"Distance dependence" or "Angle of sun rays Incidence dependence"? The Design of an Experimental Device for teaching about Seasonal Change

Ioannis Starakis & Krystallia Halkia
Department of Primary Education, University of Athens
Nauarinou 13A, 10680, Athens, Greece
gstarakis@hotmail.com & kxalkia@primedu.uoa.gr

Abstract. *The present study focuses on the presentation of an experimental device which was designed for serving the purpose of teaching about Seasonal Change.*
Late bibliography illustrates that students adopt mainly "Alteration in the distance between the Sun and the Earth" as a Scheme of explanation for the concerned phenomenon, no matter whether they have been taught its scientific model or not.
Bearing in mind that "dissatisfaction with existing conceptions" is a basic presupposition for conceptual change; students' initial Scheme of explanation about Seasonal Change must be confronted with the scientific one.
Therefore we designed an experimental device, using a model of the Earth, an illuminated model of the Sun and a photometer in order to check i) distance between the Sun and the Earth and ii) angle of the sun rays incidence on the Earth, as independent variables, concerning the prostrated radiation of light on the Earth.

Keywords. Conceptual Change, Photometer, Seasonal Change

1. Introduction

In the past three decades many researchers have examined children's and adults' ideas of basic astronomical events [1]. Some of these studies concerned Seasonal Change [2, 3, 4, 5, 6, 7, 8, 9]. The most common notion found, is the one which attributes the phenomenon to the variations in the distance between the Sun and the Earth. The basic root of this notion seems to be the everyday experience, according to which, the closer we come to a source of heat the warmer we feel [10].

According to bibliography "distance dependence" notion seems to be resistant to change, since students appear to hold it, no matter whether they have been taught the scientific model of the phenomenon or not.

Hsy [11] used a Technologically Enhanced Environment to promote second-year senior high school students' conceptual change about Seasons. Data analysis revealed that the "distance dependence" responses were doubled after the instructional approach.

Tsai and Chang [12] used the framework of cognitive "conflict map" to facilitate ninth grade student's conceptual learning about Seasonal Change and found that many of them, even after instruction, had a common alternative conception that Seasons were determined by the Earth's distance to the Sun. Moreover, according to the researchers, the target scientific concept was that Seasons are mainly caused by the Earth's 23,5degree inclination of its spinning axis. However, this tilt can explain Seasons either in the context of the scientific explanation or in the context of the "distance dependence" notion.

Starakis and Halkia [13] compared Seasonal Changes' conceptions of students who have never been taught the phenomenon before (k-5) with those of students who have been taught it twice (pre-service elementary teachers). They found a considerable increase of the corresponding percentages, from k-5 students to pre-service teachers as regards the "distance dependence" notion. Further analysis of the data revealed that as time passes after having been taught at school, students "embody" in this notion all parts of scientific knowledge *(Earth's elliptic orbit around Sun* and *Tilt of the Earth's rotational axis)* that can be assimilated, while they "reject" that part which cannot assimilated *(Angle of Sun rays incidence).*

The previously mentioned cases illustrate that "distance dependence" notion is resistant to change because teaching about Seasons does not step on the *'dissatisfaction with existing conceptions'* which is considered as a basic condition for conceptual change [14]. Therefore students have no reason to change their alternative view and incorporate into it declarative aspects of scientific knowledge. That is consistent with previous studies on how

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students embody the culturally accepted views to their initial models [15].

2. Seasons (the scientific model)

The Earth's spinning axis is not vertical to its revolution level around the Sun, but it forms a $23{,}5^{o}$ inclination, pointing always to the Polar Star. The combination of the Earth's inclination and revolution around the Sun, results in Seasonal Change. Specifically, during the Earth's revolution around the Sun, the hemisphere leaning towards the Sun is exposed to solar radiation more than the other since solar radiation prostrates more vertically to this hemisphere.

3. The present study

3.1. Theoretical framework

The present study is part of a broader research concerning the Sun-Earth-Moon system's relative movements from an educational point of view and is based on the "Model of Educational Reconstruction". In this model the understanding of students' perspectives and the interpretation of the scientific content, are closely linked, aiming at designing new teaching and learning sequences [16, 17].

Following the process of Educational Reconstruction, a preliminary analysis of the scientific content took place, followed by studies on students' conceptions about the Sun-Earth-Moon system's relative movements. These steps merged into the construction of a teaching and learning sequence which aims at investigating k-5 students' learning processes into the scientific model using the "Teaching Experiment" method. The basic idea of this method is to design an interview situation deliberately as a teaching situation [18]. Hence, the researcher acts either as an interviewer who tries to analyze students' notions, or as a teacher, who must make the appropriate teaching interventions when they are needed.

The concerned teaching and learning sequence consists of three sections: i) *Apparent Movement of the Sun* ii) *Apparent Movement of the Moon* and iii) *Seasonal Change*. For the purposes of this manuscript we focus on that part of the third section of the sequence which is seen through the eyes of the aforementioned '*dissatisfaction'* with the "distance dependence" notion.

3.2 The teaching and learning sequence

The third section of the teaching and learning sequence deals with Seasonal Change and it is mostly based on an experiment which was designed in order to simulate the prostration of solar radiation on different places of the Earth.

At the beginning of the sequence students are asked to answer the following question:
"*Why is it hotter in Summer than in Winter? How do you explain Seasonal Change on Earth?*"
(At this point it has to be stressed that k-5 students in Greece are not yet taught either of Earth's 23,5 degree inclination of its spinning axis or of Earth's rotating around the Sun)

The most popular reply according to previous pilot studies is that "*Seasons are determined by the Earth's distance to the Sun*".

Moreover students have to study a table (see Table 1) which displays the 24hour average temperatures in July of two (2) cities of the north hemisphere (Kiev and Khartoum) which are almost of the same longitude. They also observe these cities on a not inclined Earth globe (see Fig. 1) and then they are asked to interpret these data in the light of their "distance dependence" notion. Most of the students are expected to attribute the considerable difference in the average temperatures of Kiev and Khartoum to the fact that Khartoum, compared to Kiev, is situated closer to the Sun.

Table 1. Kiev's and Khartoum's temperatures

24hour Average Temperature	
CITY	*JULY*
KIEV *(UCRAINE)*	**19,4**
KHARTOUM *(SUDAN)*	**31,4**

Figure 1. Earth globe. The upper flag represents Kiev and the lower, Khartoum

Figure 2. An illuminated model of the Sun and an Earth globe (not inclined)

Figure 3. The photometer

Afterwards students operate an experimental device which is comprised of an illuminated model of the Sun, a not inclined Earth globe, set one (1) meter away from the Sun (see Fig.2), and a photometer (see Fig.3). The photometer is used as a means of measuring the difference between the prostrated "solar" radiation a) on Khartoum (see Fig. 4) and b) on Kiev (see Fig. 5).

Figure 4. Measurement of the prostrated "solar" radiation on Khartoum

Figure 5. Measurement of the prostrated "solar" radiation on Kiev

Right after these two (2) measurements: *i) the horizontal distance between the Sun and the chosen cities* (see Fig. 6 & 7) and *ii) the angle of the sun rays incidence on each city* (see Fig. 8 &9) are recognized and checked as independent variables, concerning the prostrated radiation of light on the Earth.

Figure 6. Checking distance as independent variable (a)

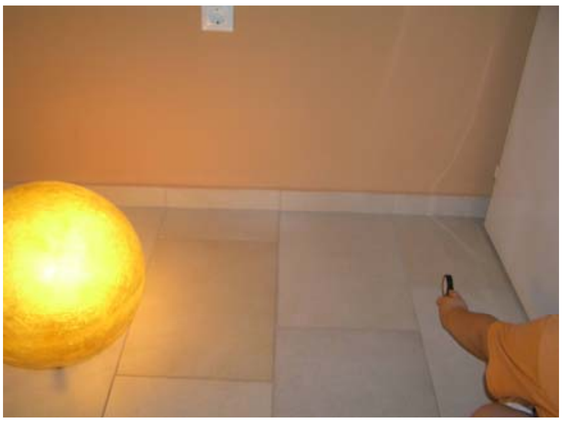

Figure 7. Checking distance as independent variable (b)

Through this procedure students are expected to become dissatisfied with their existing “distance dependence” notion and finally to reach the conclusion that the difference in the amount of the prostrated solar radiation on different places of the Earth is strongly connected with the difference in the angle of sun rays incidence.

Figure 8. Checking angle of sun rays incidence as independent variable (a)

Figure 9. Checking angle of sun rays incidence as independent variable (b)

To connect the previously mentioned conclusion with Seasons, students must study two (2) more tables (see Table 2 and Table 3) which display the 24hour average temperatures, both in January and July, of three (3) cities of the north and three (3) cities of the south hemisphere, respectively. These cities, by twos, are almost of the same latitude and longitude, (Norfolk and Concepcion, Tokyo and Adelaide, Cairo and Maseru). Students can also observe these cities on the same, not inclined, globe of the Earth (see Fig. 10) and then they are posed the following question:

“How would you set the Earth globe when it is Summer in the north and Winter in the south hemisphere, and vice versa?”

Students are expected to incline each hemisphere of the globe towards the Sun when it has Summer, on the basis of changing the angle of sun rays incidence on the Earth’s surface.

Table 2. 24hour average temperatures in North hemisphere

24hour Average Temperature of 3 cities of the North Hemisphere		
CITY	*JANUARY*	*JULY*
NORFOLK *(USA)*	**3,9**	**25,6**
TOKYO *(JAPAN)*	**3,6**	**24,6**
CAIRO *(EGUPT)*	**13,8**	**27,9**

Table 3. 24hour average temperatures in South hemisphere

24hour Average Temperature of 3 cities of the South Hemisphere		
CITY	*JANUARY*	*JULY*
CONCEPCION *(CHILE)*	**16,6**	**8,8**
ADELAIDE *(AUSTRALIA)*	**22,6**	**11,1**
MASERU *(LESOTHO)*	**23,5**	**8,5**

Figure 10. A not inclined Earth globe. Each flag represent one city of the North or South hemisphere

4. Conclusions

In this paper we described the design and the content of a teaching and learning sequence concerning Seasonal Change. The sequence is focused on the confrontation of students’ main alternative view (periodic alterations in the distance between the Sun and the Earth cause Seasons) with the scientific model through the use of an experimental device. The research is in full progress since pilot implementations of the sequence have already been completed and provided us with all the encouraging information needed in order to proceed with the central core of the "teaching experiments".

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