always changing maybe after 5 minutes* (while) *summer is always hot even if it is raining…*"(Learner 51).

Effect of rainfall: Learners 1, 4, 10, 11, 23, 27, 30, 32, 36, 38, 42, 45, 52 & 56.

These learners gave responses that imply that summer is hotter than winter because there is more rain in summer and no rain in winter. An example of these responses is that "*summer is hotter than winter because of the lot of rain therefore the hot of the Sun must make the land hot*" (Learner 32). Learner 4 has used diagrams to describe this. The winter diagram shows the Sun, trees and clouds, while the summer diagram shows the Sun, land and rain falling from clouds.

Effect of wind: Learners 24, 29 & 34.

These learners said that summer is hotter than winter because there is more cold wind in winter than in summer. An example of these responses is given by Learner 29: "*winter there is lot of wind and we feel cold so in summer it is hot and winter there is wind*".

Effect of clouds and snow: Learners 17, 41, 46 & 47.

These learners attributed temperature difference between summer and winter to clouds and snow. They said that there are more clouds and snow in winter than in summer. A typical example of these responses was given by Learner 41: "… *in winter there is too much rain and snow, and the wind mix up with the coldness of the snow and become very cold*".

Incomplete responses: Learners 37, 39 & 40.

These learners stated that summer is hotter than winter because of weather change, but gave no further explanation.

Unclear responses: Learners 2, 3, 9, 43 & 44.

These learners gave responses that do not make sense, and could not be coded.

General overview: Very few learners have a scientifically acceptable explanation of the temperature difference between summer and winter. The majority believe that summer is hotter than winter because of a change in features of the sun, or because of a change in weather conditions.

4.2.3. Question 3: Alignment of the Earth and the Sun during Equinoxes

Learners were divided into four categories according to their responses. Only the learners in category 1 drew both the Earth and the Sun during the equinox. This category is divided into three conceptions. Only two learners, in conception 1, have drawn a diagram that shows a scientifically acceptable alignment of the Sun and the Earth during equinoxes, *i.e.* the Sun being overhead at the equator at noon. Learners in the other three categories did not answer the question properly, as they drew either the Sun only or the Earth only, or did not answer the question at all.

Category 1: Learners in this category drew both the Earth and the Sun, showing three different conceptions.

Conception 1: Learners 22 and 26.

The diagrams made by these learners show the Sun overhead at the equator, as shown in Figure 4.3.

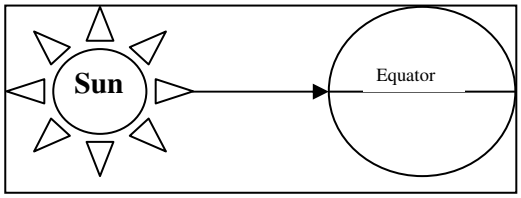


FIGURE 4.3: Earth-sun relationship during equinoxes (model 3)[*]

Conception 2: Learners 21, 55 & 56.

The diagrams drawn by these learners show the Sun's rays overhead the tropic of cancer, as shown by Figure 4.4.

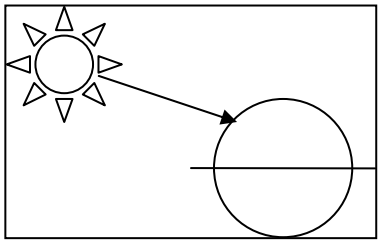


FIGURE 4.4: Earth-sun relationship during equinoxes (model 4)

Conception 3: Learners 7, 8, 24, 32 & 47.

These learners have drawn the Sun shining on a flat Earth as shown in Figure 4.5, with some written explanations like "*when it is spring time the Sun equilibrium takes place … night will occupy 12H00 long and day will occupy 12H00 long which is approximately 24H00 long*" (Learner 8).

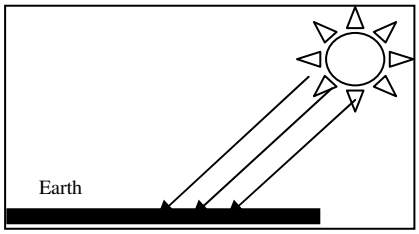


FIGURE 4.5: Earth-sun relationship during equinoxes (model 5)

[*] Reminder: Models 1 and 2 are on page 40

Category 2: Learners 5, 6, 20, 31, 34, 46, 49, 50 & 54.

These learners drew the Sun only, in some cases, showing daily movement of the Sun from East to West, as shown in Figure 4.6.

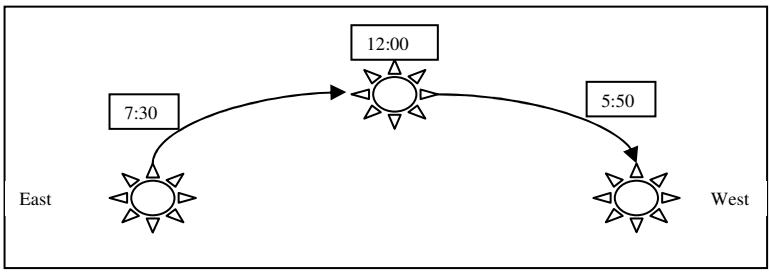


FIGURE 4.6: Earth-sun relationship during equinoxes (model 6)

(Redrawn from learners 31 & 54)

Category 3: Learners 1, 2, 9, 10, 16, 19, 30, 53, 57, 59 & 60.

These learners have drawn the spherical Earth, with some lines of latitude labeled in most diagrams, as shown in the following diagram.

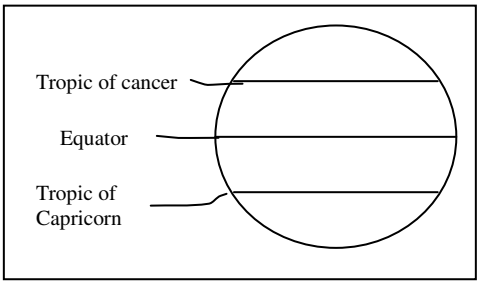


FIGURE 4.7: Earth-sun relationship during equinoxes (model 7)

Category 4: Learners 14, 17, 23, 27, 29, 33, 35, 36, 37, 38, 39, 40, 41, 42, 48, 51 & 52.

These learners made diagrams that are not relevant to the question *e.g.* circles and semicircles.

Learners 3, 4, 11, 12, 13, 15, 18, 25, 28, 43, 44, 45 & 58 did not answer the question.

General overview: A large number of learners did not answer the question, or did not seem to understand the question as they produced irrelevant diagrams. The Earth-Sun relationship during equinoxes was described by a number of alternative non-scientific models

4.2.4. Question 4: Date of the December Solstice

Learners were not able to state that the date shown in the diagram is 21st December, the date for the December solstice. They said the diagram shows dates ranging from January to December. Most of them could not state that the angle of the Sun's rays in location C at noon is 90°. The following discussion shows the number of learners who chose each month, and the corresponding angle.

January and February: Learners 5, 17, 53 & 56.

Reasons given for choosing these months show that learners did not interpret the diagram as showing the December solstice. Examples of these reasons are that "*January is the summer of the locations A to E, summer is very hot*" (Learner 56) and that "*there are no long days in February*" (Learner 5). Learners 56 and 17 said that the angle of the Sun's rays at location C is 50° while learners 5 and 53 said the angle of the Sun's rays at location C is 70°. These learners did not explain their responses.

June and July: Learners 3, 6, 7, 8, 22, 27 & 54.

The reasons given by these learners imply that the diagram shows a cold season, *e.g.* Learner 3: "*because that time is very cold*". Only learners 3, 8 and 22 chose the correct angle of the Sun's rays at location C, *i.e.* 90°, giving reasons like "*because the Sun rays penetrate direct into location C*" (Learner 8). The other four learners said that the angle of the Sun's rays at location C is 50°, giving responses like "*the Sun is very hot*" (Learner 7). Learners in this category seem to be confused, because they said that the diagram shows a cold season, but they say that the angle of the Sun's rays makes the place very hot.

August: Learners 1, 12 & 30.

These learners said that the diagram shows August, because winter ends and summer starts in August. Learners 1 and 12 said that the angle of the Sun's rays at location C is 90^{o}, but gave irrelevant explanations like "*diagram 4 is the biggest*" (Learner 1). Learner 30 did not state the angle of the Sun's rays in location C.

September

This month has been chosen by the largest number of learners, most stating that the date shown in the diagram is the 1st September because it is S*pring Day* and temperatures are expected to rise. These learners gave this response possibly because they answered the questionnaire on the 1st September, a day that was celebrated in their school as S*pring Day*. The following discussion shows learners who said each diagram shows the angle of the Sun's rays in location C at noon.

Diagram 1: Learners 26, 28, 31, 33, 37 & 38.

These learners said that the angle of the Sun's rays in location C is 30^{o}, and gave reasons that show that they do not understand that the diagram shows the December solstice. An example of their responses is "… *because the Sun rises from east to west*" (Learner 31).

Diagram 2: Learners 19, 32, 35, 36, 42, 55, 57, 58, & 60.

These learners said that the angle of the Sun's rays at noon in location C is 50^{o}. Some reasons imply that 50^{o} makes the Sun hot, for example, "*the Sun ray's exactly 50^{o} at the location C and meaning that is very hot during afternoon*" (Learner 32). Other responses are either unclear or irrelevant to the question, *e.g.* "*because the diagram 2 it shows me 50^{o} of the Sun rays*" (Learner 35).

Diagram 3: Learner 20.

This learner said that the angle of the Sun's rays at location C at noon is 70^{o} "*because of tropic of Capricorn … morning, afternoon and evening Sun ray are pointing the Capricorn diagram*". It sounds like the learner tries to say that the Sun's rays are on the tropic of Capricorn throughout the day, which would be a correct reason for 90^{o} not 70^{o}.

Diagram 4: Learners 9, 10, 13, 14, 15, 21, 29, 34, 39, 40, 41, 43, 47, 48, 51, 52 & 59.
These learners said that the angle of the Sun's rays in location C at noon is 90^{o}. They gave many scientifically unacceptable reasons for their choice, *e.g.* "*the Sun is very hot*" (Learner 13), "*the Sun is always full not half, no matter what it will always be full at 90º*" (Learner 39), and "*the Sun stand straight up* (and) *your shadow stands with you*" (Learner 41).

Learners 2, 23, 24, 44, 45, & 49 said that the date shown in the diagram is in September, but did not state the angle of the Sun's rays at location C.

December: Learners 11, 16 & 46.
These learners said that the diagram shows the 1^{st}, or the 5^{th} of December. Their reasons show that they do not associate the diagram with the December solstice. Their reasons are scientifically unacceptable, *e.g.* "*the Sun is very hot and all things happen in December*" (Learner 16). Learners 11 and 46 said that the angle of the Sun's ray in location C is 30^{o} while Learner 16 said that the angle of the Sun's rays in location C is 70^{o} "*because at this time the Sun rays are very strong*".

Learners 4, 18, 25 & 50 did not answer this question.

General overview: Learners do not know that the sun is overhead the tropic of Capricorn during the December solstice. Also, learners are not aware that during the December solstice, the angle of the sun's rays at the tropic of Capricorn is 90^{o}. Responses found in questions 3 and 4 show that learners do not understand the Earth-Sun relationship during equinoxes and solstices. Again the interpretation of diagrams seems to be a major problem for many learners.

4.2.5. Question 5: The Cause of the Leap Years

Only one learner gave a scientifically acceptable explanation for the cause of leap years. The rest gave many explanations that are scientifically unacceptable, *i.e.* God or humans cause leap years. The following discussion shows the explanations given.

Scientific Explanation: Learner 18.

This learner had an idea of a ¼-day that is not counted in each of the 3 years that have 365 days. Learner 18 stated that "*February were end by 28 days in these days we call ¼ days. It's because we add all those … ¼ day which is make a one full day in next year we get a leap year*". This learner is aware that a quarter of a day remains each year, but does not relate this to revolution of the Earth around the Sun.

Rotation of the Earth: Learners 4, 21 & 22.

These learners said that a leap year is caused by the rotation of the Earth throughout the year, *e.g.* "*it is because of the rotation of the Earth that rotates in a full year*" (Learner 22). The learners do not explain how rotation results in one extra day after four years.

Other causes: Learners 14, 23, 41, 39, 40 46 & 51.

These learners said that calendars, days, months, the year, and movement of special objects such as the Moon and the Sun cause leap years. These learners did not explain how this happens, except Learner 46 who said that "*every four years the must be a leap year the Sun and the Moon get together every four years*" (Learner 46). These learners believe that a combination of factors mentioned above causes leap years. This shows that they have a holistic worldview, ("the whole is greater than the sum of its parts"), *i.e.* they believe that many special objects cause leap years, in contrast to a mechanistic worldview that breaks wholes into parts.

Anthropomorphic causes: Learners 6, 12, 13, 26, 27, 32, 34, 35, 36 & 49.

These learners gave responses that imply that humans, animals and God cause a leap year. Examples of these responses are "*maybe its because of the Olympic games because Olympic games come after four years*" (Learner 26), "*because the elephant get*

their birth only after four years, … that's why the day are more once a leap year" (Learner 35), and "*because it makes by God means its naturally the order said so when we were born*" (Learner 34). These responses also show that some learners have undergone collateral learning, *i.e.* learning scientific concepts alongside their traditional beliefs (Jegede, 1995). One of these traditional beliefs is that elephants give birth only in leap years.

A leap year comes once in four years: Learners 5, 7, 8, 9, 10, 11, 16, 17, 19, 20, 24, 28, 29, 30, 31, 33, 37, 42, 44, 47, 48, 50, 52, 53, 55, 56, 57, 58 & 60.

These learners have not explained the cause of a leap year; they have only repeated information given in the question, *i.e.* saying that a leap year comes after four years when February has 29 days. Examples of responses are: "*the year 2004 is a leap year with 366 day … because years are not equal and seasons are not the same and the month and the day are not the same*" (Learner 55), and "*because February end the day 28 but this year end 29 February that is why days are longer or days are 366*" (Learner 20). These responses show that the learners do not understand the Earth's revolution as the cause of leap years.

Unclear responses: Learners 3, 54 &59.

These learners gave responses that are not clear, *e.g.* "*I think is a same thing that was done in the past year, that in the four years the leap will be decreasing*" (Learner 54). These responses show that the learners do not have a scientifically acceptable explanation of the cause of leap years.

Learners 1, 2, 15, 25, 38 43 & 45 did not respond to this question.

General Overview: Most learners repeated information provided in the question, and did not explain the cause of leap years. The responses show that the learners do not relate the cause of leap years to the Earth's revolution around the Sun. It emphasizes that many learners do not understand the Earth's movements, because in question 1 the majority did not attribute the cause of day and night to rotation of the Earth.

4.2.6. Question 6: Overhead Sun at Noon

Learners were not all aware that the Sun in never overhead at noon in the location specified in the question. They said that the Sun is overhead in the place in a certain season, in a certain month, or at a certain time of day. The following discussion shows the number of learners who gave each response.

Seasons: Learners 4, 8, 17, 18, 27, 41, 42, 55, 57, 59 & 60.

Learner 18 said that Benoni gets overhead Sun at noon in spring because summer is approaching. This response might have been influenced by the *Spring Day* that was celebrated on the day that learners answered the diagnostic questionnaire. Learner 60 said that "*in winter the Sun seems to be directly above our heads and no shadows are formed because there is no much Sun*". This learner seems to think that shadows are not formed when light energy from the Sun is not intense.

The rest said that Benoni gets overhead Sun at noon in summer. Learners 41, 42, 55 & 59 said this happens because the Sun is very hot in summer. This response shows that these learners do not understand the meaning of *overhead Sun*, because it is not necessarily related to high temperature. Learners 4, 8, 17, 27 and 57 said that Benoni gets overhead Sun in summer because the Sun's rays make an angle of 90^{o} at this place. This response shows that the learners understand the concept *overhead Sun,* although they are not aware that the Sun is never overhead in Benoni. Only one learner (Learner 4) seemed to be confused, because he said the Sun is overhead at the place in summer, but drew a diagram which shows the Sun causing a shadow from a tree.

Months

Learners in this category said that the Sun is overhead in certain months of the year. The following discussion shows the months chosen by these learners.

September: Learners 9, 29, 31, 33, 35, 36 & 54.

These learners said that the Sun is overhead in September because summer starts in this month. This response is related to the response given for question 4, which shows that learners gave this response because they answered the questionnaire on *Spring Day*.

November, December & January: Learners 7, 11, 12, 20, 24, 26, 32 & 46.

These learners said that the Sun is overhead at noon in either of these months because the months experience high temperatures. This reason is similar to that given by learners who said that the Sun is overhead in summer. This shows that these learners relate overhead Sun to high temperature.

Other months: Learners 6 & 19.

Learners 6 said that Benoni gets overhead Sun in April, but did not explain this response. Learner 19 said that Benoni gets overhead Sun in February because this month has high temperatures, a reason given for choosing summer months.

Time of day: Learners 10, 16, 14, 21, 22, 23, 34, 37, 38, 39, 40, 48, 49, 50, 51, 56 & 58.

These learners mentioned the time of day at which the place experiences overhead Sun. Their responses are: 9:00, 12:00, 12:30, 2:00, 5:00, and afternoon. It seems that these learners did not understand the question, because the question explicitly states noon as the time for overhead Sun.

Other responses: Learners 1, 15, 28, 44, 47, 52 & 53.

These learners gave responses that are either not clear or irrelevant to the question. Examples of these responses are "*because that time the Sun was not seen directly, if you see the Sun directly your eye can be damaged*" (Learner 1) and "*they are happens after*

four years directly above our heads" (Learner 53). These responses show that the learners do not understand the concept of overhead Sun.

Learners 2, 3, 5, 13, 25, 30, 43 & 45 did not respond to this question.

General overview: Learners are not aware that the sun is never overhead in Benoni, a place located south of the tropic of Capricorn. This agrees with a conclusion made in section 4.2.4, that learners do not understand the Earth-Sun relationship. Another possible conclusion is that learners do not understand the concept *Overhead Sun*, as most related overhead Sun to high temperatures (as if high temperatures imply overhead Sun).

4.2.7. Question 7: The Cause of Different Seasons in the two Hemispheres

No learners gave a scientifically acceptable explanation as to why the southern hemisphere experiences summer when the northern hemisphere experiences winter, *i.e.* they could not state that the southern hemisphere receives more direct Sun's rays when the northern hemisphere receives the Sun's rays at a less direct angle because of the Earth's tilted axis. Only six learners mentioned movement of the Earth in their responses. The rest gave responses that imply that the two hemispheres are different. The following discussion shows the responses given by learners.

Rotation of the Earth: Learners 5, 16, 19, 29, 38 & 46.

These learners said that the rotation of the Earth causes seasons, as shown by the following responses: "*the Earth turn to southern hemisphere to summer it leave northern hemisphere in winter*" (Learner 16), and "*the southern hemisphere has summer cause it rotate from one place to another while the northern hemisphere has winter...*" (Learner 29). These responses show that the learners understand that the movement of the Earth causes seasons, although they have a scientifically unacceptable understanding, *i.e.* using rotation instead of revolution.

Different positions: Learners 8, 9, 11, 27, 49, 52 & 55.

These learners said that the two hemispheres have different seasons because one is higher than the other. Examples of these responses are: "*because the north is high and south is low*" (Learner 52) and "*because the southern hemisphere is down than the northern hemisphere*" (Learner 27). A closer look at these responses shows that the learners refer to the two-dimensional representation of the Earth on paper, *i.e.* the northern hemisphere is always drawn above the southern hemisphere.

Position of sunrise: Learners 14, 22, 23, 26, 32, 35, 47 & 59.

These learners said that the southern hemisphere experiences summer when the northern hemisphere experiences winter because the Sun rises in the southern hemisphere. A typical example of these responses is given by Learner 32: "*because the southern hemisphere is where the Sun rise*". This response shows that learners believe that the Sun rises in the southern hemisphere and sets in the northern hemisphere, which is why temperatures are low in the northern hemisphere.

Temperatures are different: Learners 4, 6, 10, 13, 17, 30, 36, 39, 40, 51, 53, 54, 56, 57, 58 & 60.

These learners said that the southern hemisphere has summer because it has high temperatures and that the northern hemisphere has winter because it has low temperatures. Examples of these responses are "*southern hemisphere in summer because is very hot, northern hemisphere is winter because is very cold*" (Learner 17) and "*when southern hemisphere has summer the northern hemisphere is going to have winter because the high temperature moves to southern hemisphere and the low temperature is going to be at northern hemispheres*" (Learner 57). These learners have only paraphrased information given in the question, *i.e.* saying that one hemisphere experiences summer when the other experiences winter, except Learner 10 who explained the cause of different temperatures: "*in the southern hemisphere the Sun is go fast and is very hot … in the northern hemisphere the Sun go slowly and it is very cool*". The remaining learners did not explain the cause of different seasons in these hemispheres.

The two hemispheres are different: Learners 1, 12, 15, 24, 31, 33, 37, 41, 42, 45 & 50.
These learners said that the two hemispheres experience different temperatures because of differences in these hemispheres. Examples of these responses are: "*because the southern hemisphere is different from the northern hemisphere*" (Learner 1), "*because there are not the same and are not equal*" (Learner 12), and "*because of different country southern hemisphere and northern hemisphere are not the same*" (Learner 33). These learners did not describe the difference between the hemispheres, and how the difference results in different seasons.

Unclear responses: Learners 2, 3, 7, 34, 44 & 48.
The responses given by these learners are not clear, *e.g.* "*because the southern hemisphere is not worm as the northern neily by the sea*" (Learner 48). These responses have not been coded because they are difficult to understand.

Learners 18, 20, 21, 25, 28 & 43 did not answer this question.

General overview: Learners do not understand that the tilt of the earth's axis results in different seasons in the northern and southern hemispheres, as the Earth revolves around the Sun. In fact no learners mentioned the earth's axis or the earth's revolution in their responses. This agrees with the conclusion made in section 4.2.5, that learners do not understand the movement of the earth.

4.2.8: Question 8: The Change in the Position of Sunrise from Season to Season

All learners could not give a scientifically acceptable explanation for the cause of the change in the position of sunrise from summer to winter, *i.e.* they could not state that the Sun is overhead the tropic of Capricorn at noon at the December solstice, and overhead the tropic of cancer at noon at the June solstice, and that this migration affects the

positions of sunrise and sunset. Learners said that the position of sunrise is influenced by temperatures and seasons as shown in the discussion below.

Summer is hot, winter is cold: Learners 5, 9, 15, 23, 24, 27, 31, 33, 42, 49, 50, 51 & 55.
These learners said that the position of sunrise moves towards the north in winter and towards the south in summer because winter is cold and summer is hot. Examples of these responses are: "*because in winter its very cold, and in summer its very hot*" (Learner 15), and "*because in winter we have coldest days and so that is why the Sun move to north...*" (Learner 24). These learners have given the effect of the (apparent) migration of the Sun from one hemisphere to another, not the cause as required by the question.

The hemispheres must have different seasons: Learners 1, 11, 37, 38, 41, 52, 57, 58, 59 & 60.
These learners said that one season must have summer when the other season has winter. Examples of these responses are: "*because the sunrise can't move towards the north and the south at the same time. When in north is winter it means the south is going to be summer*" (Learner 57), and "*it is because when the time of winter in the north is over there must be Sun so that it become summer in the north and when time for summer is over in the south, the Sun must stop arising so that it becomes winter. There must be an exchange of weather in the north and south*" (Learner 60). It seems that these learners focused on the change in seasons, not on the positions of sunrise, as required by the question.

The duration of day-time differs: Learners 29, 30, 32, & 34.
These learners said that the position of sunrise moves towards the north in winter and towards the south in summer because days are longer in summer and shorter in winter, as exemplified by Learner 30: "*because in winter days are short and nights are long and summer days are long and nights are shorts. That why in winter it moves towards north and summer towards south*". These learners too, have given the effect of the apparent migration of the Sun, not the cause as required by the question.

The Sun moves at different rates: Learners 17, 35, 36, 45 & 56.

These learners said that the positions of sunrise change because the Sun moves faster in summer and slowly in winter, as exemplified by Learner 35: "because in winter the Sun move fast and in summer moves slowly". It seems like these learners believe that days are shorter in winter because the Sun moves fast, and that days are longer in summer because the Sun moves slowly. These learners have not answered the question, *i.e.* why the position of sunrise changes.

Rotation of the Earth: Learners 4, 8, 16, 19 & 22.

These learners said that the rotation of the Earth causes the position of sunrise to move towards the north in winter. Learner 4 gives an example of these responses: "*because of the rotating of the Earth and the seasons start this work. The Sun move towards the north when it is winter*". The learners, however, have not explained how the Earth's rotation causes the change in the positions of sunrise.

Weather elements: Learners 12, 14 & 46.

These learners said that weather elements *e.g.* snow and rain cause the point of sunrise to move towards the north in winter. Learner 46 gave an example of these reasons: "*because in winter the Sun came out toward north because there a lot of rain, snow*". These responses show that the learners do not understand why the position of sunrise moves towards the north in summer and towards the south in winter.

Unclear responses: Learners 2, 6, 7, 10, 26, 40, 44, 47, 48, 53 & 54.

These learners gave responses that cannot fit into either of the above categories, either because they are not clear, or because learners have merely repeated the question, *e.g.* "*because time is round all over the Earth or the day*" (Learner 6), and "*because the position of sunrise is north*" (Learner 53). No interpretation can be made out of these responses.

Learners 3, 13, 18, 20, 21, 25, 28, 39, & 43 did not respond to the question.

General overview: The responses given for this question agree with the conclusion made earlier, that learners do not understand the Earth's movements, *i.e.* they do not attribute the change in the positions of sunshine to revolution of the Earth. A common trend among learner's responses is that they have described the effects of the change in the positions of sunrise, not the causes as required by the question, *i.e.* they cannot differentiate between causes and effects. Many learners seem not to have read the question carefully, or perhaps do not understand the question.

4.2.9. Question 9: The Moon during the Day

Only two learners gave scientifically acceptable responses to this question. Nine learners gave responses that are scientifically unacceptable, but which imply that the Moon might be in the sky during the day. The rest said that the Moon cannot be seen during the day, with the exception of a few learners whose responses were not clear. Learners' responses are discussed below.

Scientific explanation: Learners 23 & 30.

These learners said that nothing happens to the Moon during the day, and that it can be seen, although it is usually visible at night. Learner 30 gave a typical example of these responses: "*nothing, Moon doent move during the day sometime you will see the Moon during the day. Usually you find Moon at night*".

Sunlight obscures the Moon: Learners 22, 29 & 59.

These learners said that the Moon might be in the sky during the day, but it cannot be seen because of sunlight. Learner 29 went further to say that "*during the day we cannot see the Moon cause it hides self in the sky but during the night we can see everything*

about the Moon". This response shows that Learner 29 has some organistic perspectives about the Moon, *i.e.* saying that the Moon hides.

The Moon changes colour and/or shape: Learners 4, 5, 10, 39, 45 & 51.
Responses given by these learners imply that the Moon changes shape during the day, *i.e.* it becomes half or takes a banana shape; or changes colour, *e.g.* becomes dark. Learner 29 has given an example of these responses: "*the Moon changes its colour, sometimes it's becomes a half-Moon and sometimes a full-Moon and it's also change as a banana shape*". These learners have described what happens to the Moon over time, *e.g.* over a month, because the changes in shape do not happen every day. The word used 'banana shape' shows that learners do not know the names of phases of the Moon.

The Moon shines in another place: Learners 11, 19, 26, 35, 36, 41, 48, 54, 57 & 58.
These learners said that the Moon shines in another hemisphere, another continent or another country at night. Examples of these responses are: "*the Moon goes to the north*" (Learner 54) and "*the Moon is in another country where its night*" (Learner 58). These responses show that the learners believe that the Moon cannot be seen during the day.

The Moon disappears: Learners 8, 13, 18, 24, 27, 31, 34, 37, 38, 46, 49, 50 & 60.
These learners said that the Moon disappears during the day. Most of them did not elaborate on this response, except Learner 34 who said that "*the Moon during the day inside there is a lot of clouds*". These learners believe that he Moon cannot be seen during the day.

The Moon moves with the Sun: Learners 32 & 42.
One of these learners said that "*the Moon is moving inside the Sun*" (Learner 42) while the other said that "*the Moon goes after the Sun during the day*" (Learner 32). These responses show that the learners believe that the Sun actually moves in the sky, and that the Moon moves with the Sun.

Other responses: Learners 6, 7, 9, 14, 15, 16, 17, 33, 44, 47, 52, 53, 55, & 56

The responses given by these learners do not fall in any of the above categories because either they are not clear or learners have not answered the question, *e.g.* "*the Moon is going to light at night*" (Learner 16), and "*the Sun is try to move on the sky if you look the Sun with the paper the Sun we come to down*" (Learner 9). These learners have not answered the question.

Learners 1, 2, 3, 12, 20, 21, 25, 28, 40 & 43 did not answer this question.

General overview: Learners believe that the moon cannot be seen during the day. They believe that the moon can be seen only at night. If learners better understood the Earth's rotation, they would know that as the Earth rotates, it can face both the sun and the moon at the same time.

General observations from the questionnaire:

- Most learners have alternative conceptions about the earth-sun relationship, *i.e.* on concepts related to day and night, and seasons. Particularly problematic are
    - The combined yearly revolution of the Earth around the Sun and its rotation about its own axis.
    - The tilt of the Earth's axis.
- Learners have language problems, *i.e.* the majority did not interpret the questions properly, and did not express themselves clearly.
- Learners do not properly use diagrams, *i.e.* they did not make clear diagrams when explaining their answers, and did not interpret information properly from diagrams.