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

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CHAPTER 5

DISCUSSION & CONCLUSIONS

5.1. DISCUSSION

This chapter discusses results obtained from the main study. The discussion aims at answering the two research questions, *i.e.* to state the conceptions of learners about day and night, and the seasons. The discussion takes into account how day and night, and the seasons, are presented in the two books that have been used by learners, both in the pilot and in the main study, *i.e.* Shuters Natural Sciences, Grade-9 learner's book (Ayerst, Dalton & Khumalo, 2001) and New Natural Science, Grade-8 learner's book (Opie & Enderstein, 2000).

The discussion has some limitations, *e.g.* the researcher did not observe the learning process, and therefore does not know whether teachers followed all the activities prescribed in the textbooks, and does not know other (relevant) materials that teachers might have used. The assumption is, however, that learners have the textbooks that teachers claim to have used.

Question 1: Causes of Daily Movement of the Sun

The results show that only 15% of learners described the cause of day and night as movement of the Earth, and only 7% described the Earth's movement as rotation. The results also show that none of these learners mentioned the Earth's axis in their explanations. The other learners gave alternative responses, despite a detailed explanation given in their textbooks. Opie and Enderstein (2000) explain the cause of day and night as rotation of the Earth. Ayerst *et al.* (2001) have prescribed an activity in which learners use models to investigate how rotation of the Earth causes day and night. This activity is followed by an explanation of how day and night occur.

The responses show that either learners did not construct knowledge while learning the topic, or did not learn meaningfully. Meaningful learning requires learners to **consciously** relate new knowledge to **relevant** concepts already learned (Ausubel, 1985)**.** The inability of learners to apply the knowledge shows that they did not learn meaningfully, either because the learning situation did not enable them to relate new concepts to concepts already learned, or because they did not have **relevant** underpinning concepts to make sense of the topic. The results show that only few learners (7%), who said day and night are caused by rotation of the Earth, assimilated new knowledge and/or modified their mental structures to accommodate the new knowledge.

The results show that some learners (17%) had mechanistic perspectives about the Earth-Sun relationship because they said that the Sun moves to give different times of day *e.g*. morning, afternoon, day and night. The results also show that 36% of learners had organistic perspectives about the Earth-Sun relationship, *i.e.* they attributed the cause of day and night to needs of humans. These mechanistic and organistic perspectives exist after formal instruction about the topic.

Very few learners (3%) did not respond to the question. This means that majority of learners believed that they knew the cause of day and night. The unclear responses (7%) may be attributed to lack of communication skills since the questionnaire was administered to a group of English second language speakers.

Question 2: Temperature Difference between Summer and Winter

The results show that only 7% of learners gave scientifically acceptable responses for this question**.** The rest gave alternative responses despite a detailed explanation given in the textbooks. Opie and Enderstein (2000) have prescribed an activity in which learners investigate the effect of the angle of the Sun's rays on Earth. They explain that the Earth is slightly closer to the Sun in the southern summer and slightly further in winter, but emphasize that this does not cause seasons because the entire planet would have summer when the Earth is (slightly) closer to the Sun and winter when it is (slightly) further away from the Sun. They emphasize that temperatures are high in summer because of a long

day, and because of more direct Sun's rays. Despite this explanation 8% of learners said that summers are hot because the Sun is near the Earth. This shows that meaningful learning did not take place while learning the topic.

The results show some mechanistic perspectives in this question, *e.g.* 14% of learners said that the Sun radiates more energy in summer than in winter. The majority of learners (46%) said that a change in weather conditions makes summer to be hotter than winter. This response shows that learners do not attribute temperature difference to the Earth-Sun relationship; they believe that only the Earth is responsible for this difference. This may also be considered to be a mechanistic perspective, *i.e.* learners believe that only the Earth is responsible for different temperatures for summer and winter, and that other special objects, *e.g.* the Sun, have no effect. The results also show that some learners (14%) had an organistic perspective in this question, *i.e.* they believed that summer is hot for a certain purpose: to allow plants to grow. The results show that learners hold these perspectives after learning about seasons.

A small number of unclear responses (8%) may be attributed to lack of communication skills on the learners since all of them are English second language speakers. All learners answered the question.

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

The results show that only 3% of learners understood that day-time is equal to night-time at the tropic of Capricorn when the Sun is overhead the equator at noon. The rest gave alternative responses despite detailed explanations given in their textbooks. Opie & Enderstein (2000) have prescribed an activity in which learners investigate how the angle of the Sun's energy changes throughout the year. The activity shows learners that day-time and night-time are equal when the Sun is overhead the equator at noon. Ayerst *et al.* (2001) have also prescribed an activity in which learners investigate the effect of the Earth's revolution on Sun's energy on Earth. Ayerst *et al.* (2001) specifically ask learners to describe the seasons in South Africa when the Sun is overhead the equator at noon. Despite these activities the majority of learner gave alternative explanations.

The results show that only 27% of learners drew diagrams that show both the Earth and the Sun. The majority of learners drew either the Sun only (15%), or the Earth only (19%), or some irrelevant diagrams *e.g.* rectangles and semicircles (29%). This shows that learners do not know the alignment of the Earth and the Sun during equinoxes. Learners did not ask for clarification of the question when answering the questionnaire. This means that the problem was not with question wording, but understanding the concept tested in the question. The same conclusion can be drawn from the large number of learners who did not answer the question (20%).

A conclusion that might be drawn from this question is that when learning the topic less emphasis was placed on the duration of day and night time during equinoxes, or that learners did not follow the activities recommended in their textbooks.

Question 4: Date of the December Solstice

The results show that all learners could not tell the date shown in the diagram (Appendix 2). All gave alternative responses despite detailed explanations made by Opie and Enderstein (2000) and Ayerst *et al.* (2001). The activities already explained require learners to investigate how the Sun's energy received by places on Earth changes throughout the year. Opie and Enderstein (2000) and Ayerst *et al.* (2001) explain with the help of diagrams that the Sun is overhead the tropic of Capricorn at noon on the $21^{st}/22^{nd}$ December each year, *i.e.* the angle of the Sun's energy is 90^{o}. All learners gave alternative explanations despite these explanations.

The results show that learners chose different months of the year, with the majority choosing 1^{st} September, probably because they answered the questionnaire on this date. Results also show that many learners (37%) said the angle of the Sun's rays is 90^{o}, but that all could not give the scientifically acceptable explanation for this, which shows that they might have guessed the answer.

The results suggest that meaningful learning did not take place when the topic was taught. This means that the learning environment did not enable learners to assimilate new knowledge into their mental frameworks, and to modify the mental framework in order to accommodate new information. Another possible explanation for poor performance in this question is that learners possibly do not know how to interpret diagrams. This conclusion can be made from a large number of learners who did not answer both questions 3 and 4, which require direct use of diagrams.

Question 5: The Cause of the Leap Years

The results show that only 2% of learners stated that a quarter of a day remains each year, and that the quarters add up to one day after four years. The rest gave alternative responses despite a detailed explanation made by Ayerst *et al.* (2001). After the activity that shows how the Earth revolves around the Sun, Ayerst *et al*. (2001) explain that the movement of the Earth around the Sun takes 365¼ days and that a calendar year has 365 days. Ayerst *et al*. (2001) further say that an extra day is added in the fourth year to make up for the missing quarter day. Learners gave scientifically unacceptable conceptions despite this explanation. This shows that either learners do not read their books while learning, or after learning topics, or that their teachers do not make them aware that more explanations (than classroom discourse) can be found in the textbooks. The poor performance in this question shows that learners did not construct knowledge meaningfully while learning the topic.

The results show that some learners have an organistic perspective about the Earth-Sun relationship. Twelve percent of learners seem to have a holistic perspective, *i.e.* attributed the cause of leap years to a <u>combination</u> of many factors *e.g.* the month, days, calendars, and movement of objects such as the Moon. Seventeen percent attributed the cause of leap years to human and other needs *e.g.* Olympic Games and presidential elections. Five percent of these learners related leap years to the time when elephants give birth. This is a common belief in many black societies. This response shows that 5% of learners learned the scientific knowledge side-by-side with their traditional beliefs.

This shows that the learners did not cross borders from their traditional cultures to the school science culture, but encountered collateral learning.

Almost half of learners repeated information presented in the question, *i.e.* they said that a leap year comes once in four years. This shows that they possibly did not understand what the question wanted them to explain, or that they do not know that a leap year is caused by a quarter-day that remains each year, since they did not use the revolution of the Earth in their explanations. A large number of learners who did not answer the question (10%) show that they did not know the cause of leap years.

Question 6: Overhead Sun at Noon

The results show that all learners were not aware that the Sun is never overhead at noon in the location stated in the question. Both textbooks explicitly state that the Sun is overhead the tropic of cancer on the $21^{st}/22^{nd}$ December and that the sunrise and sunset start to move towards the north after this date. This means that the Sun cannot be directly overhead at noon in places that are south of the tropic of Capricorn, including the location referred to in the question. The results show that learners did not use this knowledge presented in their textbooks.

Responses given by 19% of learners (the Sun is overhead in a certain seasons) and by 29% of learners (the Sun is overhead in a certain month) show that the learners do not know that the Sun is never overhead at the location mentioned in the questions. Responses given by 29% of learners who gave a certain time of day at which the Sun would be overhead, shows that the learners did not read the question properly, because the question clearly states that the Sun would be directly overhead at noon. A large number of unclear responses (12%) and no responses (12%) show that learners did not know the answer, as they did not ask for clarification of the question from the researcher.

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

The results show that all learners did not know why one hemisphere experiences winter when the other experiences summer, or that they were not even aware that the two hemispheres experience summer and winter at different times. They lack this knowledge despite activities suggested in their textbooks, which explain how the tilt of the Earth's axis as it revolves around the Sun enables one season to experience summer when the other experiences winter.

The majority of learners said that the hemispheres experience summer and winter because they are different, *e.g.* being in different locations (12%), having different temperatures (27%), or just being different (19%). Other learners attributed this difference to positions of sunrise. These responses show that the learners were not aware that the tilt of the Earth's axis causes seasons, nor the difference between the hemispheres. A large number of no responses (8%) show that some learners did not know why the two hemispheres experience the difference in seasons. A large number of unclear responses (10%) may be attributed to lack of communication skills among the learners. Most of these responses show that learners have a mechanistic perspective about the Earth-Sun relationship. Few responses however show an organistic perspective, *e.g.* one learner said that the Sun goes fast in summer and goes slower in winter.

Question 8: The Change in the Position of Sunrise

All learners could not explain why the position of sunrise seems to move towards the south in summer and towards the north in winter. They gave alternative responses despite detailed explanations made by Opie and Enderstein (2000). Opie and Enderstein (2000) prescribed an activity in which learners observe sunset over a week, and then describe how the positions of sunset moves in the western horizon. They explain how the Sun seems to move north and south of the equator throughout the year. They state that "the sunset seems to move slowly along the western horizon from south-west towards the north" after December 21st, South Africa's longest day of the year. (Opie & Enderstein, 2000:143). They further say that "on March 21st … the Sun sets due west (and) on June

21st it is as far north as it seems to go", after which it seems "to start to return south from the north-west" (Opie & Enderstein, 2000:143).

Most learners mentioned effects of seasonal change, *e.g.* change in duration of day-time, and change in weather conditions, *e.g.* temperature. This shows that learners did not know why the position of sunrise changes. A large number of unclear responses (19%) and of no responses (14%) also shows that learners did not know the answer for the question.

Question 9: **The Moon during the Day**

The results show that only 3% of learners knew that the Moon can be seen during the day. The concept tested in this question required common sense of daily observations learners, *i.e.* they need not learn in school that the Moon can be seen during the day. Eight percent of learners said that the Moon cannot be seen because of **powerful** rays from the Sun. This response shows that learners hardly look at the sky during the day, because if they looked at the sky each day they would see the Moon. The same conclusion can be drawn from a response given by a large number of learners (22%) who said that the Moon disappears during the day. A large number of unclear responses (24%) and no responses (15%) show that many learners did not know the answer for this question. An organistic perspective is revealed by a learner who said that the Sun hides during the day. This learner believes that the Sun moves according to purposes, and that it behaves like humans who *hide*.

5.2. CONCLUSIONS

The above discussion shows that few learners constructed knowledge while learning the topic. The alternative conceptions held by learners imply that equilibration did not take place while the topic was learned, *i.e.* learners did not (presumably) assimilate new knowledge into their existing schemes, or that they did not modify their schemes to incorporate the incoming information. This also means that meaningful learning did not take place. Learning is meaningful when learners consciously link incoming information

to relevant concept held in their mental frameworks (Ausubel, 1985). It is possible for learners to enter classrooms with relevant knowledge about day and night, and the seasons, because these concepts are part of their daily lives. A conclusion made from the results therefore, is that, either teachers did not help learners to link new knowledge to previously held knowledge, or that learners did not *consciously* link new knowledge to previously held knowledge. Rote learning occurs when new knowledge is arbitrarily incorporated into the mental framework (Ausubel, 1985).

The results also show that, as suggested by Cobern (cited by Lawrenz & Gray, 1995), some learners had alternative conceptions because of their worldviews, *i.e.* they had either organistic or mechanistic worldviews. The organistic worldview is revealed by learners who described the special objects as behaving like animals, *e.g.* the Moon cannot be seen during the day because it *hides* in the sky. Another organistic perspective revealed by the results is that some learners believe that special objects move according to certain purposes, *e.g.* the Sun rises and sets to allow people to rest. One instance revealed that learners have a holistic perspective about special objects, *i.e.* they believed that a combination of many factors causes leap years. Mechanistic perspectives were found throughout the questionnaire, *e.g.* learners said that summer is hotter than winter because of changing features of the Sun.

Another conclusion made from the results is that some learners had a problem of crossing borders from their home cultures to school science culture. This situation is exemplified by learners who related leap years to a time when elephants give birth, a common belief in some societies. Using Aikenhead's terms (1996); these learners may be referred to as **I don't know students** or **outsiders**, *i.e.* those learners who find it difficult or almost impossible to cross cultural borders. Aikenhead (1996) says that the social environment of these learners is inconsistent with school science. These learners have experienced what Jegede (1995) calls parallel collateral learning, *i.e.* they learned school science side-by-side with their cultural beliefs, and use each depending on circumstances and the context.

Fakudze's African learner model (2003) can be used to analyze the results. According to this model prior experiences are used to perceive information, which is processed in the working memory where border crossing takes place. The processes information is stored in the long term memory depending on the type of border crossing that took place. The above discussion shows that most learners did not undergo meaningful learning while learning the topic. This means that for most learners, prior knowledge was (possibly) not used when perceiving incoming information. The discussion further shows that in the working memory, border crossing was not easy for some learners. The results in general show that from the working memory, alternative conceptions were stored in the long term memories of learners.

5.3. FINDINGS

This section gives answers to the two research questions, *i.e.* it gives learners' conceptions about day and night, and seasons. The percentage of learners (from the main study) who gave each response is shown.

5.3.1. Learners' Conceptions about Day and Night

Day and night are caused by

- Rotation of the Earth (7%). These learners did not mention the Earth's axis in their explanations.
- Movement of the Earth (not specific) (8%). These learners did not mention the Earth's axis in their responses.
- Movement of the Earth and the Sun (8%)
- Movement of the Sun (8%)
- The shapes of the Earth and the Sun (5%)

The Sun *moves*

- To fulfill human and other needs (36%)
- To show different times of day, *e.g.* morning and evening (17%)

The moon can be seen during the day (3%)

The moon cannot be seen during the day because

- The moon disappears (22%)
- Sunlight obscures the moon (8%)
- The moon changes colour/shape (10%)
- The moon shines on other places that experience night (17%)

5.3.2. Learners' Conceptions about Seasons

Summer is hotter than winter because

- Days are longer in summer, and the Sun's rays are more direct (on the place that experiences summer) than in winter (7%)
- Of changing features of the Sun (25%):
    - More radiation in summer than winter
    - The Sun is closer to the Earth in summer than winter
    - There is no Sun in winter
- Summer is the growing season (14%)
- Of change in weather conditions (46%)

The southern hemisphere experiences summer when the northern hemisphere experiences winter because

- Of rotation of the Earth (10%)
- Of positions of sunrise (14%)
- The two hemispheres are different (19%)
- The two hemispheres are in different locations (12%)
- The two hemispheres have different temperatures (27%)

Day-time is equal to night-time in places along the tropic of Capricorn when

- The Sun is overhead at the equator at noon (3%)
- The Sun is overhead at the tropic of cancer at noon (5%)
- The Sun shines on a flat Earth (8%)

All learners could not state that the diagram (question 4, appendix 2) shows a date for December solstice. They mentioned many dates from January to December, but none gave 21st or 22nd December.

Only 37% of learners (correctly) stated that the angle of the Sun's rays at location C (question 4, appendix 2) is 90^{o}, but they all gave scientifically unacceptable explanations for this, *e.g.* "*the Sun is always very hot*".

All learners were not aware that the Sun is never overhead in a place located south of the tropic of Capricorn. They believed that the Sun would be overhead at this place in certain months or seasons.

All learners did not give a scientifically acceptable reason for the changing positions of sunrise and sunset between summer and winter. Examples of given responses are:

- Summer is hot (22%)
- Seasons have to be different (17%)
- Duration of day-time differs (7%)
- The Sun moves at different rates (8%)
- The Earth rotates (8%)
- Weather affects the positions of sunrise and sunset (5%)

Learners said a leap year comes once in every four years because of:

- A quarter day that remains each year, added once in four years to make an extra day (2%)
- Rotation of the Earth (5%)

- Anthropomorphic causes (17%)
- Other causes, *e.g.* months, moon, *etc.* (12%)

5.4. RECOMMENDATIONS

The research findings show that learners have many alternative conceptions despite the learning they have undergone, and detailed explanations and activities given in their text books. The following might be the possible causes for the lack of scientific understanding in learners:

- Teachers might not be competent with the topic, since the content area **Planet Earth and Beyond** is new in the natural sciences[*].
- Teachers might have not used three-dimensional models when teaching the topic.
- Learners' attention might have not been drawn to information presented in the textbooks used in schools.

Based on the above possible causes of alternative conceptions, the following recommendations are made:

- Some in-service training courses should be offered to teachers, to increase their understanding of scientific concepts
- Learners should be encouraged to use their textbooks, and to follow activities prescribed in these books.
- Some 3-dimentional models should be used when teaching the topic, *e.g.* objects of different sizes can be used to represent the Earth, the Moon and the Sun.

[*] The content area **Planet Earth and Beyond** was part of Geography, not natural sciences in the former curriculum, *i.e.* before Curriculum 2005 and Revised National Curriculum Statement.