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Day/night Cycle: Mental Models of Primary School Children

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ABSTRACT The study investigated the mental models of primary school children related to the day/night cycle. Semi-structure interviews were conducted with 40 fourth-grade and 40 sixth-grade children. Qualitative and quantitative analysis of the data indicated that the majority of the children were classified as having geocentric models. The results also indicated that a large number of primary school children did not appropriately conceptualize the essential prerequisites for understanding the day/night cycle, and that their observational skills were limited. It was also concluded that children's age (class) and their mathematical achievement were good predictors for the quality of their mental models.

KEYWORDS: Alternative conceptions, day/night cycle, mental models.

Introduction

Research studies have well documented that students form ideas and reasonable explanations about several physical phenomena, long before they enter the primary school classes (Dykstra, Boyle, & Monarch, 1992). Constructivist perspectives of knowledge development (Tobin, 1993) offer an explanation for the origin of student alternative conceptions (Strike & Posner, 1992; Vosniadou, 1994). Gunstone, Gray, and Searle (1992) clearly stated that children idiosyncratically construct their own meanings from sensory inputs, and that the different conceptions, so commonly found, are the outcomes of this personal construction process. Children develop ideas and beliefs about the natural world through their everyday life experiences stemming from sensory experiences, language experiences, cultural background, peer groups, mass media, as well as from formal instruction (Duit & Treagust, 1995).

These initial ideas have been described by many terms, such as, misconceptions, pre-conceptions, alternative conceptions, and alternative frameworks (Wandersee, Mintzes, & Novak, 1994). Vosniadou (1994) regards misconceptions to be spontaneous constructions, which are often generated on the spot, and are not deeply held specific theories. These conceptions arise as "individuals attempt to assimilate new information into existing conceptual structures that contain information contrary to the scientific view" (Vosniadou, 1994, p. 45).

Student alternative conceptions that are grounded on everyday experiences are often strongly held and resistant to change (Driver, 1989; Driver & Easley, 1978;

Osborne & Freyberg, 1985), even when a sound teaching method or a carefully designed instructional intervention is employed (Driver & Oldham, 1986; Vosniadou, 1991; Duit, 1994). Thus, students may undergo instruction in a particular science topic, do reasonably well in a test on this topic, but without changing their original ideas on this topic, even when these ideas are in conflict with the scientific concepts they are taught to them (Fetherstonhaugh & Treagust, 1992). Duit and Treagust (1995) attributed this resistance to students being satisfied with their own conceptions and, therefore, seeing little value in the new concepts. It seems that students look at the new learning material "through the lenses of their preinstructional conceptions" (Duit & Treagust, p. 47) and may find the new material incomprehensible. Osborne, Bell, and Gilbert (1983) stated that students often misinterpret, modify, or reject scientific viewpoints based upon the way they really think about how and why things behave, and it is not surprising that students may persist almost totally with their existing views (Treagust, Duit, & Fraser, 1996). When the students' existing knowledge prevails, the science concepts are rejected or there may be misinterpretation of the science concepts to fit or even support their existing knowledge structure. Posner, Strike, Hewson, and Gertozog (1982) argued that in order to foster conceptual change and therefore enhance conceptual understanding, students need to experience cognitive conflict and consequent dissatisfaction with their existing ideas, and must also understand the fruitfulness of the new explanations.

A domain of Natural Sciences in which, for example, students develop their own mental models based on the experiences of daily life is astronomy, and especially an astronomical phenomenon called the day/night cycle. Thus, the main purpose of the present study was to investigate the extent to which primary school children understand the major concepts relating to the day/night cycle. The research also examined the differences between fourth- and sixth-grade children and between boys and girls, and to what extent factors, such as, children's gender, class, language and mathematical achievement, and their father's and mother's educational background could explain their understanding of the day/night cycle.

Literature Review

Piaget (1929) using clinical interviews proposed a developmental sequence of four stages through which children's understanding of the day/night cycle is developed. Children belonging to the first stage consider that the need to sleep constitutes the precursor and the cause of night, and, in reality, they are not interested in explaining the phenomenon. At the second stage, children begin their efforts to state the causes of the day/night cycle stating, for example, that night is caused by a big and black cloud, or that night is produced by 'black air.' At the third stage, children attribute the alternation of day and night to the obstruction of sun rays caused by various factors, and, finally, at the fourth stage, the children conceive that night is caused exclusively by the disappearance of the sun, due to its movement or to the movement of other celestial bodies.

Klein (1982) examined the conceptions of 24 7-8-year-old American children about various astronomical phenomena, including the day/night cycle. She found

that the majority of children had not understood that the alternation of day and night is caused by the earth's rotation around its axis. Sadler (1987) investigated the ideas of 25 ninth-grade students about the day/night cycle. This study revealed the following five distinct explanations of the reasons relating to the alternation of day and night: (a) the earth spins, (b) the sun moves around the earth, (c) the moon blocks out the sun, (d) the sun goes out at night, and (e) the atmosphere blocks the sun at night.

Jones, Lynch, and Reesink (1987) conducted clinical interviews to examine the conceptions of 20 9-12-year-old Tasmanian children about the day/night cycle. They found that these children constructed five different mental models to explain the day/night cycle. These models were classified in two qualitatively different categories, geocentric and heliocentric models. Baxter (1989) also conducted individual interviews about the phenomenon of day/night cycle with 100 9 to 16 years old children from five schools in Great Britain. Baxter (1989) classified children's conceptions for the phenomenon into six different perceptual levels. The schema that was developed by Baxter (1989) constituted a synthesis of the work of Piaget (1929) and Jones et al. (1987).

Some other studies (Vosniadou & Brewer, 1992, 1994) investigated children's cosmological knowledge and concluded that children construct a small number of well-defined mental models for explaining the day/night alternation. They also reported that the majority of children had coherent day/night explanations and they were applying their models in a consistent way, while they differentiated among three types of models, that is, intuitive (or initial) models, synthetic models, and scientific models. More specifically, initial models are constructed from observations of everyday life; synthetic models constitute attempts to integrate scientific and everyday information; and scientific models that represent the scientific explanation of the phenomenon.

Several cross-cultural studies that were conducted in Samoa, India, Greece, and among native Indian-American children in South Dakota indicated that children in different parts of the world form almost identical mental models of the earth and the day/night cycle (Brewer, Hendrich, & Vosniadou, 1987; Samarapungavan, Vosniadou, & Brewer, 1996; Diakidoy, Vosniadou, & Hawks, 1997). Based on this conclusion, Vosniadou, Skopeliti, and Ikospetaki (2004) claimed that the developmental sequence of mental models, from intuitive through synthetic, and finally scientific, is universal.

Several other studies (Osborne, Wadsworth, Black, & Meadows, 1994; Valanides, Gristi, Kampeza, & Ravanis, 2000) have provided strong evidence that students, teachers, and even kindergarten children can be moved to the scientific explanation of the phenomenon, after appropriate teaching interventions that take into account their alternative conceptions regarding the phenomenon as well as their conceptual understanding.

Methodology

The study sample consisted of 40 fourth-grade and 40 sixth-grade children with equal numbers of boys and girls. Individual semi-structure interviews were admini-

stered to all the children. The interview raised questions about the cause of the day/night cycle, and the duration of the day and night. Each interview, which lasted about 15-25 minutes, was tape-recorded and transcribed for further analysis. Sixth-grade children were taught the day/night cycle approximately six months prior to the conduction of the research, but fourth–grade children were not.

Results

Qualitative Analyses

The Constant Comparative Analysis method (Glaser & Strauss, 1967; Strauss & Corbin, 1990) was employed to analyze the data. Using this approach, three rubrics were developed. The first rubric concerned the mental models of the day/night cycle, the second the duration of the day (and night), and the third students' explanations concerning the duration of the day (and night).

Thus, is in-depth analysis of the interviews indicated that the participating children constructed a variety of 18 mental models to explain the day/night cycle. These models were classified in three qualitatively different categories: pre-geocentric models, geocentric models, and heliocentric models. This classification of students' mental models for the day/night cycle deviates from the usual way in which mental models relating to the day/night cycle are classified. In the literature, students' mental models are usually classified either as geocentric and heliocentric, or as intuitive, synthetic, and scientific. Table 1 shows the distribution of the identified mental models among the children who participated in the present study, while a complete list of these models and their characteristics is presented in Appendix A.

Table 1
Mental Models of Children by Grade (Age)

	Mental Models		
	Pre-Geocentric Models (P-GM	Geocentric Models (GM)	Heliocentric Models (HM)
Fourth-grade children	5	28	7
Sixth-grade children	2	31	7
Total	7	59	14

The information in Table 1 clearly indicates that the majority of the participating children (n=59) were classified as having GM. Even the majority of the sixth-grade children (n=31) adopted GM to explain the day/night cycle, despite the fact that the phenomenon and its explanation had been taught to them approximately six months ago, while only three students adopted the scientific model.

Pre-Geocentric Models (P-GM): Four mental models were classified as pre-geocentric models (P-GM) although some researchers, i.e., Samarapungavan et al., (1996), classified some of these as geocentric models (GM). In these four models, the earth was placed between the sun and the moon, but the movements of the sun

and the moon were not consistent with the geocentric model. In geocentric models, the earth is the centre of the solar system, and the sun and the moon are orbiting the earth, while the three celestial bodies are considered to be spherical. On the contrary, in P-GM the earth is placed between the sun and the moon, but it is considered to be flat, while there is only day (or only night) across the whole earth, and the moon is considered as a self-luminous object, as indicated in Appendix A. One of the P-GM was also identified for the first time (Mental model 3).

In P-GM, the alternation of day and night was explained in three different ways: (a) based on an instant movement of the clouds (Model 1), (b) based on an instant and conjoint motion of the sun and the moon (exchange of places) (Models 2 and 4), and (c) based on an instant movement of the sun (going up and down) (Model 3).

"Instant movement" is considered the movement of the sun and the moon, when they do not continue moving beyond two specific times every 24 hours, when day changes into night, and then when night changes again into day. "Conjoint motion" is considered the movement of the sun and the moon, when their movements are not independent, but any movement of one of them presupposes the simultaneous and corresponding movement of the other. In the relevant literature, similar movements were not identified, or even, if they were identified, they were described using other terms (i.e., hydraulic model).

Geocentric Models (GM): Eight mental models were classified as geocentric models (GM) (Appendix A), and two of them were identified for the first time (Models 7 and 10). In GM, the earth was considered to be the centre of the solar system, and the students who adopted GM (n=59) conceptualized the earth as a spherical object, but they did not use the concept of spherical earth consistently. In addition, all these children accepted that day exists only on the hemisphere that is illuminated by the sun rays, and the majority of them (n=43) stated that the moon is a self-luminous object that is absolutely necessary for night to exist Thus, these children believed that if the moon were to disappear due to some reasons, then there would be continuous day across the globe (they considered the earth to be flat) (n=19), or the night without the moon would be totally different, because there would be absolute dark on earth (n=24).

The GM were classified into two different categories. Six mental models were placed in the first category, where the sun and the moon are placed in diametrically opposite sides of a stationary earth (Models 5-10). The alternation of day and night was explained by the movements of the sun and the moon in two different ways. Some students (n=16) thought that the sun and the moon move in an "instant" and "conjoint motion" at two predetermined moments, so that day changes into night and then night changes into day again (Models 5-8). Some other students (n=15) thought that the sun and the moon are orbiting in a simultaneous and "conjoint motion" around the earth, but only three of them seemed to conceptualize the progression of day and night (morning, midday, afternoon, midnight etc.) (Models 9 and 10).

Two other mental models were placed in the second category (Models 11 and 12). In these mental models, the sun was considered to be stationary and the earth

to rotate around its axis, while the self-luminous moon was either stationary (n=27) or was orbiting around earth (n=1). In this category of mental models, the day/night cycle was explained by the rotation of earth around its axis.

Heliocentric Models (HG): Six mental models were classified as heliocentric models (HM) (Models 13-18), while one of the HM was identified for the first time (Model 13). Thus, the sun was placed in the centre of the solar system and all the students (n=14) accepted that the earth is a spherical body that is rotating around its axis. Consequently, they explained that day exists only on the hemisphere that is illuminated by the sun rays travelling in straight lines. All these children attributed the day/night cycle to the rotation of the earth around its axis.

The HM were also classified in two different categories. For the two mental models in the first category (Models 13 and 14), the sun and the self-luminous moon were considered to be stationary, while the earth was simultaneously rotating around its axis and revolving either around the two celestial bodies or, successively, first around the sun and then around the moon forming a helical curve. All the children (n=4) accepted that the moon is a self-luminous body and that it is absolutely necessary for the existence of night on earth.

Four other mental models were placed in the second category (Models 15-18). In these mental models, the earth was considered to simultaneously rotate around its axis and revolve around the stationary sun, while the moon was considered to be stationary, to be revolving around the earth or to be moving in a "conjoint motion" with the earth. The majority of these children (n=7) suggested that the moon is a non-luminous body and not necessary for the existence of night on earth.

Based on these results, it seems that the sixth-grade children who participated in the study constructed synthetic models and that the teaching did not take into consideration their existing preconceptions about the day/night cycle. The results also indicate that a large number of the participating children did not appropriately conceptualize the essential prerequisites for correctly understanding the day/night cycle. Some children provided explanations indicating that they did not conceptualize the earth as a spherical object and considered it to be flat, having the properties of any other physical object. Other children (n=31) claimed that the earth is always rotating around its axis, but they did not attribute the day/night cycle to this movement. On the contrary, most of them (n=57) thought that the moon is a self-luminous object that it is absolutely necessary for the night to exist. These children believed that if the moon were to disappeared due to any reason, there would be only day across the whole earth that was considered as being flat (n=23), or that night without the moon would be quite different, because there would be absolute dark on earth (n= 34).

Day/night Cycle Duration: The participating students also faced a lot of difficulties in correctly estimating the total duration of the day/night cycle The majority of the children (n= 62) reported that the duration of day/night cycle is 24 hours, but there were also children that could not report the duration of the cycle (n= 10), while other children (n= 8) stated that the duration of the day/night cycle is unchangeable (i.e., the duration of the day is always equal with the duration of

the night or that the duration of the day is always bigger than the duration of the night) and different from 24 hours (i.e., 12, 16, 30, or 48 hours).

Most of the children could not connect the duration of day (and night) with the seasons and none of the children provided correct explanations for the continuously changing duration of the day (night) that is related to the earth's tilt. Some children (n=17) attributed the duration of the day and night to the change of time (i.e., daylight savings) twice a year during spring and autumn. Other children (n=15) provided explanations based on physical phenomena (i.e., heat, ozone hole, solar radiation, and clouds), and the movement of the earth, the sun and the moon (n=19). Also, 29 children did not provide any explanation for the changing duration of day and night through out a year.

A more detailed analysis of children's explanations about the day/night cycle indicated that a lot of them faced several constraints in their thinking, due to their level of cognitive development. For example, some children (n=11) thought that the speed of earth's rotation around its axis is not always constant, and considered that one hemisphere can turn faster than the other one, or that the earth is accelerated or decelerated mysteriously (7 children), while others (n=5) did not conceive that the bigger duration of day has as a result the smaller duration of the night, and vise-versa.

Children's Observational Skills: It was also obvious that children's observational skills were limited. Thus, many children (n=43) did not even observe either the phenomenal movement of the sun on the sky during the day (they state that the sun is stationary) or the appearance of the moon at different points on the sky both during day (n=42) and night (n=37).

Quantitative Analyses

The three rubrics that had been developed using the Constant Comparative Analysis method (Glaser & Strauss, 1967; Strauss & Corbin, 1990) were also used to quantify the data and proceed to statistical analyses as well. For the quantitative analysis, numerical values were attributed to the levels of each rubric, which represented the performance of each student on the corresponding variable, while the sum of the scores on the three rubrics constituted their total performance. For the first rubric, that consisted of the 18 progressively and qualitatively better mental models relating to the day/night cycle (Appendix A), scores from 1-18 were assigned depending on the mental model constructed by each individual student. Thus, score 1 was assigned to the most incomplete mental model (mental model 1) and score 18 was attributed to the scientific model (mental model 18). In addition, each student was given one additional point, if he had realized that the moon is a non-luminous object, another one point if he had realized that the moon does not always appear during night, and another point, if he had observed the appearance of the moon on the sky during day. The overall performance for this variable was 1-21. Rubric 2, consisted of 5 levels, and children´s performance ranged from 0-4, as indicated in Table 2. Similarly, rubric 3 consisted of 5 levels and children's performance ranged from 0-4, as indicated in Table 3, while their total performance ranged from 1-29.

Table 2
Rubric 2: (Duration of the Day/night Cycle and Duration of Day and Night)

Levels	Levels/ Score
• Do not know the total duration of the day/night cycle	0
• The total duration of the day/night cycle is different from 24 hours • The duration of the day/night cycle changes	1
• The total duration of the day/night cycle is 24 hours • Do not know whether the duration of the day/night cycle changes	2
• The total duration of the day/night cycle is 24 hours • The duration of day and night and the duration of the day/night cycle do not change.	3
• The total duration of the day/night cycle is 24 hours • The duration of day and night change, but the duration of the day/night cycle does not.	4

Table 3
Rubric 3: Explanation of the Day/night Cycle

Levels	Levels/ Score
• Do not know the duration of the day/night cycle	0
• The duration of the day/night cycle is different from 24 hours • The duration of the day/night cycle changes	1
• The duration of the day/night cycle is 24 hours • Do not know whether the duration of day and night changes	2
• The total duration of the day/night cycle is 24 hours • The duration of the day and night and the duration of the day/night cycle do not change.	3
• The total duration of the day/night cycle is 24 hours • The duration of the day and night change, but the duration of the day/night cycle does not	4

Differences in Children's Performance

ANOVA 2 (gender) x 2 (grade level) with children's total performance as the depended variable was initially performed. Table 4 presents the results of this analysis.

Table 4
ANOVA 2 (Gender) Ã 2 (Class) with Children's Total Performance as the Depended Variable

Variable	*SS*	df	MS	*F*	Level of Significance
Gender	143,113	1	143,113	0,144	0,706
Class (Grade level)	3,612	1	3,612	5,692	0,020*
Gender x Class	10,513	1	10,513	0,418	0,520
Error	1910,956	76			
Total	22071,000	80			

* *p*.<0,05

The results in Table 4 indicate that sixth-grade students had significantly higher total performance than fourth-grade students, F (1, 76) =5,692, *p*. <0.02, while there were no other significant differences. Nevertheless, children's mean total performance was rather small, 17,15 and 14,48, for sixth- and fourth-grade students, respectively, indicating the limitations of their understanding of the day/night cycle.

A 2 (gender) x 2 (class) MANOVA, with children's performance on each dimension (mental models, duration of day and night, and explanation of the day/night cycle) as the dependent variables, was then conducted. Table 5 shows the results of MANOVA.

The results in Table 5 clearly indicate that significant differences existed only between sixth- and fourth-grade children's performance relating to their mental models about the day/night cycle, F (1, 79) =5,280, *p*. <0, 05. Nevertheless, children's mean performance relating to their mental models about the day/night cycle was 10,62 and 8,58, for sixth- and fourth grade children, respectively, indicating that sixth-grade students adopted more advanced mental models than fourth-grade children who mainly adopted P-GM and GM. Sixth-grade children also adopted mainly GM that were qualitatively more advanced than those adopted by fourth-grade children.

Multiple regression analysis with children's total performance as the dependent variable, using the stepwise method, indicated that 18,3% of the total variance of students' total performance could be explained by their grade level (age) and their mathematical achievement.

Table 5
2 (Gender) x 2 (Class) MANOVA with Children's Performance on Each Dimension of the Day/night Cycle as the Three Dependent Variables

Variable	Dependent Variable	*SS*	df	MS	*F*	Level of Significance
Gender	Mental Model	84,050	1	84,050	0,013	0,911
	Duration of the Day/night Cycle	2,813	1	2,813	0,231	0,632
	Explanations of the Day/night Cycle	0,500	1	0,500	0,000	1,000
Class	Mental Model	0,200	1	0,200	5,280	0,024*
	Duration of the Day/night Cycle	0,125	1	0,125	0,411	0,523
	Explanations of the Day/night cycle	0,000	1	0,000	0,041	0,839
Gender x Class	Mental Model	11,250	1	11,250	0,707	0,403
	Duration of the Day/night Cycle	1,013	1	1,013	0,411	0,523
	Explanations of the Day/night cycle	0,450	1	0,450	0,373	0,543
Errol	Mental Model	1207,700	76	11,250	0,707	0,403
	Duration of the Day/night Cycle	171,050	76	1,013	0,411	0,523
	Explanations of the Day/night cycle	91,700	76	0,450	0,373	0,543
Total	Mental Model	8678,000	80	11,250	0,707	0,403
	Duration of the Day/night Cycle	975,000	80	1,013	0,411	0,523
	Explanations of the Day/night cycle	310,000	80	0,450	0,373	0,543

* p. <0,05

Discussion and Implications

The results of the present study clearly point out that the day/night cycle and its correct conceptualization is much more complex than what teachers, authors of textbooks, and curriculum designers think that it is. The results indicate that both fourth- and sixth-grade children face many difficulties in their effort to understand and explain the day/night cycle. Taking into consideration that sixth-grade children had already been taught the day/night cycle, it seems that their teachers did not take into consideration either child's alternative conceptions for the phenomenon or the essential prerequisites for understanding the day/night alternation, and that teaching was rather restricted to delivering canned and thus inert knowledge. These findings underscore the potential impact of instruction on restructuring learners' initial conceptions, and confirm the claims of several researchers (Posner, Strike, Hewson, & Gertzog,1982); Pines & West, 1986; Vosniadou,1991) concerning the kind of instruction that is more likely to facilitate conceptual change. Similarly, Schmidt (1997) pointed out that the identification of children's

alternative conceptions about various astronomical phenomena, and more specifically for the alternation of day and night, has the potential to improve considerably the teaching/learning process. Teaching interventions that took into consideration children's alternative conceptions reported encouraging results (Osborne et al., 1994; Valanides et al., 2000, Taylor et al., 2003). Consequently, teachers should not only know the mental models that students construct for the day/night cycle by examining the relevant literature, but they must also develop several ways to detect the mental models and the alternative conceptions of their students, and take them into consideration when planning their teaching interventions.

The results also indicate that there are some essential prerequisites for understanding the day/night cycle and its duration, such as: (a) earth has a spherical shape, (b) the day/night is caused exclusively by the earth's rotation around its axis, (c) it is impossible to have only day or only nigh across earth, (d) the earth's axis is tilted, (e) the moon is a non-luminous body, and is not related with the day/night cycle, (f) both luminous and non-luminous objects emit light rays that travel in straight lines.

Additional research efforts should be also designed to identify the hierarchical relations among these concepts, and identify both an appropriate teaching sequence and the corresponding age for effectively teaching each concept. Obviously, any prerequisite concepts relating to the day/night cycle should be taught earlier, and any preconceptions should be taken into account for designing learning environments that can foster conceptual understanding of the day/night cycle and its explanation.

Teachers must also pay attention to their students' observational skills, and how to organize observational data and be able to abstract information from data, by involving children in relevant activities both inside and outside the school. Schur, Galili, and Valanides (2005) stressed that children's ability to proceed in meaningful and systematic observations of the various astronomical phenomena is a basic condition for the understanding of many astronomical concepts, because it constitutes the first step for any generalisation in their understanding.

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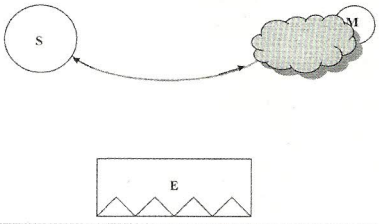
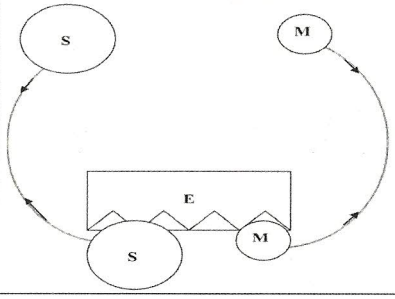
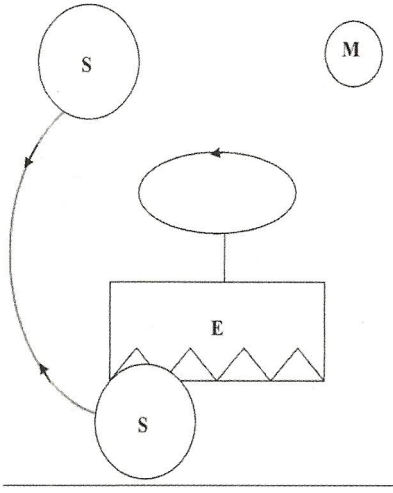
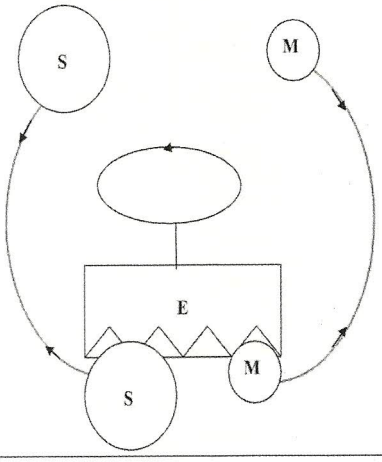
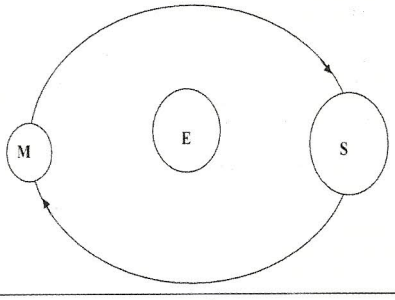
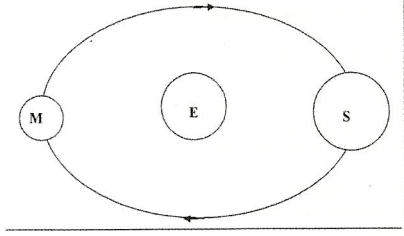
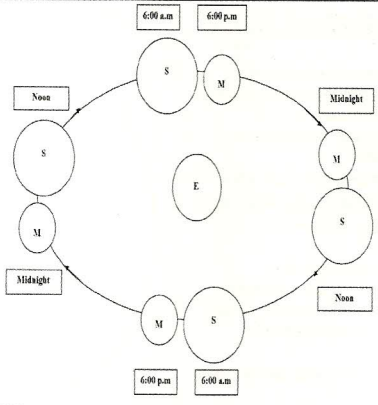
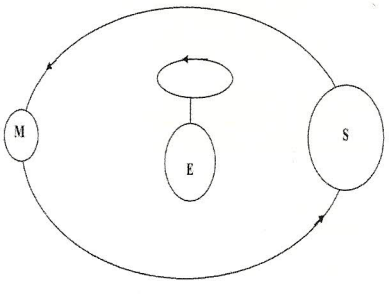
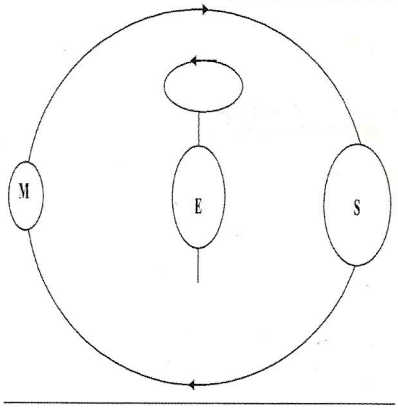
Appendix A
The Identified Mental Models of the Day/Night Cycle.

A/A	Mental Models		Number of children	
	Basic characteristics	Shape	Fourth-grade	Sixth-grade
	Pre-Geocentric Models ▪ The earth is flat ▪ The moon is a self-luminous object ▪ There is only day or only night across the whole earth ▪ The majority of the children though that the moon is absolutely connected with the existence of night. ▪ The day/night cycle is explained based on an instant movement of the clouds or an exchange of positions between the sun and the moon.			
1	▪ The sun, the moon and the earth are stationary. ▪ The alternation of the day and night is explained by the instant movement of the clouds. ▪ The moon is not connected with the existence of the night.		1	0
2	▪ Only the earth is stationary.* ▪ The sun and the moon move twice a day in an instant and conjoint motion, so that day changes into night and then night into day again. at ▪ The moon is absolutely connected with the existence of the night.*		2	0
3	▪ The earth is rotating around its axis.* ▪ The moon is stationary. ▪ The moon is not visible during the day, because of the brilliant sun. ▪ Only sun moves.* ▪ The sun moves instantly twice during ▪ The day/night cycle is not attributed to the earth's rotation around its axis. ▪ the day/night cycle is explained based on an instant movement of the sun (going up and down). ▪ The moon is absolutely connected with the existence of the night.		0	1

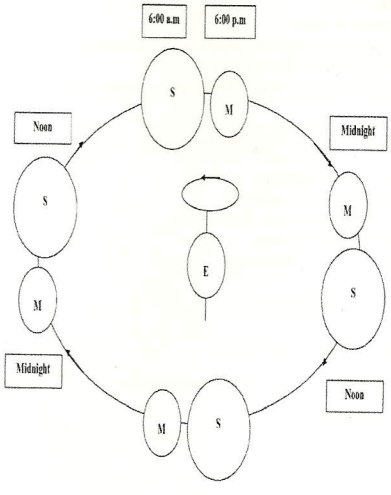
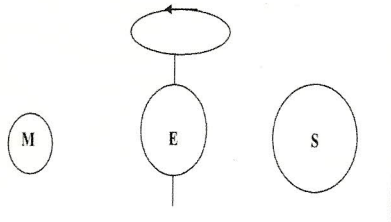
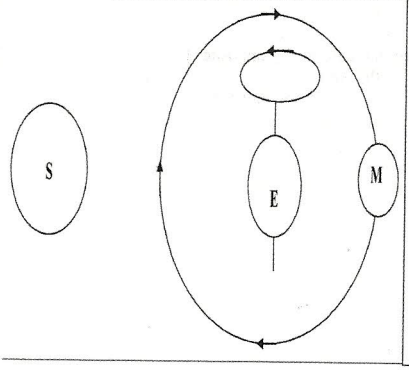
Appendix A (continued)

A/A	Mental Models		Number of children	
	Basic characteristics	Shape	Fourth-grade	Sixth-grade
4	▪ The earth is rotating around its axis. ▪ The day/night cycle is not attributed to the earth's rotation around its axis. ▪ Only the sun and the moon move.* ▪ The sun and the moon move twice during the day/night cycle (an instant and conjoint motion.)* ▪ The day/night cycle is explained by an instant and conjoint motion of the sun and the moon (exchange of positions). ▪ The moon is necessary for night to exist.		2	0
Geocentric Models ▪ The earth is considered to be a spherical body. ▪ The moon is a self-luminous object and necessary for night to exist. ▪ Day exists only in the hemisphere, which is illuminated by the sun rays.				
5	▪ The sun and the moon are placed in diametrically opposite sides of the stationary earth.* ▪ The sun and the moon move in an instant, and "conjoint motion" twice during the day/night cycle ▪ The day/night cycle is explained based on the movements of the sun and the moon.		5	3
6	▪ The sun and the moon are placed in diametrically opposite sides of the stationary earth. ▪ The sun and the moon move in a continuous, and "conjoint motion".* ▪ The day/night cycle is explained based on the movements of the sun and the moon.		5	1

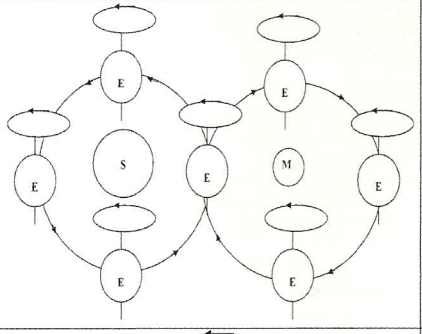
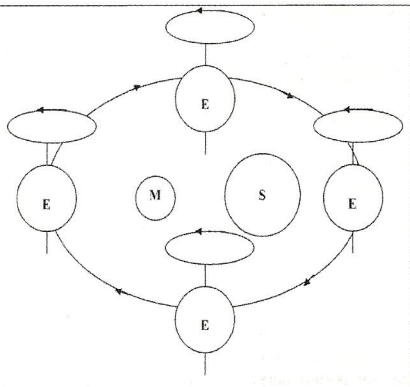
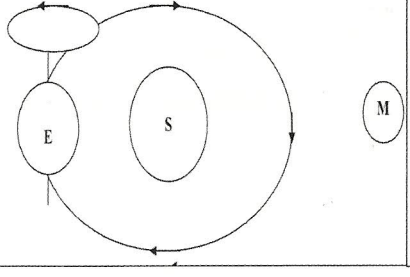
Appendix A (continued)

A/A	Mental Models		Number of children	
	Basic characteristics	**Shape**	**Fourth-grade**	**Sixth-grade**
7	▪ The sun and the moon were placed in diametrically opposite sides of the stationary earth. ▪ The sun and the moon move in a simultaneous and "conjoint motion". ▪ The alternation of the day and night is explained based on the movements of the sun and the moon. ▪ The children make efforts to explain the progressively of day and night (morning, midday, afternoon and midnight).* ▪ The moon is absolutely connected with the existence of the night.		1	1
8	▪ Earth is rotating around its axis. * ▪ The alternation of the day and night is not attributed to the earth's rotation. ▪ The sun and the moon are placed in diametrically opposite sides of the earth. ▪ The sun and the moon move in an instant and "conjoint motion"* . ▪ The alternation of the day and night is explained based on the movements of the sun and the moon		7	1
9	▪ Earth is rotating around its axis. ▪ The alternation of the day and night is not attributed to the earth's rotation. ▪ The sun and the moon are placed in diametrically opposite sides of the earth. ▪ The sun and the moon move in a continuous, simultaneous and "conjoint motion" around the earth.* ▪ The alternation of the day and night is explained based on the movements of the sun and the moon. ▪ The moon is absolutely connected with the existence of the night. ▪		3	3

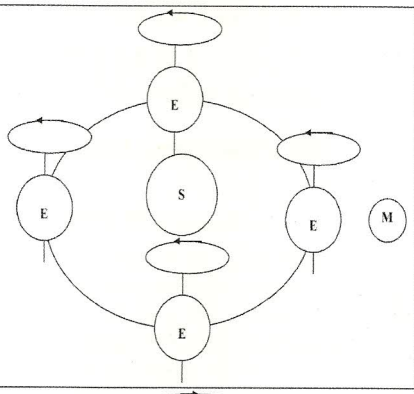
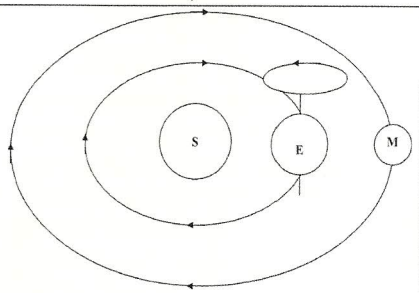
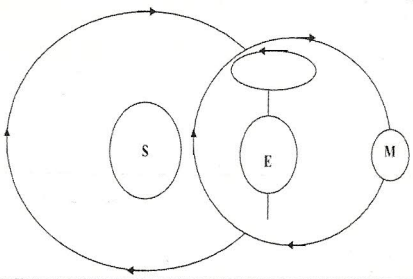
Appendix A (continued)

A/A	Mental Models		Number of children	
	Basic characteristics	Shape	Fourth-grade	Sixth-grade
10	▪ Earth is rotating around its axis. ▪ The alternation of the day and night is not attributed to the earth's rotation. ▪ The sun and the moon are placed in diametrically opposite sides of the earth. ▪ The sun and the moon move in a continuous, simultaneous and "conjoint motion" around the earth. ▪ The child makes efforts to explain the progressively of day and night (morning, midday, afternoon and midnight).* ▪ The alternation of the day and night is explained based on the movements of the sun and the moon. ▪ The moon is not connected with the existence of the night. ▪ The moon is not a self-luminous object.		1	0
11	▪ Earth is rotating around its axis. ▪ The alternation of the day and night is attributed to the earth's rotation. ▪ The sun and the moon are stationary in diametrically opposite sides of the earth.* ▪ The alternation of the day and night is explained based on the earth's rotation around its axis.*		6	21
12	▪ Earth is rotating around its axis. ▪ The alternation of the day and night is attributed to the earth's rotation. ▪ Only the sun is stationary. ▪ The moon is orbiting around the earth.* ▪ The alternation of the day and night is explained based on the earth's rotation around its axis ▪ The moon is a self-luminous object. ▪ The moon is absolutely connected with the existence of the night.*		0	1

Appendix A (continued)

A/A	Mental Models		Number of children	
	Basic characteristics	Shape	Fourth-grade	Sixth-grade
Heliocentric Models ▪ The earth is a spherical body. ▪ Day exists only in the hemisphere which is illuminated by the sun rays. ▪ The earth is rotating around its axis. ▪ The day/night cycle is attributed to the rotation of the earth around its axis.				
13	▪ Earth is simultaneously rotating around its axis and revolving successively, first around the sun and then around the moon, forming a helical curve.* ▪ The sun and the moon are stationary.* ▪ The moon is a self-luminous object. ▪ The moon is necessary for night to exist. ▪		2	0
14	▪ Earth is simultaneously rotating around its axis and revolving around the sun and the moon. ▪ The sun and the moon are stationary.* ▪ The child makes efforts to explain the progression of day towards night (morning, midday, afternoon and midnight).* ▪ The moon is a self-luminous object. ▪ The moon is necessary for night to exist. ▪		1	1
15	▪ Earth is simultaneously rotating around its axis and revolving around the sun.* ▪ The sun and the moon are stationary. ▪ The moon is not a self-luminous object. ▪ The moon is not necessary for night to exist.		0	2

Appendix A (continued)

A/A	Mental Models		Number of children	
	Basic characteristics	Shape	Fourth-grade	Sixth-grade
16	▪ Earth is simultaneously rotating around its axis and revolving around the sun. ▪ The sun and the moon are stationary. ▪ The children make efforts to explain the progression of day towards night (morning, midday, afternoon and midnight).* ▪ The moon is not a self-luminous object. ▪ The moon is not necessary for night to exist.		1	1
17	▪ Earth is simultaneously rotating around its axis and revolving around the sun. ▪ Only the sun is stationary. ▪ The moon is revolving around the sun and the earth.* ▪ The moon is a self-luminous object. ▪ The moon is necessary for night to exist.		1	0
18	▪ It is the scientific model. ▪ Earth is simultaneously rotating around its axis and revolving around the sun. ▪ Only the sun is stationary. ▪ The moon is orbiting around the earth.*		2	3

*Shows the characteristic of the mental model which is different from the previous one.