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

Mosoloane, Retselisitsoe

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CHAPTER 2

LITERATURE REVIEW

The following discussion (sections 2.1 and 2.2) shows some conceptions that learners have about the Earth-Sun relationship, *i.e.* day and night and the seasons. The discussion shows that there are various conceptions held by learners of different ages: primary school learners, high school learners, university students (including pre-service teachers) and some in-service training teachers. The discussion also shows that these conceptions are found in many parts of the world.

Section 2.3 deals with a theoretical framework that has been used to analyze results for this study. The framework includes meaningful learning, learners' worldviews, border crossing and collateral learning.

2.1. DAY AND NIGHT

Research shows that ideas held by learners about the cause of day and night range from the very naïve to the scientifically acceptable. Research also shows that learners have many unacceptable ideas about the effect of day and night on special objects, *e.g.* the presence of the Moon during the day. The following discussion outlines these conceptions, starting with the scientific, and then showing the alternative conceptions related to day and night.

2.1.1. The Scientific Conception

Many studies show that some learners have scientifically acceptable conceptions about the cause of day and night: *e.g.* 60% of 42 ten-and-eleven year olds in the U.K. (Sharp, 1996); 62% of 76 university students (Trumper, 2000), almost 50% of 448 junior high school students (Trumper, 2001a), and 64% of 378 senior high school students (Trumper, 2001b) in Israel; 56% of seven-to-seventeen year old deaf and hearing children in

Norway (Roald & Mikalsen, 2001); 91% of 12-year olds in the U.K. (Dove, 2002); and 52% of 102 secondary students in Greece (Bakas & Mikropolous, 2003). Research also shows that some pre-service and in-service training teachers have scientifically acceptable ideas about the cause of day and night *e.g.* 32% of 31 B.Ed. students, 56% of 41 PGCE students and 88% of 17 in-service training teachers in Manchester, U.K. (Parker & Heywood, 1998). The following is an example of a drawing made by learners who have a scientifically acceptable conception related to day and night. The diagram shows that day and night are caused by rotation of the Earth on its axis.

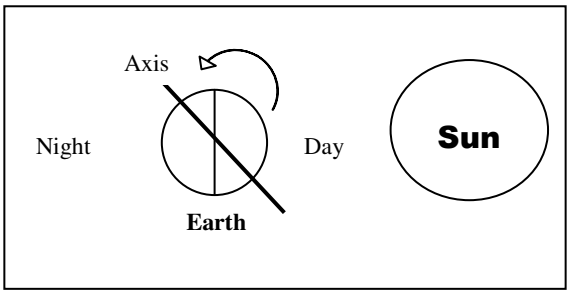

FIGURE 2.1: Cause of day and night-The scientific conception
(Redrawn from Parker & Heywood, 1998:507)

Concerning the effects of day and night, only 40% of ten-and-eleven year olds in the U.K. (Sharp, 1996) and 7% of 15 four-to-eight year olds in Australia (Fleer, 1997) said that the Moon can be seen during the day. The rest gave responses that are scientifically unacceptable. The following discussion outlines scientifically unacceptable ideas held by learners about day and night.

2.1.2. Animate or Anthropomorphic Conceptions

The responses given by the majority of four-to-eight year olds (Fleer, 1997) in Australia (exact number not given) imply that day and night occur because the Sun behaves like a person or an animal *i.e.* it moves because of certain purposes. Examples of these responses are that night occurs because "the Sun goes down under the clouds and in hills

and everything" and that "the Sun has gone down…to bed…under grass" (Fleer, 1997:107). When asked about the stars during the day, 47% said that stars cannot be seen during the day because they disappear to some unknown place, or go to bed (Fleer, 1997). When asked whether the Moon can be seen during the day 53% said that it cannot be seen. Various reasons were given, *e.g.* it goes behind the mountains, it goes up in space, and it comes out at dark (Fleer, 1997). Other animate conceptions have been reported by Sharp (1996) and Bakas and Mikropolous (2003) *e.g.* that the Sun goes behind clouds during the night. The following diagram illustrates this conception.

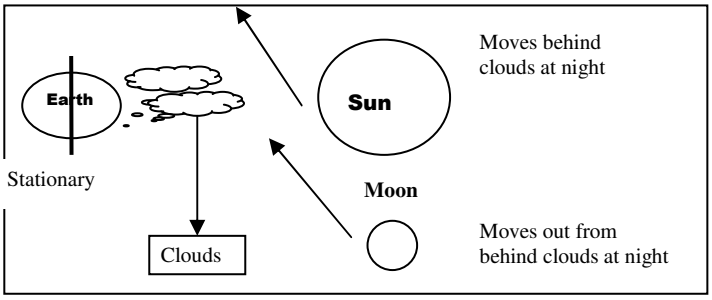

FIGURE 2.2: Cause of day and night-The anthropomorphic conception

(Redrawn from Sharp, 1996:701)

2.1.3. The Moon Obscures the Sun at Night

This conception has been given by 12.9% of B.Ed. students (Parker & Heywood, 1998) and by 2% of children in the U.K. (Sharp, 1996). The Earth is considered to be stationary, while the Sun and the Moon are believed to move in the sky, obscuring each other to make night and separating to make day. The following diagram shows this conception.

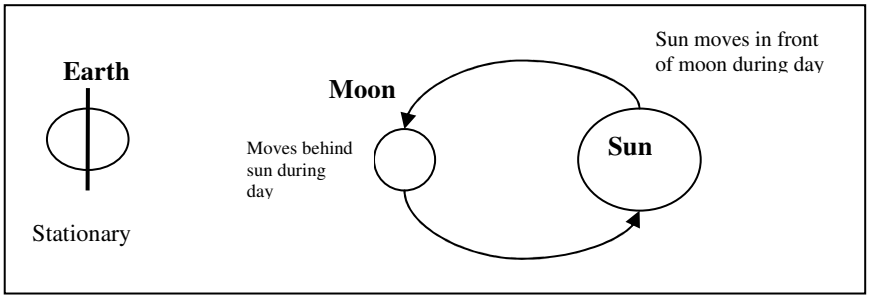

FIGURE 2.3: The Moon obscuring the Sun

(Redrawn from Sharp, 1996:701)

2.1.4. Daily Revolution of the Earth about a Stationary Sun

Some learners believe that the Sun is stationary, and that the Earth revolves daily to give day and night. The Earth experiences day when it is on one side of the Sun (*e.g.* side (a) in Figure. 2.4) and experiences night when it is on the other side of the Sun (*e.g.* side (b) in Figure 2.4). This conception has been given by 36% of junior high school students (Trumper, 2001a), 30% of senior high school students (Trumper, 2001b), 1% of 12-year olds in the U.K (Dove, 2002), and 35.3% of secondary students in Greece (Bakas & Mikropolous, 2003) who responded to closed questions; and by 2% of ten-and-eleven year olds in the U.K. (Sharp, 1996), 12.9% of B.Ed. students and 17.1% of PGCE students in the U.K. (Parker & Heywood, 1998) who responded to open-ended questions.

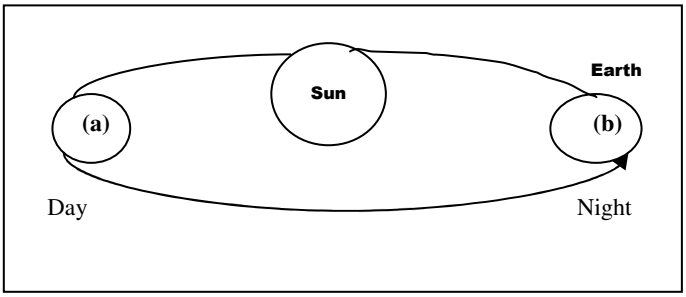

FIGURE 2.4: Daily revolution of the Earth

(Redrawn from Parker & Heywood, 1998:507)

2.1.5. Daily Revolution of the Sun

Learners who hold this conception believe that the Earth is stationary and that the Sun revolves around the Earth to make day and night (Sharp, 1996; Parker & Heywood, 1998; Roald & Mikalsen, 2001; Trumper, 2001a & 2001b; Bakas & Mikropolous, 2003). There are two versions for this conception, the first being that the Earth is flat, and that the Sun and the Moon rise one after another to make day and night respectively (Parker & Heywood, 1998).

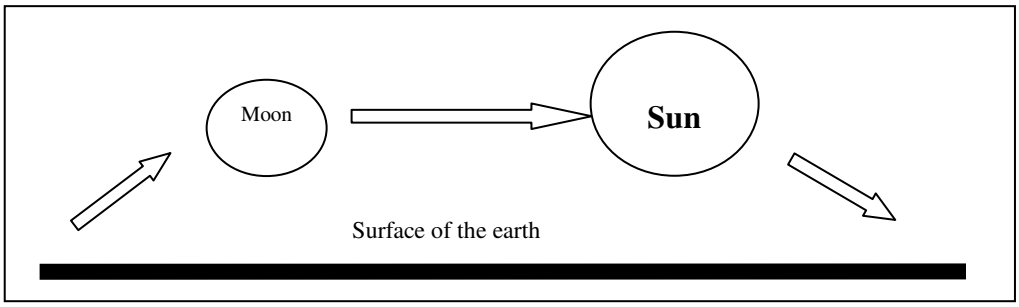

FIGURE 2.5: Sun and Moon revolve around flat Earth

(Redrawn from Parker & Heywood, 1998: 507)

The other version of this conception is that the stationary Earth is spherical in shape, and that the Sun and the Moon move in diametrically opposite directions, the Sun being on the day side and the Moon being on the night side of the Earth (Figure 2.6).

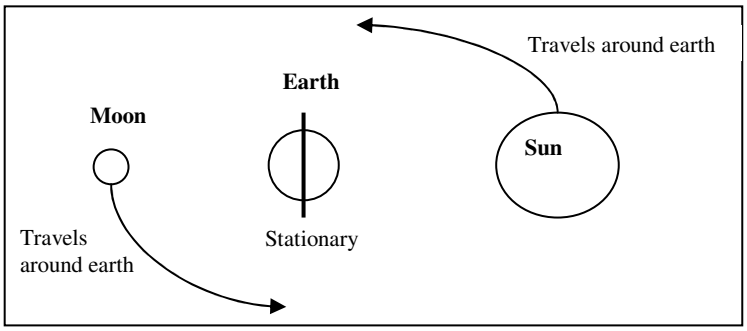

FIGURE 2.6: Sun and Moon revolve around spherical Earth

(Redrawn from Sharp, 1996:701)

2.1.6. Day-Side and Night-Side of the Universe

Learners who hold this conception believe that the Earth is between the day side and the night side of the universe. The Sun is on the day-side of the universe, but it does not cause the day; while the Moon and stars are on the night side of the universe (Roald & Mikalsen, 2001). The Earth spins in the interface between the day-side and the night-side of the universe to give day and night. The following diagram shows this conception.

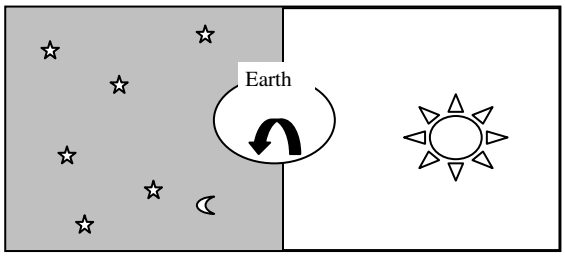

FIGURE 2.7: Universe has day-side and night-side
(Modified from Roald & Mikalsen, 2001:430)

2.1.7. The Sun Moves Up-And-Down and the Earth Spins

Learners who believe in this conception say that the Sun moves up in the morning when the Moon and the stars move down, and that the opposite happens at night (Roald & Mikalsen, 2001). The up-down is considered to be an absolute direction. These learners believe also that the Earth rotates daily to give day and night, and that the Earth moves annually around the Sun. The diagram made by a student is shown in Figure 2.8.

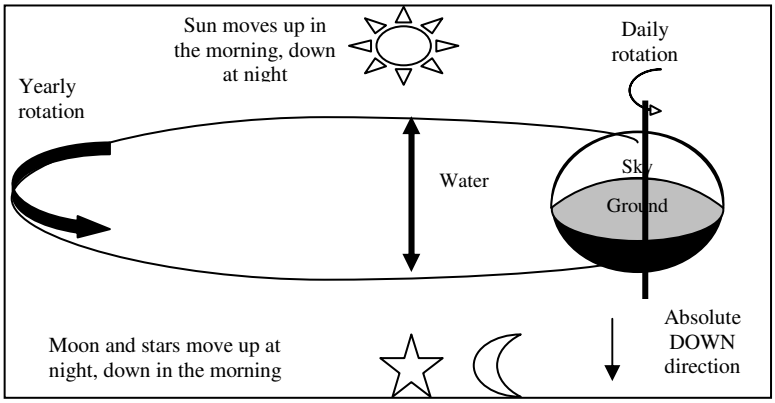

FIGURE 2.8: The Sun moves up and down

(Redrawn from Roald & Mikalsen, 2001:428)

2.2. THE SEASONS

Research shows that learners and teachers hold different conceptions about the cause of seasons, and about effects of seasonal change, *e.g.* overhead Sun at noon and positions of sunrise and sunset as seasons change. The following discussion shows that these conceptions range from very naïve ideas to ones that are scientifically acceptable today.

2.2.1. The Scientific Explanation

Many researchers report that some of their subjects had a scientifically acceptable conception about the cause of seasons, *e.g.* 77% of 708 seventh-to-twelfth graders in Michigan (Aron, Francek, Nelson & Bisard, 1994), 19% of ten-and-eleven year olds in the U.K (Sharp, 1996), 2% of 49 pre-service teachers in Kentucky (Atwood & Atwood, 1996), 9.7% of B.Ed students, 9.8% of PGCE students and 23.5% of in-service training teachers in the U.K. (Parker & Heywood, 1998), 67.1% of university students (Trumper, 2000), 46% of junior high school students (Trumper, 2001a), 62% of senior high school students (Trumper, 2001b), and 7% of deaf and hearing pupils (Roald & Mikalsen, 2001). Their subjects explained that seasons are caused by the Earth's tilted axis as it revolves around the Sun once in a year. The subjects further explained that different places on

Earth experience different seasons because of the Earth's tilted axis. Figure 2.9 below shows this idea.

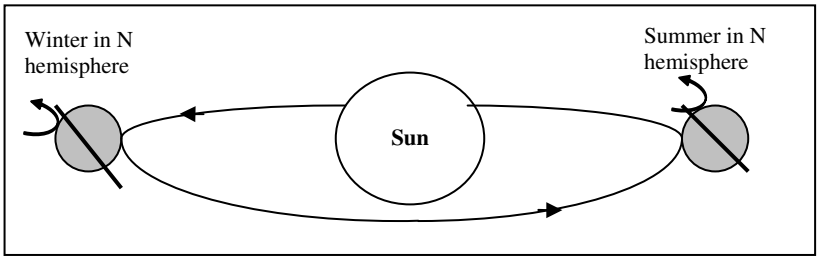

FIGURE 2.9: Cause of seasons-The scientific conception

(Redrawn from Parker & Heywood, 1998:510)

Concerning the effects of seasonal change, only 32% of junior high school students (Trumper, 2001a), 36% of senior high school students (Trumper, 2001b) and 32.9% of university students (Trumper, 2000) correctly stated that in Haifa, north of the tropic of cancer, the Sun is never directly overhead at noon. Also, only 27.6% of university students correctly stated the sunset position after the autumn equinox in Haifa, and only 17.1% correctly stated the position of sunrise on the 21st June in Haifa (Trumper, 2000). These learners answered closed questions, and could not give further explanations for this response. The following alternative conceptions have been reported about seasons.

2.2.2. The Naïve Conceptions

Three percent of 12 year olds in Greece (Bakas & Mikropolous, 2003) said that seasons are caused by air masses and sea currents. A naïve conception reported by 4% of seventh-to-twelfth graders in Michigan (Aron *et al*., 1994) is that varying degrees of atmospheric pollution dilute the Sun's light to give different seasons. Four percent of pre-service elementary teachers in Kentucky (Atwood & Atwood, 1996) said that the rotation of the Earth on its axis causes seasons.

2.2.3. The Distance Model

This conception has many versions, the first being that the Sun is stationary while the Earth revolves around in an oblique orbit, as shown in Figure 2.10, to make seasons (Parker & Heywood, 1998). The Earth experiences summer when it is nearer the Sun and experiences winter when it away from the Sun. This model, however, does not explain why different parts of the Earth experience different seasons at a given time.

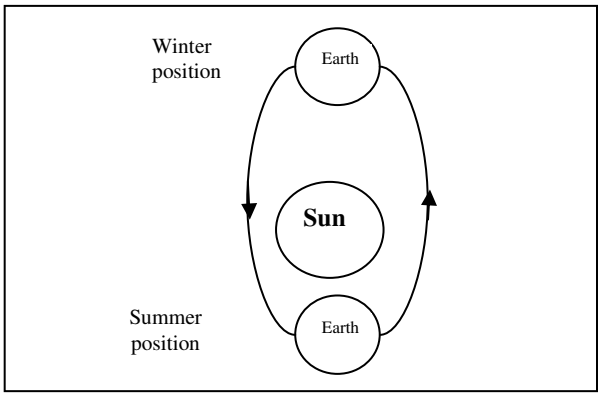

FIGURE 2.10: Cause of seasons; distance model (1)

(Redrawn from Parker & Heywood 1998: 510)

The second version of this model is that the Earth moves in an oblique orbit, but this movement is considered to be responsible for day and night, and not the seasons (Roald & Mikalsen, 2001). The Earth is believed to move in different orbits, each orbit being responsible for a particular season (Figure 2.11).

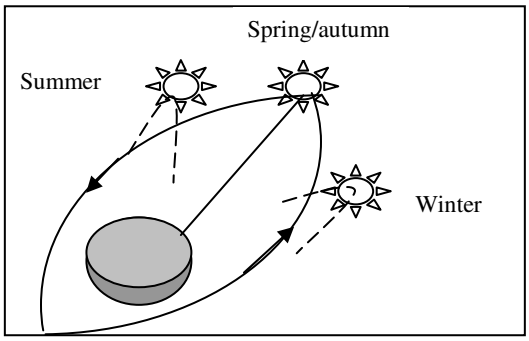

FIGURE 2.11: Cause of seasons; distance model (2)

(Redrawn from Roald & Mikalsen, 2001:429)

The last version of this model is that the Earth rotates on its axis to give day and night, and that (a) it moves towards the Sun in summer and away from the Sun in winter (Sharp, 1996) or that (b) the Sun move towards the Earth in summer and moves further away from the Earth in winter (Roald & Mikalsen, 2001) as shown in the diagram below.

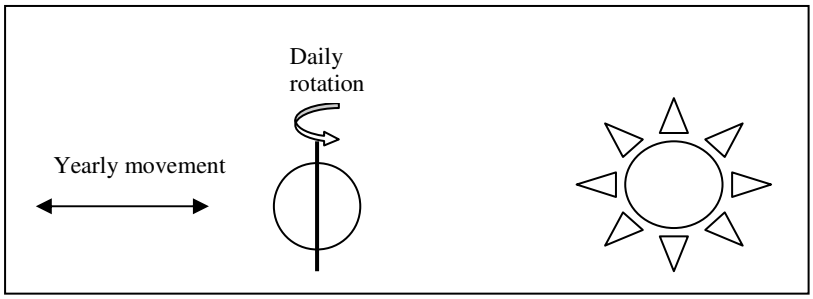

FIGURE 2.12: Cause of seasons; distance model (3)

(Redrawn from Roald & Mikalsen, 2001:431)

2.2.4. The Wobbly Earth Model

This model is held by pre-service and in-service training teachers (Atwood & Atwood, 1996; Parker & Heywood, 1998). These teachers believe that as the Earth moves around the Sun, its axis wobbles to face the Sun in summer and to face away from the Sun in winter. A typical response from one of the teachers is that "the seasons are caused by the tilting of the Earth's axis toward and away from the Sun. While it is winter here, we are

farther away from the Sun, but some places on Earth are closer to the Sun so it is summer there" (Atwood & Atwood, 1996:557). Figure 2.13 shows this model.

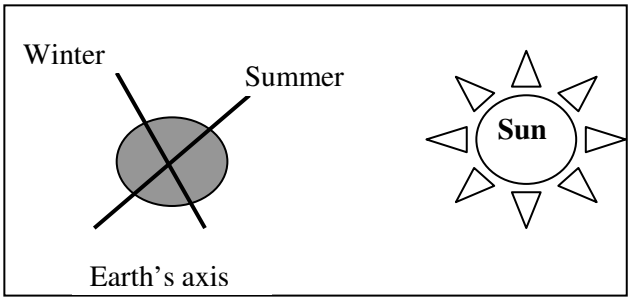

FIGURE 2.13: The wobbly Earth model
(Redrawn from Parker & Heywood, 1998:510)

2.2.5. Uneven Radiation from the Sun

This conception is held by learners whose conception of day and night is described in section 2.1.6 above, *i.e.* that the universe has a day side and a night side. These learners believe that the Earth is in the interface between the day side and the night side of the universe (Figure 2.14 below), and that it revolves around the Sun each day along this interface (Roald & Mikalsen, 2001). They believe that the Sun has a summer side and a winter side, and that it spins on its axis once a year to make summer and winter on Earth.

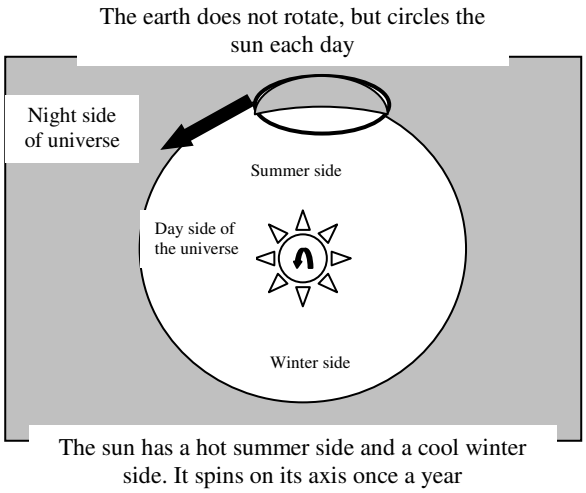

FIGURE 2.14: Uneven radiation from the Sun

(Modified from Roald & Mikalsen, 2001:432)

2.2.6. Different Heating Capacities of the Sun

Learners who hold this conception believe that the Earth and the Sun are stationary, and that the Sun heats up in summer and cools down in winter (Sharp, 1996). This explanation, however, does not explain why days are longer in summer than in winter.

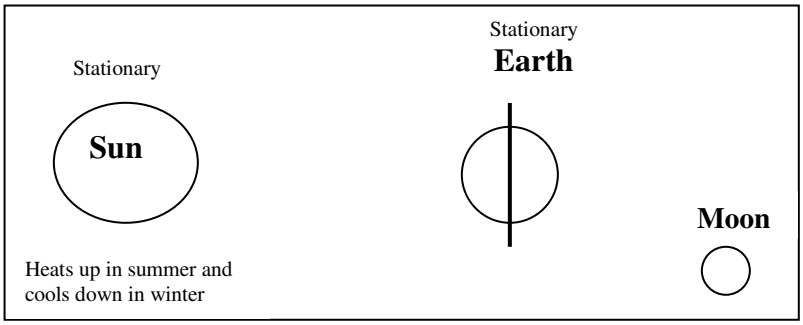

FIGURE 2.15: The Sun's energy changes

(Redrawn from Sharp, 1996:703)

2.2.7. Effects of Seasonal Change on Position of Sun

As mentioned earlier very few learners correctly stated that the Sun is never overhead at noon in Haifa (Trumper, 2000; 2001a; 2001b). Thirty five percent of junior high school students (Trumper, 2001a), 36% of senior high school students (Trumper, 2001b), and 47.4% of university students (Trumper, 2000) said that the Sun is always overhead at noon in Haifa. A misconception given by 53.3% of university students (Trumper, 2000) is that on the 21st June the Sun rises directly from the east in Haifa, a place that is to the north of the tropic of Cancer.

The following table summarizes the conceptions described above, with a brief explanation for each conception.

TABLE 2.1: Summary of Documented Conceptions

Conception	Brief explanation
Day & Night	
Scientific	The Earth rotates on its axis once in 24 hrs around a stationary Sun
Animate/anthropomorphic	The Sun and other special objects behave like animals/people *e.g.* they move for different purposes
The Moon obscures the Sun	The Moon covers the Sun at night and uncovers it during the day
Daily revolution of the Earth	The Earth moves around the Sun each day
Daily revolution of the Sun	The Sun moves around the flat or spherical Earth each day
Universe has day-and-night side	The universe has a day-side and a night-side, and the Earth rotates to face each of these in turn
Sun moves up-and-down, Earth spins	The Sun moves up in the morning when the stars and the Moon move down. The opposite happens at night. The Earth rotates daily
The seasons	
Scientific	The Earth's tilted axis causes seasons as the Earth revolves around the Sun once in a year
Some naïve conceptions	Atmospheric pollution, air masses, sea currents *etc.* cause seasons
Distance model (1)	The Earth moves in an oblique orbit, summer occurs when the Earth is near the Sun and winter occurs when the opposite happens
Distance model (2)	The Sun orbits the Earth on different orbits, one for each season
Distance model (3)	The Sun moves closes to the Earth in summer and away in winter
The wobbly model	The Earth's axis turns towards the Sun in summer and away in winter
Summer & winter side of the Sun	The Sun has summer side and winter side, and spins once year
Different heating capacities	The Sun radiates more heat in summer and less in winter

2.3. THEORETICAL FRAMEWORK

The following ideas: meaningful learning, learners' worldviews, border crossing and collateral learning have been used when analyzing the results for this research project.

2.3.1. Meaningful Learning

The construct now commonly used in teaching and learning is constructivism, which states that knowledge is not transferred from teachers to learners, but is constructed within the mind of learners. Learners modify the incoming information by relating it to what already exists in their mental frameworks in a process called **assimilation** (Piaget, 1964). The mental structure is also modified to adapt to incoming information, a process called **accommodation** (Piaget, 1964). Learning is **meaningful** when learners *consciously* relate incoming information to *relevant concepts* already learned (Ausubel, 1985). Rote learning occurs when learners incorporate incoming information without relating it to what already exists in their mental frameworks (Ausubel, 1985), and this may result in misconceptions.

2.3.2. Learners' Worldviews

Cobern (1993; cited by Lawrenz & Gray, 1995) says that learners can have misconceptions, not necessarily because they do not understand, but because they do not believe what is taught. According to Cobern, *alleged misconceptions* result from factual (mis) understanding or from an alternative worldview. A learner's worldview is a "set of beliefs held consciously or unconsciously about the nature of reality and how one comes to know about it" (Proper, Wideen & Ivan, 1988:547; cited by Ogunniyi, Jegede, Ogawa, Yandila & Oladele, 1995:818). This means that a worldview does not only enable individuals to fit in their sociocultural environments, but also "determines the likelihood in which a new idea is assimilated into the cognitive structure" of the learner (Ogunniyi *et al.*, 1995).

In a study using science teachers from Botswana, Indonesia, Philippines, Nigeria and Japan, Ogunniyi *et al.* (1995) found that most of their subjects held different views from the science they taught, and that those who were from nonwestern cultures could not clearly differentiate between scientific and non-scientific worldviews, which means that they might "have entered and left schooling with different, and competing view points about nature" (Ogunniyi *et al.*, 1995:822). Ogunniyi *et al.* (1995) conclude that this may affect the way these teachers teach, *i.e*. it can enhance or fail to correct misconceptions that learners have about the universe.

In a study conducted in two South African universities, Lemmer *et al.* (2003) found that some first year students in two universities had different views about the composition of the universe. These conceptions range from Aristotelian, through Newtonian, to ones that are scientifically accepted today. Lemmer *et al.* (2003:564) classified these conceptions into two categories: mechanistic worldviews which involve "formal … reasoning and … operational definition of concepts", and organistic worldviews which can further be described as

- **Animism:** students describing spatial bodies as if they behave like animals.
- **Holism:** belief that members of the universe are connected, *i.e*. parts of a whole to be studied together.
- **Teleology:** belief that special objects behave according to certain purposes, *e.g*. the Sun is at centre because it is source of energy, stars twinkle to make the heaven *beautiful.*
- **Egocentrism:** belief that man (or the Earth) is the centre of the universe.

Lawrenz & Gray (1995) found that worldviews held by student teachers in one South African university were related to:

- The type of science course studied, *e.g*. physics students had a numerical and orderly worldview.
- Home location, *e.g*. those from urban areas understood distance to be time related (possibly because of traffic).
- Type of family situation, *e.g*. those from extended families understood distances

to be more personal and less numerical.

2.3.3. Border Crossing & Collateral Learning

The studies by Ogunniyi *et al.* (1995) and Lorenz & Gray (1995) describe some worldviews held by teachers, and explain how these worldviews can result in misconceptions, and also how worldviews can affect (or prohibit) construction of scientific knowledge.

Aikenhead (1996:2) says that when students learn science at school, they cross "cultural borders, from the subcultures of their peers and family into the subcultures of science and school science", *i.e.* they cross the borders from one culture to another. He uses Phenal *et al.*'s (1991) model of students' multiple worlds and Costa's (1995) categories of students' success at school to describe:

- **Potential scientists** as students who's "worlds of family and friends are congruent with both worlds of school and science" (Aikenhead, 1996:16). These students do not experience problems when crossing borders, *i.e.* they experience ***smooth*** border crossing.
- **Other smart kids** as students whose "worlds of family and friends are congruent with world of school but inconsistent with world of science" (Aikenhead, 1996:16). School science may not have immediate relevance to their lives, but is relevant to their future plans. "Border crossing into school is ***managed*** so well that few students express any sense of science being a foreign subculture" (Aikenhead, 1996:18).
- **I don't know students** as those whose "worlds of family and friends are inconsistent with worlds of both school and science", who have learned to pass without understanding, and who do not want to replace their commonsense conceptions with those of science (Aikenhead, 1996:16). Border crossing is ***hazardous*** for these students.
- **Outsiders** as students whose worlds of school and science are inconsistent and irreconcilable with those of peers and family. Border crossing is ***impossible*** for these students.

Jegede (1995) has given a *cognitive experience* of border crossing, which is called collateral learning. This is "the process whereby a learner in a non-western classroom constructs, side by side and with minimal interference and interaction, western and traditional meanings of a simple concept" (Jegede, 1995:117). There are four types of collateral learning:

- **Secured collateral learning**, where there is interaction of knowledge gained from traditional and scientific worldviews. Learners resolve a conflict between these views, and develop "satisfactory reasoning for holding to both schemata even though the schemata may appear to conflict" (Aikenhead & Jegede, 1999:278).
- **Dependent collateral learning,** where knowledge from one worldview challenges knowledge from another worldview (Jegede, 1995). There is interaction of knowledge gained from conflicting worldviews; a learner uses the combined knowledge depending on the need (Aikenhead & Jegede, 1999). An example is that of a person who uses traditional and western medicines depending on their suitability (Aikenhead & Jegede, 1999).
- **Simultaneous collateral learning**, where learning a concept in science class facilitates learning of a related concept in traditional worldview, or vice versa (Aikenhead & Jegede, 1999).
- **Parallel collateral learning,** where learners experience "no visible disequilibrium" having acquired both the traditional and the scientific concepts (Jegede, 1995:119). These concepts do not interact al all, and the context determines one that will be used *e.g*. one used at school while the other at home (Aikenhead & Jegede, 1999).

Fakudze (2003) uses border crossing and collateral learning to describe the **African learner model**. According to this model, a learner pays *attention* to the in-coming information, and *perceives* it using prior knowledge and expectations. The incoming information then goes to the *working memory* where border crossing takes place. From the working memory the information is stored in the *long term memory*, and the storage depends on the type of border crossing that occurred, *i.e.* the information will be encoded as parallel, secured or dependent knowledge.

The above ideas, obtained from literature, have been useful in this research project. The alternative conceptions have been used for questionnaire construction, *i.e.* the questionnaire addressed most of the alternative conceptions discussed above. The theoretical framework discussed above has been used when analyzing the results obtained from the questionnaire.