THE ROLE OF ANALOGIES IN COLLEGE STUDENTS' UNDERSTANDING OF COUNTER-INTUITIVE EXPOSITORY TEXTS

Irini Skopeliti
eskopel@phs.uoa.gr
Svetlana Gerakaki
sgerak@phs.uoa.gr
Stella Vosniadou
svosniad@phs.uoa.gr

Cognitive Science Lab,
Department of Philosophy and History of Science,
National and Kapodistrian University of Athens
University Campus, Ano Ilissia, 15771, Athens, Greece

ABSTRACT

We investigated the role of analogies in college students' understanding of scientific information in counter-intuitive expository texts. The expository texts presented the scientific explanation of the seasons, with or without the use of analogy. Forty undergraduate students of the University of Athens participated in the study. The Analogy Group received the text presenting the scientific explanation with an analogy. The No-Analogy Group received the text presenting the scientific explanation without an analogy. We expected better recall and comprehension of the scientific explanation in the Analogy Group than in the No-Analogy, since it would present an unfamiliar and incongruent explanation through a highly familiar domain. We also expected that the participants in the Analogy Group would change their original explanations verbally and in pictorially, thus revealing the creation of a more complete situation model from the text. The results confirmed our hypotheses. More specifically, the results showed better recall from the Analogy Group compared to the No-Analogy Group. Also, the Analogy Group gave significantly more improved and consistent explanations in the post-test than the No-Analogy Group. The results of the present study support our hypotheses and agree with findings from previous studies showing that the use of an appropriate analogy in science texts that provide counter-intuitive explanations can improve the comprehension of the text.

INTRODUCTION

The present study investigated the influence of analogy in the comprehension and recall of expository text which presented the scientific explanation of the seasons. Previous studies have shown that there are considerable difficulties in the comprehension of the scientific explanation of the seasons and persistent misconceptions regarding the cause of the seasons' change not only in the case of elementary school children but also in the case of college students.

Studies with college students (Schneps & Sadler, 1988; DeLaughter, Stein, Stein, & Bain, 1998; Trumper, 2000) and with elementary school teachers (Atwood & Atwood, 1996) have shown that they have considerable difficulties understanding that the cause of

seasonal change has to do with the tilt of the Earth's axis and, consequently, with the result of the different angles (direct or not) that the Sun's rays hit the surface of the earth. Instead, the most common explanation of the seasons was based on the difference in the distance of the Earth from the Sun throughout the year. Many adults believe that the earth is closer to the sun during the summer than during the winter. Studies conducted in our lab have also confirmed the above mentioned results (Siereki, Vosniadou, Masouri, & Gallika, 2003) showing that adult participants explain the seasons based on changes in the distance between the Sun and the Earth during the year. The purpose of the current study was to investigate whether the use of an analogy can help adults to better comprehend the scientific explanation of the seasons.

Text comprehension research has shown that readers find it difficult to comprehend information contained in expository texts when this information comes in conflict with their prior knowledge (see Dole, 2000 for a review). Analogies can help in this process because the unfamiliar, counter-intuitive, information is presented through an analogy from a familiar domain. The use of analogy to facilitate the understanding of counter-intuitive information has been investigated by a number of researchers. However, it is not clear yet how the analogy exactly contributes to facilitate such conceptual change processes (Brown & Clement, 1989; Chiu & Lin, 2005; Dagher, 1994; Duit, 1991; Gentner, 1983; Wong, 1993; Vosniadou & Ortony, 1989).

The purpose of the present study was to investigate in greater detail the processes thereby which readers map counter-intuitive information into the knowledge base and the role that analogy plays in this process, in the context of Vosniadou's framework theory of conceptual change (Vosniadou, 1994, 2006, 2008).

Taking into consideration the results of previous studies that investigated the use of analogy to facilitate the understanding of counter-intuitive information in biology (Venville & Treagust, 1996), in physics (Gentner & Gentner, 1983; Clement, 1993), and more generally in unfamiliar topics like dreams and termite societies or in the healing of an infection (Vosniadou & Schommer, 1988), we conducted studies in elementary school children which aimed at investigating the influence of analogy in the restructuring processes required in the comprehension of counter-intuitive, expository text which presented the scientific explanation of the day/night cycle (Vosniadou, Skopeliti, Gerakakis, 2007, in preparation). The results showed that the use of an analogy from a different but highly familiar domain helped children recall more information and draw fewer erroneous inferences from a scientific text which included an analogy compared to a scientific text without an analogy. The children in the Analogy Group were also more likely to change their original explanations in the posttest than the children in the No-Analogy Group. The children in the No-Analogy condition mostly added the scientific information in their existing explanatory structures creating internally inconsistent explanations of the day/night cycle in their recalls and in their posttest explanations.

The present study aimed at further testing the effects of analogy used in counter-intuitive texts, in the explanation of the phenomenon (that of the seasons) and using an adult group as opposed to children. We used an adult group in the present case because the explanation of the seasons is particularly difficult for elementary school children who lack a great deal of the necessary information about the solar system to understand the scientific explanation. Second, we were interested in finding out whether adults can indeed profit from an analogy as much as children. It could be argued that because adults have developed better text comprehension strategies and have more adequate prior knowledge, they would be perfectly capable of understanding the scientific explanation of the seasons if clearly stated in a text without the use of an analogy.

The expository texts used presented the scientific explanation of the seasons in terms of the tilt of the earth's axis. In the Analogy Condition the same explanation was used but

the text also included an analogy between the way the Sun's rays fall on to Earth's surface during the course of the day and during the course of the year (Analogy-text). More specifically, the text explained that the Sun's rays hit the Earth during the summer at a direct angle causing it to be warmer, in a way that is analogous to the angle of the Sun's rays hitting the Earth at noon time, during the day, causing the temperature to be warmer at noon compared to early in the morning.

We hypothesized that the participants could comprehend the scientific explanation of the seasons better when an analogy was present, because the analogy presents the new and unfamiliar explanation drawing upon the participants' prior knowledge from a highly familiar situation. The information that during the course of the day it is warmer at noon when the Sun's rays hit the surface of the earth at a directly vertical angle, is part of our every day knowledge and it is readily accessible and intuitively understood by most people. Thus, we expected a greater number of idea units recalled from the scientific text with analogy compared to the scientific text without analogy and fewer distortions of the text in the form of erroneous inferences. We also expected the participants to form a more cohesive situation model from the Analogy text (Kintsch, 1988, 1992) and thus greater consistency between their verbal explanations and drawings.

Our dependent measures were: 1) Number and kind of idea units recalled from the expository text; 2) changes in explanations of the mechanism of seasons before and after reading the text examining in particular the consistency between the participants' verbal explanations and their drawings.

METHOD

Participants

Forty adults participated in the study. All of them were undergraduate students in a Department of Social Studies at the University of Athens. Their mean age was 19 years and 10 months.

Materials

Two kinds of expository texts were written for the purposes of this study. Both texts gave the scientific explanation for the change of seasons. The Analogy text gave the scientific explanation and also used an analogy which was based on the structural similarity between the way the sun's rays hit the surface of the earth, in a direct or in an extreme angle during the course of the year, and the way sun's rays hit the earth during the course of the day, early in the morning and at noon.

The Analogy text was longer than the scientific text (317 words compared to 224 words), but was counterbalanced with the scientific text controlling for the number and type of sentences. Table 1 shows the texts used for the purposes of the study. The analogy information is presented in bold and it was not present in the No-Analogy text.

An open-ended questionnaire, consisting of 6 questions, was used as pretest and posttest. In the pretest the participants were first asked to make a drawing, and show in their drawing how the seasons change. Then they were asked to write down how the seasons change and to reply to four generative questions concerning the seasons.

The change of the seasons during the year

The Earth's seasons are the result of the difference in the angle in which the Sun's rays hit the Earth, caused by the tilt of the Earth's axis as the Earth revolves around the Sun. **An analogous difference in the angle of the Sun's rays on the Earth can also be observed during the day, when it is warmer at noon than early in the morning.**

The Earth's axis is not vertical to the plane of the Earth's ecliptic orbit around the Sun, but it is tilted. Because of this tilting the different parts of the Earth (the Northern and Southern hemispheres) are oriented more vertically towards the

Sun's rays at different times of the year.

When the Northern hemisphere is oriented towards the Sun, the Sun's rays hit the Northern hemisphere at a more directly vertical angle and cause it to be warmer. When this happens it is summer in the Northern hemisphere. **In an analogous way, at noon, when the Sun is up in the sky, and its rays hit the Earth at a direct angle, the temperature is as high as it can get during the day.** When it is summer in the Northern hemisphere, the sun's rays hit the Southern hemisphere at an extreme sideways angle, causing it to be cold there. When this happens, it is winter in the Southern hemisphere. **This is analogous to what happens early in the morning, when the Sun's rays hit the Earth at an extreme sideways angle causing the temperature to be lower compared to noon time.**

The more directly vertical is the angle of the Sun's rays on the Earth, the warmer it gets **(summer-noon)**. Contrary, the more extreme sideways is the angle of Sun's rays on the Earth, the colder it gets **(winter-morning)**.

That is how we can explain Earth's seasons which are the result of the stable tilt of Earth's axis during its revolution around Sun which causes the Sun's rays to hit the Earth (Northern or Southern hemisphere) at a different angle.

Table 1: Analogy Text

Procedure

The participants were randomly assigned to one of the two experimental conditions and the pretest was administered. Afterwards, the participants were given copies of one of the two texts to read on their own for 20 minutes. Then the experimenter removed the text and presented the adults with a recall question ('Please write as much information as you can recall from the text that you read'). The posttest was administered last.

RESULTS

Pretest

Using a set of criteria developed in prior research (Siereki, Vosniadou, Masouri, & Gallika, 2003), two experimenters scored each question independently. Agreement was calculated at 85%. All disagreements were discussed and the scoring of the participants was repeated. Reliability amongst two scorers at the second scoring was 96%.

Following this original scoring, the participants' responses in the pretest were evaluated based on their verbal explanations and on their drawings. The two experimenters assigned each participant to one of four 'explanation categories': 'scientific' if all responses were consistent with the scientific explanation (tilt of earth's axis); 'initial' if all responses were consistent with an explanation that showed no exposure to the scientific information and was usually based on the movement of the Sun (e.g., The seasons change because sun moves away and comes close to the earth); "alternative" if the responses presented some intermediate explanations based on an amalgamation of the scientific and initial response type (e.g., The Earth axis tilts (changes orientation) during the year); and as "inconsistent" if the responses were internally inconsistent (the inconsistency could be either at the verbal level only or between the verbal explanation and the drawing) (e.g. The seasons are the result of the tilt of the Earth's axis and the differences in the distance between Earth and Sun during the year).

Table 2 shows the frequency and the percent of the participants placed in the different explanation categories in the pretest. Group I after the pretest received the No-Analogy text, while Group II received the Analogy text. As expected, the great majority of the participants were placed in the 'initial' and the 'alternative' model categories. There were no statistically significant differences between Group I and Group II.

Explanation Types	Group I (N=20)	Group II (N=20)
Initial	8 (40%)	8 (40%)
Alternative	11 (55%)	9 (40%)
Scientific	-	1 (5%)
Inconsistent	1 (5%)	3 (15%)

Table 2: Frequency/Percent of Explanations of the Seasons in the Pretest

Recall

The texts were divided into idea units. An idea unit usually represented a whole sentence consisting of a subject, verb and an object or an adjective specifying some attribute of the subject. In some cases long sentences were divided into two or more idea units in order to distinguish between different kinds of information. In general, separate idea units represented various aspects of the detailed mechanism of seasons described in the texts. Causal and temporal connectors between idea units were treated as separate idea units in order to distinguish the cases where the participants made explicit reference to causality or temporal order. The scientific text was divided in sixty-one idea units and the Analogy text was divided into eighty-three idea units, of which sixty-one (the same as before) corresponded to the scientific explanation and the remaining to the analogy.

The idea units recalled by the adults from both text types were collected (two scorers, reliability 97%) and were assigned one point each. The scores were subjected to a one-way ANOVA [text (scientific*analogy)]. The results showed statistically significant main effects for text type [*F(1,39)=18,636, p<.001*] As shown in Figure 1, students from the No-Analogy condition recalled fewer idea units (mean score: 21.20), in comparison to the students from the Analogy condition (mean score: 29.50).

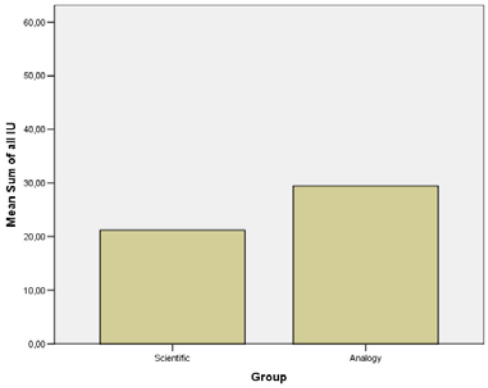

Figure 1: Means Sum of Idea Units Recalled as a Function of Text

It would be argued that the Analogy Group recalled more idea units because the Analogy text was longer by 22 idea units compared to the No-Analogy text. However, it could also be argued that the Analogy Group had a harder comprehension task to accomplish, since the participants were asked to read a longer and more complex text in the same time period. Nevertheless, we decided to also compare the two conditions considering only the common idea units in the two texts and ignoring the idea units recalled from the passages describing the analogy. An analysis of variance performed on these data showed marginally significant results [*F(1,39)=3,878, p=.056*], in favor of the Analogy Group.

The above mentioned analyses did not, however, consider whether the idea units were correctly recalled or were distorted. In the next analysis we separated erroneous inferences from correct recalls. The results showed that the number of erroneous inferences was greater in the case of the No-Analogy Group than in the Analogy Group. More specifically, erroneous inferences representing major distortions of the scientific explanation of the seasons were observed in 16 out of the 20 participants in the No-Analogy Group (80%), but only in 9 out of the 20 participants in the Analogy Group (45%).

Most of the erroneous inferences observed showed lack of understanding either of how the earth's axis tilt is related to the sea-

sons or of the difference in the way the sun's rays hit the earth during summer and winter. These were exactly the pieces of information that the Analogy Group understood best.

As shown in Table 3, there was a difference in favor of the Analogy Group both in the total number of erroneous inferences obtained and in the number of participants who drew erroneous inferences.

Types of Erroneous Inferences	No-Analogy Group (N=20)	Analogy Group (N=20)
Mistakes in understanding the Earth's axis tilt	14	6
Mistakes in the representation of how the sun's rays hit the earth	7	4
N of participants who created distortions	**16/20 (80%)**	**9/20 (45%)**

Table 3: Frequency of Erroneous Inferences Created in Participants' Recalls

A chi-square analysis gave statistically significant results in favor of the Analogy Group where fewer participants created erroneous inferences [$x^2(1)=5,227$, $p<.05$].

Next, we excluded the distorted idea units from the sum of the common idea units recalled form both texts and used an analysis of variance to compare only the means of the idea units correctly recalled in the two groups. The results showed statistically significant main effects in favor of the Analogy Group [$F(1,39)=5,878$, $p<.05$]. As shown in Figure 3, students from the Analogy Condition recalled a greater number of common idea units correctly.

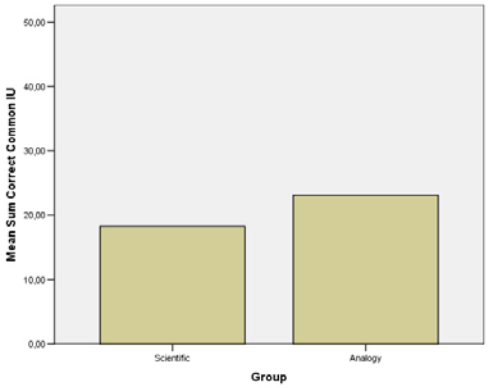

Figure 3: Means Sum of Common Idea Units Recalled Correctly as a Function of Text

Pretest and Posttest Comparisons: Influence of Text Type on Adults' Explanations

In an attempt to investigate how the different text types influenced students' explanations of the seasons, we looked at changes in their verbal and pictorial explanations from the pretest to the posttest. Participants were categorized in the same four different categories of explanations regarding their verbal explanations and their drawings as in the pretest – i.e., initial, alternative, scientific and inconsistent.

Two adults from the No-Analogy Group changed their original explanations to the scientific explanation and five from the Analogy Group gave responses consistent with the scientific explanation of seasons. Additionally, as shown in Figure 4, four participants from the No-Analogy Group changed their verbal explanations but did not change their drawings, or simple added the scientific information to their original verbal explanation. This had as a result the creation of internally inconsistent explanations.

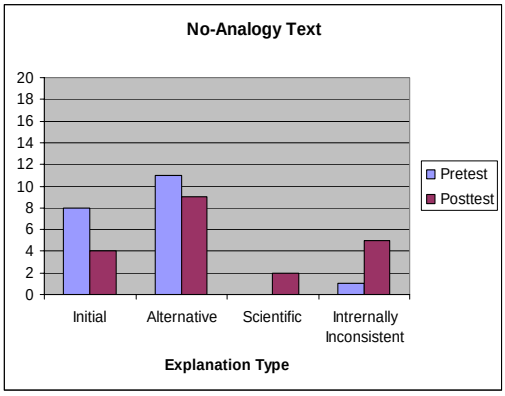

Figure 4: Frequency of responses in each category type explanation for scientific text without analogy in Pretest & Posttest

On the contrary, the students who read the Analogy text changed consistently their explanations in the posttest and moved either from an initial to a well defined alternative explanation or from an alternative to the scientific explanation. Additionally, as Figure 5 shows, two of the three students who gave internally inconsistent explanations in the pretest gave internally consistent alternative explanations in the posttest while the other one gave consistently the scientific explanation.

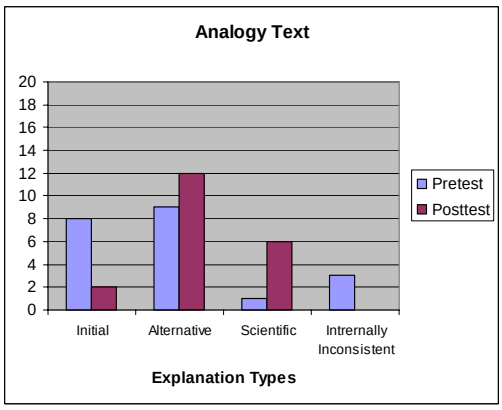

Figure 5: Frequency of responses in each category type explanation for scientific text with analogy in Pretest & Posttest

In order to see the change effect from the pretest to the posttest in greater detail we re-categorized the participants in three different categories; (1) no change in verbal response and drawing, (2) consistent change (change to a well defined verbal response and drawing resulting in either scientific or alternative explanations), and (3) inconsistent change (changes to a confused verbal response or change to a well defined verbal response but no change in drawing). Table 4 shows that 40% of the participants who read the No-Analogy text and 70% of the participants who read the Analogy text improved their explanations in the posttest and gave a consistent explanation, alternative or scientific. However, there were some participants from the No-Analogy Group (only 20%) who gave internally inconsistent responses in the posttest.

A chi-square test comparing the two texts showed statistically significant differences between the two experimental groups [$x^2(2)= 11,692,\ p<.005$] in favor of the Analogy Group.

Explanation Types	**No-Analogy Group (N=20)**	**Analogy Group (N=20)**
No Change	8 (40%)	6 (30%)
Consistent Change	8 (40%)	14 (70%)
Inconsistent Change	4 (20%)	-

Table 4: Frequency/Percent of changes in adults' explanations on day/night cycle in the Posttest

Figure 6 shows in a more salient way the difference found between the two experimental groups and the effect of the Analogy text on the participants' understanding of the scientific explanation. The great majority of the adults who read the scientific text with the analogy changed their original explanations to a more sophisticated one, alternative or scientific.

These participants managed to change not only their verbal explanations but their drawing as well.

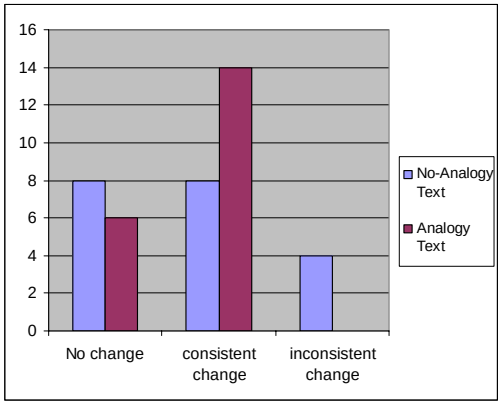

Figure 6: Frequency of changes in adults' explanations on day/night cycle in the Posttest

DISCUSSION

The results of the present study supported previous findings that readers find it difficult to understand texts which present scientific information incongruent to their background knowledge (Dole, 2000; Caillies, Denhiere, & Kintsch, 2002; McNamara, Floyd, Best, & Louwerse, 2004; Van Den Broek & Kendeou, 2008). As hypothesized, the inclusion of an analogy from a different but highly familiar domain helped participants to recall more information from the Analogy text as compared to the No-Analogy text. These results are consistent with previous studies which investigated the influence of analogy in the comprehension of science text (Brown & Clement, 1989; Chiu & Lin, 2005; Wong, 1993). More specifically, participants form the Analogy Group recalled in greater detail the information from the text that was structurally very similar to what the analogy was describing and had to do with the dynamic description of the mechanism of seasons' change.

Analysis of the changes in the participants' explanations from the pretest to the posttest showed that the changes occurred in different ways. In some cases the participants who read the No-Analogy text changed only their verbal explanations and not their drawings which remained the same as in the pretest. This difference caused several incongruities between the same participant's verbal explanation and his/her drawing in the posttest.

However, in the Analogy text the participants changed both their verbal responses and their drawings, indicating better integration of the information given from the text. This finding adds to our previous findings (Vosniadou, Skopeliti, & Gerakakis, 2007) and supports our hypothesis that the presentation of the analogical mechanism from a familiar domain helps participants form a better, more cohesive situation model from the text (Kintsch, 1988, 1992).

In other cases, the participants who read the No-Analogy text added the scientific information into their existing knowledge base creating erroneous inferences which represented major distortions of the text information. Most of the participants with initial prior knowledge did not understand fully the scientific information given in the text and they added the scientific explanation to their original explanation. These findings are consistent with the Vosniadou's framework theory approach to conceptual change. According to this approach readers usually add the new, scientific information to their incongruous prior knowledge. These additive mechanisms may lead to the construction of misconceptions which can be interpreted as "synthetic" errors (Vosniadou, 1994, 2006; Vosniadou, Vamvakoussi, Skopeliti, 2007).

On the contrary, participants from the Analogy Group did not simply add the new information into their knowledge base. They were more likely to restructure their original explanatory frameworks into more sophisticated ones that were closer to the scientific explanation. Thus, it seems that analogy can help in the restructuring processes because it presents the unfamiliar scientific structure through a different but a highly familiar domain.

In general the findings of the present study confirm previous findings from research based on cross-sectional developmental studies that point to small and gradual changes in the knowledge base (Vosniadou & Brewer, 1992, 1994). It appears that learning from text mechanisms are rather conservative, consisting predominantly of adding and/or deleting pieces of information, thus causing local inconsistencies in the knowledge base which need time to be repaired. Analogies can play a positive role in learning process in that they seem to facilitate more global changes.

ACKNOWLEDGMENTS

This work was supported by the project ANALOGY: Human-The Analogy Making Species, financed by the FP6 NEST Program of the European Commission. (STREP Contr. 029088)

REFERENCES

Atwood, K. R. & Atwood, A. V. (1996). Preservice Elementary Teachers' Conceptions of the Causes of Seasons. *Journal of Research in Science Teaching, 33*(5), pp. 553-563.

Brown, D. & Clement, J. (1989). Overcoming misconceptions via analogical reasoning: Abstract transfer versus explanatory model construction. *Instructional Science, 18*, pp. 237-261.

Chiu, M. H. & Lin, J. W. (2005). Promoting fourth graders' conceptual change of their understanding of electric current via multiple analogies. *Journal of Research in Science Teaching, Vol. 42*, No. 4, pp. 429-464.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching, 30*(10), pp. 1241–1257.

Dagher, Z. R. (1994). Does the use of analogies contribute to conceptual change? *Science education, 78*, pp. 601-614.

DeLaughter, J., S. Stein, C. Stein, and K. Bain, Preconceptions about earth science among students in an introductory course, *EOS Trans. Am. Geophys. Un., 79*(36), 429, 1998

Dole, J. A. (2000). Readers, texts and conceptual change learning. *Reading and Writing Quarterly, Vol. 16*, No, 2, pp. 99-118.

Duit, R. (1991). On the role of analogies and metaphors in learning science. *Science Education, 75*, pp. 649-672.

Gentner, D. (1983). Structure-mapping: A theoretical framework. *Cognitive Science, 7*, pp. 155-170.

Gentner, D., & Gentner, D. R. (1983). Flowing waters or teeming crowds: Mental models of electricity. In D. Gentner & A. L. Stevens (Eds.), *Mental models* (pp. 99-129). Hillsdale, NJ: Lawrence Erlbaum Associates. (Reprinted in M. J. Brosnan (Ed.), *Cognitive functions: Classic readings in representation and reasoning*. Eltham, London: Greenwich University Press.

Kintsch, W., (1988). The Role of Knowledge in Discourse Comprehension: A Construction-Integration Model. *Psychological Review, 95*(2), pp. 163-182.

Kintsch, W. (1992). How readers construct situation models for stories: The role of syntactic and causal inferences. In A. F. Healy, S. Kosslyn, R. M. Shiffrin (Eds.) *From learning processes to cognitive processes: Essays in honor of William K. Estes, 2*, (pp. 261-278). Hillsdale, NJ: Lawrence Erlbaum Associates.

Siereki, V., Vosniadou, S., Masouri, G., & Gallika, D. (2003, May). *How Adults Conceptualize the Change of Earth's Seasons* (in Greek). Paper presented at the biennial meeting of the Greek Psychological Association, Rhodes, Greece.

Schneps, M. H., & Sadler, P. M. (1988). *A private universe*. New York: Annenberg/CPB.

Trumper, R. (2000). University student's conceptions of basic astronomy concepts. *Physics Education, 35*(1), pp. 9-14.

Venville, G. J. & Treagust, D. F. (1996). The role of analogies in promoting conceptual change in biology. *Instructional Science, 24*, pp. 295-230.

Vosniadou, S. (1994). Capturing and modelling the process of conceptual change. *Learning and Instruction, 4*, pp. 45-69.

Vosniadou, S. (2006). The conceptual change approach and its re-framing. In S. Vosniadou, A. Baltas & X. Vamvakoussi (Eds). *Reframing the conceptual change approach in learning and instruction* (pp.1-15). Advances in Learning and Instruction Series. Oxford, UK: Elsevier Press.

Vosniadou, S., & Brewer, W.F. (1992). Mental models of the earth. *Cognitive Psychology, 24*, pp. 535-585.

Vosniadou, S., & Brewer, W.F. (1994). Mental models of the day/night cycle. *Cognitive Science, 18*, pp. 123-183.

Vosniadou, S. & Ortony, A. (1989). Similarity and analogical reasoning: A synthesis. In S. Vosniadou & A. Ortony, (Eds.), *Similarity and analogical reasoning* (pp. 1-17). Cambridge: Cambridge University Press.

Vosniadou, S., & Schommer, M. (1989). Explanatory analogies can help children acquire information from expository text. *Journal of Education Psychology, 80*(4), pp. 524-536.

Vosniadou, S., Skopeliti, I., & Gerakakis, S. L. (2007). Understanding the role of analogies in restructuring processes. In A. Schwering, U. Krumnack, K.U. Kuhnberger, & H. Gust (Eds.), *Analogies: Integrating Multiple Cognitive Abilities*, (pp. 9-43), Publications of the Institute of Cognitive Science, Volume 5-2007, University of Osnabruck, Germany.

Vosniadou, S., Skopeliti, I., & Gerakakis, S. L. (in preparation). Using Analogies to Foster on Conceptual Restructuring.

Wong, E.D. (1993). Understanding the generative capacity of analogies as a tool for explanation. *Journal of Research in the Science Teaching, 30*, pp. 1273-1290.