Addressing k-5 students' and pre-service elementary teachers' conceptions of seasonal change



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# Addressing k-5 students' and pre-service elementary teachers' conceptions of seasonal change

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**Abstract**

In this paper, primary school students' and pre-service teachers' ideas of seasonal change are investigated. The research was carried out in nine primary schools in Athens and in the Primary Education Department of the University of Athens. Written reports were used for gathering data while students also had the opportunity to support their answers with drawings. The results showed the following. (1) Pre-service teachers address notions which involve the movement of the Sun and/or the Earth, while primary school students address human centred, tautological and phenomenological notions as well. (2) Both primary school students and pre-service teachers mainly adopt two schemes of explanation: alterations in the distance between the Sun and the Earth and alterations in the Earth–Sun relative orientation/illumination.

## Introduction

In the past three decades many researchers have examined children's and adults' ideas of basic astronomical events (see Bailey and Slater 2004). Some of these studies have concerned seasonal change (Baxter 1989, Mant and Summers 1993, Sharp 1996, Atwood and Atwood 1996, Galili and Lavrik 1998, Parker and Heywood 1998, Trumper 2001, Frede 2006, Hsy 2008).

The most common results that can be extracted from these studies are the following.

- Young students address notions which involve near and familiar objects/phenomena (clouds, day length, weather phenomena, etc).
- As they get older they replace them with other notions which involve the movement of the Sun and/or the Earth.
- The most common notion is one which attributes seasonal change to variations in the distance between the Sun and the Earth (Baxter 1989).

However, in many cases, significant deviations are recorded among certain studies, either in the percentages or the existence of a notion itself, without any further justifications. For example, while in Baxter's (1989) and Trumper's (2001) studies, a high percentage of 15–16 year old students attributed seasonal change to the inclination of the Earth's spinning axis (around 50%), the corresponding percentage in Galili and Lavrik's (1998) study was just 20%.

This paper is part of broader research concerning the Sun–Earth–Moon system from an educational point of view and is based on the 'Model of Educational Reconstruction'. In this

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model the understanding of students' perspectives and the interpretation of scientific content are closely linked, aiming at designing new teaching and learning sequences (Duit *et al* 2005).

Consequently, our paper focuses on addressing and comparing seasonal change conceptions of students in Greece who have never been taught the phenomenon before (k-5 students) with conceptions of students who have been taught it twice (pre-service elementary teachers), not as a means of exploring obstacles to learning but as points to start from and mental instruments to work with in further learning (Duit and Treagust 2003).

## Seasons (the scientific model)

The Earth's spinning axis is not vertical to its revolution level around the Sun, but forms a 23.5° inclination, pointing always to the Polar Star. The combination of the Earth's inclination and its 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 arrives at this hemisphere more vertically.

## Seasonal change in the Greek curriculum

In the Greek educational system, seasons are taught either in elementary (sixth grade) or in high school (seventh grade) in geography. The relevant textbooks present the scientific knowledge of the phenomenon 'in black and white', accompanied by explanatory figures. It has to be mentioned that students' conceptions are not taken into account in these textbooks.

## The present study

The present study took place (a) in nine primary schools in Athens, from different socioeconomic regions, with a sample of 142 fifth grade students and (b) in the Primary Education Department of the University of Athens, also with a sample of 142 undergraduate elementary pre-service teachers. Each of the participants had approximately 15 min to answer the following question in writing.

'Why is it hotter in summer than in winter? How do you explain seasonal change on Earth?'

Apart from giving a written response, both the k-5 students and the pre-service teachers had to support their answers with drawings. Two students and one pre-service teacher did not answer the question.

## Results

### *Theoretical framework*

The answers of the participants were categorized according to a two-level hierarchical structure proposed by Galili (1995). According to this model of categorization, several seemingly different explanations (*facets of knowledge*) may be expressed. However, they can share a common explanatory mechanism (*scheme of knowledge*). For example, the notions that 'seasonal change is caused by alteration in the distance between the Sun and the Earth, due to the Earth's elliptic orbit around the Sun' and 'seasonal change is caused by alterations in the distances between the Earth's northern and southern hemispheres from the Sun, due to the tilt of the Earth's spinning axis' are two different facets of the same scheme (alteration in the distance between the Sun and the Earth).

### *Schemes*

Therefore, according to both k-5 students' and pre-service teachers' responses, the following schemes were identified.

(1) Angle of Sun rays' incidence on Earth. (For example: *in summer, Sun rays arrive on the Earth more vertically than in winter.*)

(2) Alteration in the Earth–Sun relative orientation/illumination. (For example: *as the Earth spins, the part that 'sees' the Sun has summer and the other part has winter.*)

(3) Alteration in the distance between the Sun and the Earth. (For example: *in summer, the Earth comes closer to the Sun, while in winter, the opposite happens.*)

(4) Mixed (combinations of 1–3 schemes). (For example: *as the Earth follows its elliptic orbit around the Sun, it sometimes goes further away, compared to other points of the orbit. This is when we have winter. This also has to do with the Earth's spinning. When certain*

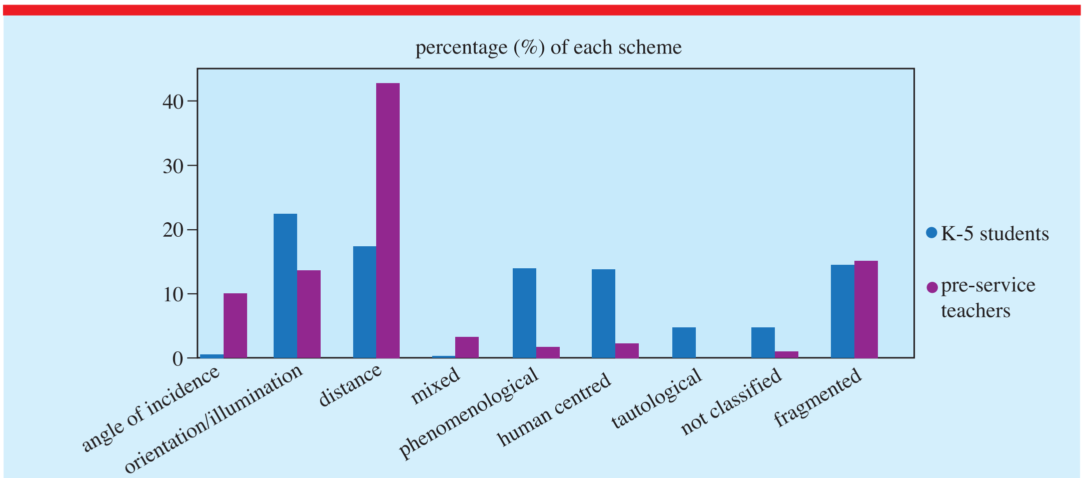


**Figure 1.** Percentage of each scheme and each population of the sample.

**Table 1.** Frequency of answers in each scheme and each population of the sample.

| (Scheme) | Number of k-5 students | Number of pre-service teachers |
|---|---|---|
| (1) Angle of Sun rays' incidence on the Earth | 1 | 17 |
| (2) Alteration in the Earth–Sun relative orientation/illumination | 33 | 21 |
| (3) Alteration in the distance between the Sun and the Earth | 26 | 62 |
| (4) Mixed (combinations of 1–3 schemes) | 0 | 6 |
| (5) Phenomenological notions | 21 | 4 |
| (6) Human centred notions | 21 | 5 |
| (7) Tautological notions | 8 | 0 |
| (8) Unclassified notions | 8 | 3 |
| (9) Fragmented notions | 22 | 23 |
| Total | $N = 140$ | $N = 141$ |

*places on the Earth do not 'look at' the Sun, these places also have winter.*)

(5) Phenomenological notions. (For example: *clouds block Sun rays in winter.*)

(6) Human centred notions. (For example: *if there were no summer, we would not go on vacation.*)

(7) Tautological notions. (For example: *in summer the temperature is high.*)

(8) Unclassified notions. (For example: *God created the seasons.*)

(9) Fragmented notions. (For example: *the seasons change because the Earth orbits the Sun.*)

Table 1 presents the frequency of answers in each scheme and each population of the sample, while figure 1 presents the corresponding percentages.

*Data analysis*

*Angle of Sun rays' incidence on the Earth.* Only one k-5 student (0.7%) used this causal mechanism in his reply, being at the same time far from the scientific model. This student wrote the following.

> *In winter the Sun goes under the Earth and hits it sideways with its rays, while in summer the Sun comes in front of the Earth and hits it vertically with its rays.*

**Table 2.** Frequency of answers of each facet within the orientation/illumination scheme.

| Facet within the orientation/illumination scheme | Number of k-5 students | Number of pre-service teachers |
|---|---|---|
| (a) Earth orbits Sun | 9 | 8 |
| (b) Earth spins | 11 | 2 |
| (c) Earth rotates around Sun and spins | 2 | 4 |
| (d) Sun rotates around Earth | 2 | 2 |
| (e) Sun moves across the northern and southern hemispheres of Earth | 1 | 0 |
| (f) No further explanation provided | 4 | 4 |
| (g) Fragmented explanation | 4 | 1 |
| Total | $N = 33$ | $N = 21$ |

This was a presumable result since k-5 students (i) have never been taught the phenomenon before and (ii) their everyday experience could not lead them to the adoption of such ideas.

Regarding pre-service teachers, the corresponding percentage (11.2%) was not high, bearing in mind that they have been taught the phenomenon twice. Among these university students ($N = 17$), only one came close to the scientific explanation. The rest either just mentioned 'the angle of Sun rays' incidence on Earth', without any further explanation:

> *during summer Sun rays strike the Earth vertically; in winter, sideways...*

or tried to combine unsuccessfully and not thoroughly this causal mechanism with the Earth's rotation around the Sun:

> *as the Earth orbits the Sun, in summer Sun rays strike more vertically in certain places while in winter they strike sideways....*

*Alteration in the Earth–Sun relative orientation/illumination.* A number of k-5 students ($N = 33$, or 23.3%) and pre-service teachers ($N = 21$, or 14.8%) adopted the second scheme, according to which, when a place of Earth is orientated towards the Sun it 'receives' more Sun rays and has summer, compared to the places which 'receive' fewer or no Sun rays and have winter. It seems that students who have adopted this scheme of knowledge confuse the causal mechanism of seasonal change with that of the day and night cycle.

This scheme, according to both k-5 students' and pre-service teachers' responses, manifested itself in five facets (table 2). Each of them linked the alterations in the Earth–Sun relative orientation to the following movements.

(a) The Earth's spinning (figure 2(a)).
(b) The Earth's revolution around the Sun.
(c) A combination of (a) and (b).
(d) The Sun's revolution around the Earth.
(e) The Sun moving across the northern and southern hemispheres of the Earth.

There were also some cases where respondents just addressed the parameter of orientation without stating how this orientation changes. For example, one pre-service teacher wrote:

> *It has to do with the Earth's position compared to the Sun. When the Sun illuminates a certain place on the Earth, this place has summer. The opposite place is not illuminated. This place has winter.* (Figure 2(b).)

Data analysis revealed a relative decrease in the corresponding percentages from k-5 students to pre-service teachers. This decrease is mostly with respect to facet (b) which ascribes periodic alteration in the Earth–Sun relative orientation to the Earth's spinning ($N = 11$ for k-5 students, $N = 2$ for pre-service teachers). This is consistent with the previous findings, according to which as students get older, they adopt the scientific model of the day and night cycle in higher percentages (Baxter 1989). Hence, one could assume that pre-service teachers confront themselves cognitively if they try to use the

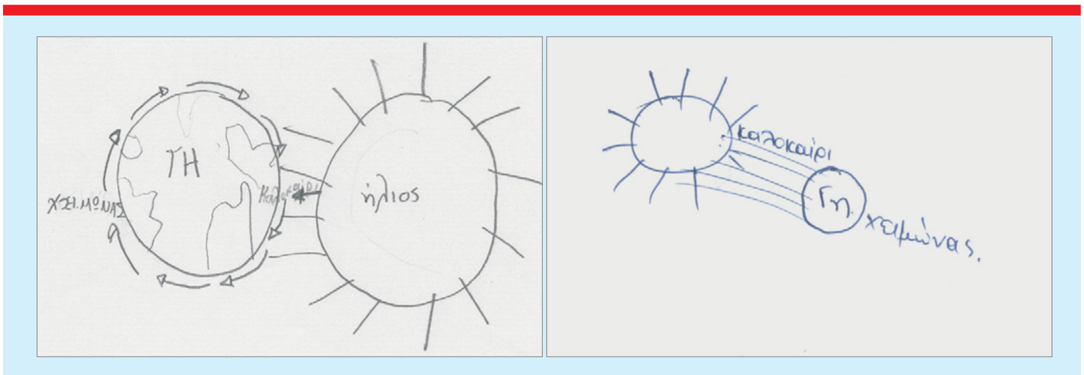


**Figure 2.** In Greek 'Καλοκίαρι' means 'summer' and 'Χειμώνας' means 'winter'. (a) k-5 student's drawing and (b) pre-service teacher's drawing.

same movement of the Earth (spinning) and the same causal mechanism (illumination of the Earth from the Sun) in order to explain two completely different phenomena (day–night cycle, seasons). A typical example of such a confrontation is the written answer of one of the two pre-service teachers who displayed facet (b):

> *The Earth spins (but I am not sure whether this spinning lasts one day or one year). Anyway, I would answer that because the Earth spins around its axis, each season, the Sun illuminates us or not.... If so, then what happens with day and night?*

In contrast, when the chosen movement differs from the one which explains the day–night cycle (see facets (a), (c), (d) and (e)), there is not such a confrontation, as shown in the results. For example, one pre-service teacher, displaying facet (d), wrote:

> *According to the Sun's revolution around Earth, three months per year the Sun 'illuminates' and warms a certain part of the Earth (summer).... At the same time the Sun does not 'illuminate' the opposite part of the Earth (winter).*

*Alteration in the distance between the Sun and the Earth.* The basic root of this scheme seems to be the everyday experience, according to which, the closer we come to a source of heat the warmer we feel (Halkia 2006). It is worth, however, stating that data analysis revealed a considerable increase of the corresponding percentage from k-5 students ($N = 26$, or 18.3%) to pre-service teachers ($N = 62$, or 43.7%).

Moreover, k-5 students' highest frequency facet of this scheme (14 out of 26) refers to the simple statement that the Earth approaches and goes away from the Sun or vice versa (figures 3(a) and (b)):

> *When the Earth is close to the Sun we have summer. When the Earth goes away from the Sun, winter is coming....*

Pre-service teachers' highest frequency facet (27 out of 62) refers to the periodic variation in the distance between the Sun and the Earth, due to the Earth's elliptic orbit around the Sun (figure 4(a)). One pre-service teacher explained:

> *Because the Earth's orbit is elliptic.... Therefore, when it approaches the Sun we have summer and when it is far from the Sun, winter.*

Another facet within this scheme (only pre-service teachers displayed it) connects the Earth's tilt of its spinning axis with the variation in the distances between the Earth's Northern and Southern Hemispheres from the Sun (figure 4(b)). There were seven (7) pre-service teachers (4.9%) who held this facet:

> *Because the Earth has a tilt. Therefore, when the Northern Hemisphere is near the Sun it has summer and when it is far from Sun it has winter.*

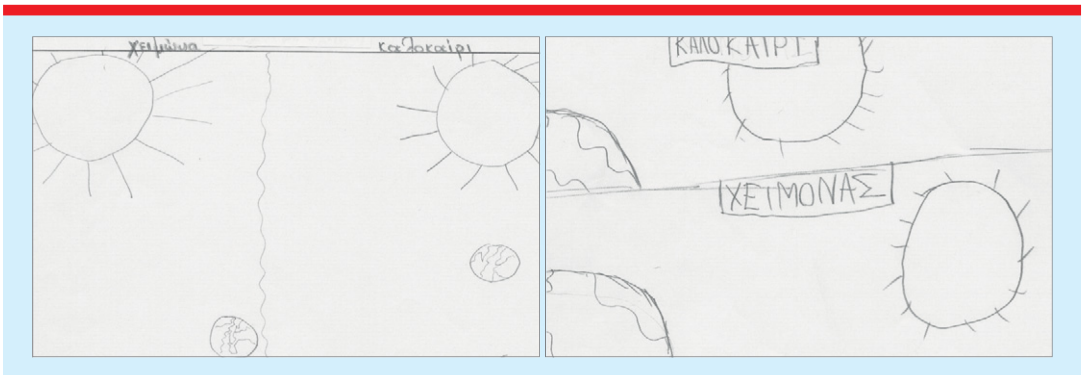


**Figure 3.** In Greek 'Καλοκαίρι' means 'summer' and 'Χειμώνας' means 'winter'. (Both are k-5 students' drawings.)

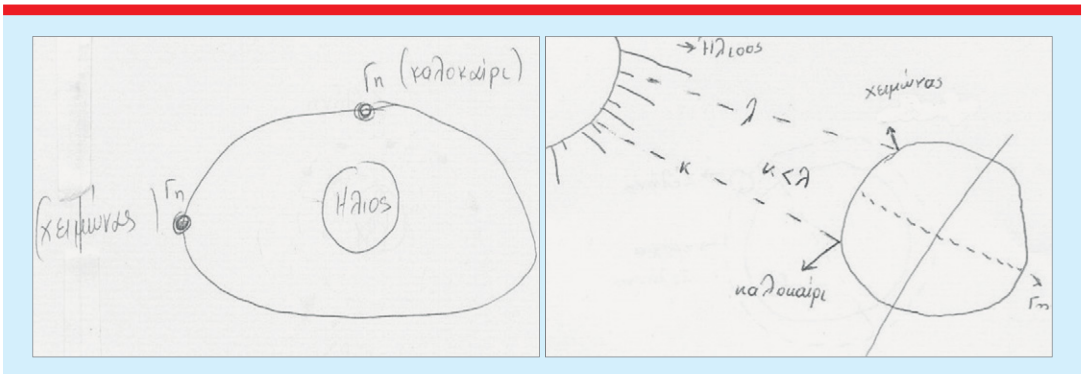


**Figure 4.** In Greek 'Καλοκαίρι' means 'summer' and 'Χειμώνας' means 'winter'. (a) 'Elliptic orbit' facet and (b) 'Earth's tilt' facet. (Both are pre-service teachers' drawings.)

There were also some replies in the context of a 'distance' dependence scheme, both from k-5 students ($N = 5$, or 3.5%) and from pre-service teachers ($N = 14$, or 9.8%), which have never been recorded before in the related literature. According to these responses, when a place on the Earth is orientated towards the Sun it has summer since it is closer to the Sun than an oppositely situated place. One pre-service teacher explained:

> *Because in summer the part of the Earth where we stand is closer to the Sun, it gets warmer. On the contrary, in winter the same part is far away from the Sun, so it gets colder. . . .*

(Figure 5 corresponds to the pre-service teacher who gave the above answer.)

Given that teaching seasonal change in the Greek educational system does not touch on 'dissatisfaction with existing conceptions' (Posner *et al* 1982), it seems that, as time goes by, students incorporate declarative aspects

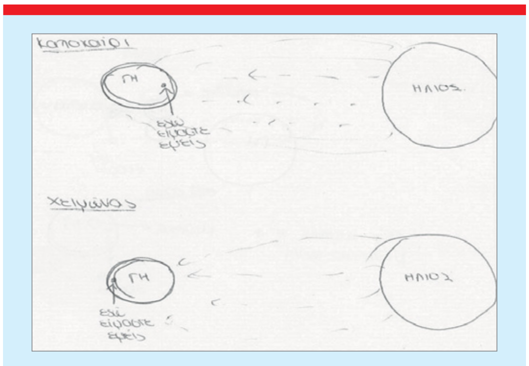


**Figure 5.** In Greek 'Καλοκαίρι' means 'summer' and 'Χειμώνας' means 'winter'. (Pre-service teacher's drawing.)

of scientific knowledge (*elliptic orbit, tilt of the rotational axis, etc)* into the aforementioned 'distance' dependence scheme.

*Mixed (combinations of 1–3 schemes).* Only very few pre-service teachers ($N = 6$, or 4.2%) gave responses within this scheme. They tried to combine a 'distance' dependence scheme either with 'angle of incidence' or with 'orientation/illumination' dependence schemes, resulting mostly in incoherent outcomes:

> *When we have summer in Greece, Sun rays strike vertically. At the same time the Earth is closer to the Sun due to the elliptic orbit around the Sun....*

*Phenomenological notions.* A percentage of 14.8% ($N = 21$) of k-5 students attributed seasonal change to (a) weather phenomena (snowing, Sun shining, etc), (b) clouds as obstacles for Sun ray propagation, (c) warm and cold air-streams, (d) day length and (e) the change of the Sun's position on the horizon during the year. In other words, they made use of everyday experienced objects and phenomena. The corresponding percentage for pre-service teachers is minimized (2.8%, or $N = 4$).

*Human centred notions.* As far as the percentages of this scheme are concerned, the picture is analogous to the previous one. Twenty-one k-5 students (14.8%) related seasonal change to human needs:

> *Because people cannot survive only with cold, they need heat as well ....*

*That happens because we must swim in summer ... play with snow in winter ... all kinds of flowers must blossom in spring and make our city beautiful.*

On the other hand, only five pre-service teachers (3.5%) adopted this scheme:

*In order to be able to adapt to all temperatures....*

*Tautological notions.* Only a few k-5 students ($N = 8$, or 5.6%) gave responses within this scheme by reproducing the content of the question they were given:

> *...As time passes, seasons change. It is hot in summer and it is cold in winter. That is to say that for every season we have a different temperature.*

*Unclassified notions.* Some explanations (*God's will, hot and cold planets, natural warming and freezing of the Earth, molecules' movement, etc)* either from k-5 students (5.6%, or $N = 8$) or from pre-service teachers (2.1%, or $N = 3$) could not fit into any of all the aforementioned schemes and could not form distinguishable schemes owing to their small number.

*Fragmented notions.* Finally, 22 k-5 students (15.5%) and 23 pre-service teachers (16.2%) gave answers which either (i) did not make any sense or (ii) did not include any causal mechanism for seasonal change. Answers in category (ii) just involved celestial movements (*the Earth's spinning, the Earth's revolution around the Sun, a combination of the two aforementioned movements, the Sun's revolution around the Earth*) or the tilt of the Earth's rotational axis:

> *As the Earth rotates around the Sun, the weather changes....*

(Figure 6(a) corresponds to the k-5 student who gave the above answer.)

> *Seasonal change is owed to the Earth's tilt....*

(Figure 6(b) corresponds to the pre-service teacher who gave the above answer.)

Unlike other studies (Baxter 1989, Atwood and Atwood 1996, Galili and Lavrik 1998), the present study did not classify such answers into specific categories because, according to the model of categorization we followed, there was no accounting for why these movements or the Earth's tilt affect seasonal change.

## Conclusions

Four basic conclusions could be drawn from the data analysis of our research concerning k-5 students' and pre-service teachers' conceptions of seasonal change.

(1) Confirming previous studies (Baxter 1989), it seems that, as time goes by, children move

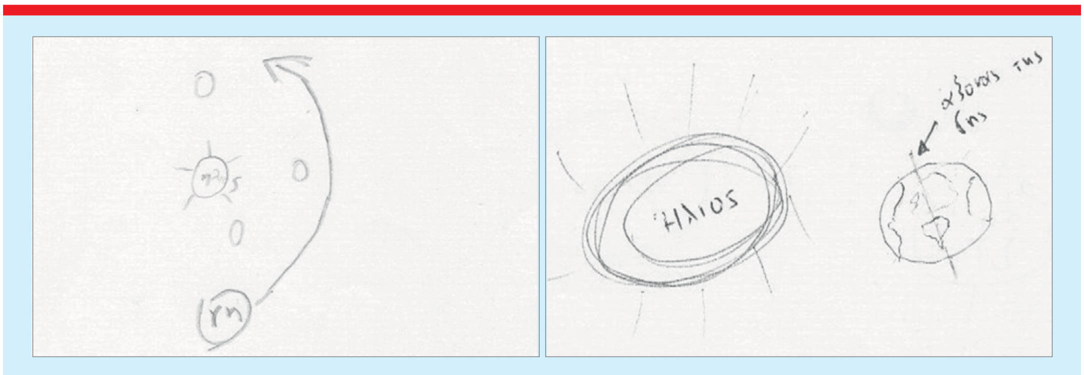

**Figure 6.** (a) k-5 student's drawing and (b) pre-service teacher's drawing.

from (a) human centred, (b) tautological and (c) phenomenological notions to notions which involve Sun and/or Earth movements.

(2) Despite the fact that pre-service teachers, unlike k-5 students, have been taught about seasonal change twice (both in elementary and in high school), very few of them adopt the 'angle of Sun rays' incidence on Earth' scheme. The results showed that pre-service teachers, within this scheme, cannot present a coherent explanation of the seasonal change. They only reproduce pieces of scientific information in a piecemeal fashion.

(3) Both k-5 students and pre-service teachers adopt mainly (a) 'alteration in the distance between the Sun and the Earth' and (b) 'alteration in the Earth–Sun relative orientation/illumination' as seasonal change's causal mechanisms. Regarding the 'alteration in the distance between the Sun and the Earth' scheme, a considerable increase in related percentages from k-5 students to pre-service teachers takes place. This is mainly because, as time passes after having been taught at school, students 'embody' in this scheme all parts of scientific knowledge *(Earth's elliptic orbit around the 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)*. This is consistent with previous studies on how students embody the culturally accepted views in their initial models (Vosniadou and Brewer 1994). As regards the 'alteration in the Earth–Sun relative orientation/illumination' scheme, it seems resistant to change as long as it is not confronted with the scientific explanation of the day and night cycle.

(4) Conclusions (2) and (3) lead us to the final conclusion that teaching of seasonal change in school should touch *firstly* on the dissatisfaction with students' initial schemes and *secondly* on activities aiming at explaining why a different angle of the Sun rays' incidence results in a difference in the Sun's radiation received.

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## References

Atwood R K and Atwood V A 1996 Pre-service elementary teachers' conceptions of the causes of seasons *J. Res. Sci. Teach.* **33** 553–63

Bailey J M and Slater T F 2004 A review of astronomy education research *Astron. Educ. Rev.* **2** 20–45

Baxter J 1989 Children's understanding of familiar astronomical events *Int. J. Sci. Educ.* **11** 502–13

Duit R, Gropengieber H and Kattmann U 2005 *Towards Science Education Research that is Relevant for Improving Practice: The model of Educational Reconstruction, Developing Standards in Research on Science Education* ed H E Fischer (London: Taylor and Francis) pp 1–9

Duit R and Treagust D F 2003 Conceptual change: a powerful framework for improving science teaching and learning *Int. J. Sci. Educ.* **25** 671–88

Frede V 2006 Pre-service elementary teacher's conceptions about astronomy *Adv. Space. Res.* **38** 2237–46

Galili I 1995 A modern understanding of origins of students' difficulties to operate with the weight concept *Thinking Physics for Teaching* ed C Bernardini, C Tarsitanti and M Vicentini (New York: Plenum)

Galili I and Lavrik V 1998 Flux concept in learning about light. A critique of the present situation *Sci. Educ.* **82** 591–614

Halkia K 2006 To Iliako Sistima mesa sto Simpan *Panepistimiakes Ekdoseis Kritis*

Hsy Y S 2008 Learning about seasons in a technologically enhanced environment: the impact of teacher-guided and student-centered instructional approaches on the process of students' conceptual change *Sci. Educ.* **92** 320–44

Mant J and Summers M 1993 Some primary school teachers' understanding of the Earth's place in the universe' *Res. Pap. Educ.* **8** 101–29

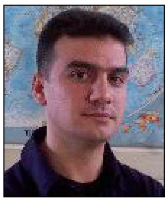
Parker J and Heywood D 1998 The Earth and beyond: developing primary teachers' understanding of basic astronomical events *Int. J. Sci. Educ.* **20** 503–20

Posner G J, Strike K I, Hewson P W and Gertzog W A 1982 Accommodation of a scientific conception: toward a theory of conceptual change *Sci. Educ.* **66** 211–27

Sharp J G 1996 Children's Astronomical belief's: a preliminary study of year 6 children in south-west England *Int. J. Sci. Educ.* **18** 685–712

Trumper R 2001 A cross-age study of junior high school students' conceptions of basic astronomy concepts *Int. J. Sci. Educ.* **23** 1111–23

Vosniadou S and Brewer W F 1994 Mental models of the day/night cycle *Cogn. Sci.* **18** 123–83



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