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Author: Koulaidis, Vasilis & Christidou, Ilia

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2. an initial analysis of explanations as well as causal relationships children use.

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Children's Misconceptions and Cognitive Strategies Regarding the Understanding of the Ozone Layer Depletion

Vasilis Koulaidis and Ilia Christidou, Aristotle University of Thessaloniki, Department of Primary Education,Thessaloniki 54006, Greece

INTRODUCTION

The research project to be presented in this paper aims at studying the way different cognitive strategies are employed and information concerning the greenhouse effect and the ozone layer depletion is processed by primary school children.

Specifically, concerning the aim of this paper we are mainly focusing on

1. an initial analysis of the metaphors primary school children use in order to render unfamiliar processes understandable, and
2. an initial analysis of explanations as well as causal relationships children use.

Problems like the greenhouse effect or the depletion of the ozone layer appear very frequently in the mass media, especially television and newspapers, through reports, documentaries, articles, etc. People seem to be increasingly concerned about the effects of human activities on the planet. However, a full understanding of the environmental problems and an estimation of their causes and possible trends, require sufficient knowledge of the science involved. Therefore there is need to incorporate environmental issues in science curricula[1]. The educational goals of such teaching could be:

a. to equip students with appropriate problem solving and decision making skills[2]

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[1] see Brody M., Chipman E., Marion S., (1989), Student knowledge of scientific and natural resource concepts concerning acidic deposition, *Journal of Environmental Education,* 20 (2): 32 - 42.

[2] see Brody, M. (1991), Understanding of pollution among 4th, 8th and 11th grade students, *Journal of Environmental Education,* 22(2), 24 - 33, Zoller, U., Weiss, S., (1983), The issue of "sensitive" interdisciplinary science - oriented curricula in the social service, *European Journal of Science Education,* 5(2), 147 - 155, Zoller, U., (1984), Strategies for environmental education within contemporary science education, *European Journal of Science Education,* 6(4), 361 - 368, Ross, S., (1991), Physics in the global

b. to increase the popularity and topicality of science curricula.

In curriculum design one must take into account students' existing knowledge related to the topics to be taught. Children's views concerning particular science topics have also proved essential for the design and evaluation of curriculum materials.

The paper is organised along the following axis:

a. Theoretical premises: children's representations.

b. Methodological framework, i.e.

b1. Description of the sample

b2. Description of the research instrument

b3. Presentation of the scheme of data analysis

c. Data analysis and interpretation in three steps:

c1. First step: presentation of "stories".

c2. Second step: analysis and discussion of metaphors usesis on their role in causality.

c3. Third step: models provided by children.

Some of the fundamental ideas for the design of our research instrument and the analysis of our data were based on the CHATTS project[3].

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greenhouse, *Physics Education,* 26, 175 - 181, Iozzi, A. L., (1989), What research says to the educator. Part One: Environmental Education and the affective domain, *Journal of Environmental Education, 20(3), 3-9.*

[3] CHATTS (Children And Teachers Talking Science) is a research project based at the University of London Institute of Education that was accomplished between 1990 and 1992. We owe special thanks to professor Jon Ogborn, Tim Brosnan and Dr Katherine Hann for their essential help.

THEORETICAL PREMISES: CHILDREN'S EXISTING KNOWLEDGE

Determining what children already know, i.e. their representations, is a prerequisite for meaningful teaching. Having an idea of children's representations could facilitate the design of appropriate teaching materials and strategies to encourage conceptual change.

The spectrum of meanings of the term 'representation' seems to be very wide. Indeed, one can distinguish the following: similarity (representation in art, e.g. painting), reproduction (representation in photographic images), copy (representation as a copy of the original, e.g. photocopy), repetition (representation as writing, e.g. words which represent an idea, concept).

Moving from 'common sense' to 'scientific' usages one can see a similar diversity. Three general remarks seem relevant:

a. There is no consensus on the meaning of the term and the kind of representations used by the subject.

b. For this reason, reference to representations is made through a whole cluster of terms.

c. This terminological diversity does not necessarily reflect fundamental theoretical differences.

Cognitive psychologists have been using terms such as: 'knowledge structures' and 'schemata'[4] (Rumelhart), 'scripts'[5] (Schank and Abelson), 'mental models' (Johnson Laird[6], Gentner and Stevens[7]). It should be noted, though, that in this context the usage of different terms does not signify radically different theoretical approaches. It seems that connectionism is the common theoretical frame of reference. It can be argued that the essential

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[4] see Rumelhart, D.E., (1980), Schemata: The building blocks of cognition, in Spiro, R.J., Bruce, B.C., Brewer, W.F., (eds.), *Theoretical issues in reading comprehension*, (Hillsdale, N.J.: Erlbaum).

[5] see Schank, R.C., Abelson, R., (1977), *Scripts, plans, goals and understanding*, (Hillsdale, N.J.: Erlbaum).

[6] see Johnson-Laird, P.N., (1983), Mental Models, (Cambridge: Cambridge University Press).

[7] see Gentner, D., and Stevens, D.R., (1983), Mental Models, (Hillsdale, N.J.: Erlbaum).

element of connectionism is the notion that mental representation finds expression as:

a. activation levels of ensembles of simple processors and/or

b. a measure of cohesion of these simple processors.

Within the cognitive framework, the typology of mental representations proposed by Johnson-Laird[8] merits attention. According to this typology mental representations can be distinguished in:

1. **Propositional representations**, which are strings of signs corresponding to a certain natural language. Put another way, this states that a certain propositional representation is a mental representation which can be expressed in words.

2. **Mental models**, which are of salient significance, according to Johnson-Laird, and are nothing else but structured analogues of the whole environment.

3. **Mental images**, each of which is a certain perception of a mental model as viewed from a certain perspective.

People presented with scientific knowledge interpret it in their own way. They construct their own meanings. They relate new information to their relevant existing knowledge. This way they end up with their own representations. These representations might change over time with the input of new data and experiences.[9] Moreover, their reasoning ability is context

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[8] see Johnson-Laird, P.N., (1983).

[9] see West, L., Fensham, P., Garrad, J., (1985), Describing the cognitive structures of learners following instruction in chemistry. In West, L., Pines, L., (Eds.), *Cognitive structure and conceptual change*. Academic Press, Inc.
For instance, text comprehension research findings suggest that the comprehension of a passage presupposes the interaction of the learner's existing knowledge, or 'schema', with the sentence input. Understanding a text involves constructing representations of the propositions that constitute it and of the ways these propositions are interconnected.
During text comprehension the new input must be connected both to the reader's general knowledge and to his/her internal representation of the text. As reading proceeds, a "textual concept" is built which allows the reader to have a particular memory "image" of the passage, containing all the information extracted form it, as well as a "semantic model", a set of selected possible situations which could correspond to the one described by the text.
As Garnham suggests, "people represent texts,...using mental models that are structurally similar to parts of the world, but which bear no simple relation to

dependent. This may mean that a large part of their reasoning ability is connected to specific pieces of knowledge[10]. Children have conceptions of scientific phenomena and processes, which provide them with a seemingly coherent view of the world. When they are faced with new information and try to interpret it, they use their previous knowledge, often based on experience, and their everyday vocabulary. Their explanations give us access to their own conceptualisation of the new situation[11].

METHODOLOGY

3.1. The sample

For the purposes of the programme 35 primary school children from state urban primary schools in the city of Thessaloniki were interviewed. Twelve were fifth-grade students (approximately 11 years old) and twenty-three were sixth graders (approximately 12 years old). The students' achievement in science was not taken into account for the selection. In most of the cases the teacher was simply asked to indicate children with no special problems in understanding a simple text and in expressing their views.

3.2. The research instrument: interviews and activities

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the linguistic structure of the text". In those models, information is organised in memory around representations of the entities involved, rather than around their names or descriptions of them. Thus, mental models are structures serving as bases for the interpretation of propositions and being constantly updated through the processing of new input. See Schank, R., Kass, A., (1988), Knowledge representation in people and machines. In Eco, U., Santabrogio, M., Violi, P., (Eds), *Meaning and mental representations,* Indiana University Press, Miller, G. (1979), Images and models, similes and metaphors. In Ortony, A. (Ed.), *Metaphor and Thought,* Cambridge University Press, Garnham, A., (1987), *Mental models as representations of discourse and text*. Ellis Horwood Limited.

[10] Rumelhart, D., Norman, D., (1981), Analogical Processes in Learning. In Anderson, J., (ed.), *Cognitive Skills and Their Acquisition,* Hillsdale, N.J. Lawrence Erlbaum Ass.

[11] see Head, J., Sutton, C., (1985), Language, understanding and commitment. In West, L., Pines, L., (Eds.), *Cognitive structure and conceptual change*. Academic Press, Inc.

The data were collected through individual semi-structured interviews[12]. The material we used to initiate the discussion included popularised scientific information about the greenhouse effect and the ozone layer depletion, which was further simplified so as to be understandable by primary school children.

Each session comprised three interviews and lasted for about 90 minutes. The first interview comprised two activities and aimed at initiating the subjects into the general topics of interest for the conversation. The second interview, which constituted the main core of the session, included four activities. During this part of the conversation children had the opportunity to process new information through the use of various cognitive strategies. The last interview was based on three activities determined to check how the newly encountered information could be manipulated by students in order to outline their previously formatted representations of the central phenomena, namely the greenhouse effect and the ozone layer depletion.

3.2.1. The first interview

In order to introduce the main issues of the discussion, at the beginning of the first interview students were told that they were to listen to a 2.5 minute excerpt of an environmental radio programme for children and were required to listen to it carefully. This programme provided simplified but rather dense information concerning the greenhouse effect and the ozone layer. After they had listened to the recorded extract, children were asked to state what they perceived to be its main messages.

The interview proceeded with a preliminary discussion based on the commentary of some pictures and everyday material. The pictures illustrated a power plant, a car's exhaust-pipe in full activity, a flooded town and a greenhouse. The everyday material consisted of an ozone friendly shaving foam can and a suntan lotion. With this preliminary interview we intended to

[12] see Brody M., Chipman E., Marion S., (1989), Student knowledge of scientific and natural resource concepts concerning acidic deposition, *Journal of Environmental Education,* 20 (2): 32 - 42.

create questions in the students' minds, rather than get resolute answers, in order to stimulate them to look for better answers during the second interview.

3.2.2. The second interview

For the first activity of the second interview, two leaflets titled "Who is warming up the earth?" and "Is the earth wearing sunglasses?" were handed to the subjects. These provided the essential information about the causes and the potential effects of global warming and the ozone layer depletion. Children were left to read the leaflets for as long as they felt appropriate, and subsequently the interviewer introduced a set of 19 cards (some of which illustrated), with the key words of the two phenomena. The key words included: sun, earth, atmosphere, oxygen, carbon dioxide, methane, trees, animals, carbon, gasoline, rubbish, climate, heat, polar ice, CFCs, ozone, refrigerators, sprays, and ultra-violet rays. The students were told that they were permitted to look back into the information material during the next three activities of this interview as often as they felt necessary.

To get the children familiarised with the main terms of the issues, we first asked them to try and find ways of grouping the cards. During this activity, the first weak relationships were created between the most important scientific terms involved in the processes under discussion. No limit was imposed as for the number of groups, or the number of cards per group. The interviewer insisted on prompting and recording the criteria employed by the subjects for the formation of the groups without giving any examples. Typical grouping criteria are, for example, "things that destroy ozone", "causes of pollution", "methane production", or "greenhouse effect".

The activity that followed constitutes the most important part of the second interview, as it focuses on the very details of the main scientific processes. This is accomplished by looking at the specific causal relationships between the key entities on the cards. Thus, we asked the children to try and pair the cards under the general scheme "A changes B" and we encouraged them to find as many different pairs as possible. Again the interviewer gave no examples, but after the formation of each pair insisted on prompting the kind of change the cause A causes to B and the process through which this

change is made. During this part of the conversation children had the opportunity to express their views on a wide variety of scientific concepts and phenomena, such as the movement of gases in the atmosphere, the combustion of fossil fuels, or photosynthesis. Through this approach the same phenomena were explored over and over from many different perspectives. It was also in the course of this activity that the most integrated explanations were produced.

The cards with the key terms were also used for the forth activity of the second interview. However, in contrast with the two previous activities, this time we aimed at reconstructing the initial picture by putting the explanations already given together and connecting them to form a whole. For this purpose we used a structured set of questions concerning carbon dioxide (the main cause of the greenhouse effect) and CFC's (the main cause of the ozone layer depletion). The questions focused on the production of those substances, their nature, movement, their effects on the atmosphere and the final consequences on the planet. Answering each question children put the corresponding cards on a large piece of paper, producing a map, or a 'puzzle', illustrating their view of the two phenomena in a rather macroscopic manner.

This sort of recapitulation gave children the opportunity to link the information they had been given according to the ways they felt this information could best be arranged. Sometimes, while trying to reconcile two or more explanations of the same process, students felt that some of their previous statements were incoherent and thus tried to cure the possible inconsistencies. In this case they were usually reminded by the interviewer that they could always look into the information material for possible answers. Thus, this activity gave us the opportunity to gain a general aspect of each subject's construction based on the information we had given them.

3.2.3. The third interview

As a first activity in this interview children were asked to draw a picture of what they perceived to be the most important aspects of the phenomena we had just been discussing. We assumed that if children were left to produce their own illustrations without pressure, they would try to express

their basic conceptions in a more concrete manner, by graphically representing their already existing visualisations, or even coming up with new ones[13].

A short discussion followed, during which the subjects analysed their paintings. Quite often this discussion revealed new aspects of their conceptualisations, which had either been formulated but not made explicit earlier, or had been created while they were producing their illustrations.In the last activity of the third interview, also the final part of the whole session, we simply asked the students to choose three cards that they considered to be the most relevant to each phenomenon, and three cards that they considered totally irrelevant to each phenomenon. This activity often opened new perspectives of the children's views of the phenomena.

At the end of the discussion a questionnaire was filled in by the interviewer with background information about each child, concerning their address, exact age, their parents' professional and educational status, and the most prevalent information resources about environmental issues for him/her.

3.3. The scheme of data analysis

The first step of our analysis comprises the formation of "stories", i.e. the collection of different parts of each transcript where relevant children's ideas were isolated. Thus for each transcript we arrived at a summary consisting of distinct "stories" characterised by thematic cohesion. Examples of possible stories appearing in a summary could be "Ozone depletion", "Greenhouse effect", or "Trees and Oxygen". Relevant statements could appear at different points of the conversation, since students used to return to the same issues during the interviews, adding new information or giving totally different accounts of the phenomena under consideration. All relevant

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[13] Since we were interested in the explanatory aspect of the pictures rather than the aesthetic, we suggested that the students should act as if they were trying to explain through their paintings what is going on in the atmosphere to a 5-year-old child.

statements, even the incoherent ones, were collected and condensed under representative titles. The story titles were selected by the interviewer as best indicators of their content.

Our next effort concerning stories, is their classification regarding their degree of uniqueness. Thus, we separate those stories suggested by all the subjects, which we call the "common" stories, from the original stories, each implied by one subject, which are characterised as "unique" stories.

The second step of the analysis concerns the metaphors and explanations, in particular

a. classification of metaphors used by children

b. an analysis of the role of metaphors in explanation and causality.

The third step of the analysis includes the presentation of models provided by children in their attempt to explain various scientific processes. Those models constitute personal constructions, reflecting children's representations of the phenomena discussed during the interviews.

ANALYSIS AND INTERPRETATION OF THE DATA

4.1. An overview of stories

Table 1 displays the number of stories extracted from each session transcript, as well as the topic each story refers to.

The wide thematic scope, illustrated in the table, indicates that children covered a variety of different topics during the interviews. The most common topic, introduced in every conversation concerned the ozone layer and its depletion. Other common stories refer to the atmosphere pollution, the role of trees in oxygen production, and the greenhouse effect.

The average number of different stories extracted from each conversation is four, ranging from two to eight stories in the most extreme cases.

Table 1: Presentation of stories

Subject	Number of stories	Story titles
1	6	CFCs and Ozone, Carbon dioxide, Methane, Heat - climate, Greenhouse Effect, Food
2	5	Ozone, Climate, Rubbish, Trees - Oxygen, Carbon dioxide and Methane
3	4	CFCs and Ozone, Carbon dioxide and Climate, Methane, Trees and Oxygen
4	3	CFCs and Ozone, Carbon dioxide, Atmosphere
5	5	Ozone and CFCs, Carbon dioxide, Methane, Atmosphere pollution, Heat and Climate
6	3	Ozone and CFCs, Greenhouse Effect, Methane
7	3	Ozone and CFCs, Greenhouse Effect, Trees - Oxygen
8	7	Ozone and Sprays, CFCs, Carbon dioxide, Atmosphere Pollution, Trees and Oxygen, Sun and Heat, Methane
9	2	CFCs and Ozone, Pollution

10	4	Ozone Depletion, Climate and Heat, Animals and Carbon dioxide, Trees and Oxygen
11	4	Ozone Depletion, Oxygen - Carbon dioxide, Heat and Polar Ice, Earth and Atmosphere
12	6	Ozone Depletion, Atmosphere Pollution, Sun and Heat, Carbon dioxide - Oxygen, Earth and Polar Ice, Animals and Plants
13	4	Ozone Depletion, Oxygen - Carbon dioxide, Climate and Heat, Coal and Trees
14	3	Ozone Depletion, Greenhouse Effect, Oxygen - Carbon dioxide
15	3	Ozone Depletion, Oxygen - Carbon dioxide, Sun and Earth
16	4	Greenhouse Effect, Ozone Depletion, Trees and Oxygen, Heat and Climate
17	2	Ozone Depletion, Earth
18	4	Ozone Depletion, Methane - Carbon dioxide, Sun and Earth, Atmosphere
19	4	Ozone Depletion, Carbon dioxide, Methane, Trees and Oxygen
20	6	Ozone Depletion, Heat, Greenhouse Effect, Climate, Atmosphere, Trees and Carbon dioxide
21	2	Ozone Depletion, Polar ice
22	4	Ozone Depletion, Oxygen - Carbon Dioxide, Climate, Sun and Trees

Table 1: Presentation of stories

Subject	Number of stories	Story titles
23	4	Pollution, Sun, Ozone Depletion, Gasoline
24	6	Air Pollution, Ozone Depletion, Ultraviolet Rays, Polar Ice, Plants, Sun
25	3	Atmosphere and Ozone, Sun, Methane
26	5	Ozone Depletion, Carbon dioxide, Methane, Atmosphere, Pollution
27	6	Ozone Depletion, Polar Ice, Atmosphere, CFCs, Trees and Oxygen, Sun
28	3	Ozone Depletion, Sun and Earth, Methane
29	4	Ozone Depletion, Greenhouse Effect, Climate, Carbon dioxide
30	4	Atmosphere and Ozone, Pollution, Ultraviolet Rays, Polar Ice
31	8	Rubbish, Sprays and Fridges, CFCs, Carbon dioxide, Effects of Ozone Depletion, Gasoline and Atmosphere, Sun and Trees, Climate, Methane and Ultraviolet Rays
32	2	Atmosphere, Ozone Depletion
33	5	Ozone Depletion, Greenhouse Effect, Carbon dioxide, Sun, Trees-Oxygen
34	4	Atmosphere, Methane, Trees and Oxygen, Greenhouse Effect
35	6	Ozone, Greenhouse Effect, Atmosphere, Trees - Oxygen, Methane, Climate

4.2. Stories: children's representations

The presentation of the stories prompted during the interviews comprises two stages. First, we will present the stories which consist of generally accepted statements. These include statements that were common in all transcripts.

Second, some "unique" stories will be illustrated, each found in only one summary.

4.2.1. The "common" stories

4.2.1.1. The ozone layer

It is worth noting that during the conversations the main emphasis was given by children on the process of the ozone depletion. The regular function of the ozone layer was usually referred to only implicitly, while the main focus was on the disastrous effects of its depletion. Nevertheless, there are some interesting examples of descriptions of the ozone layer as an entity:

> "First of all I imagine the earth as a ball, a ball made of glass, surrounded by a protective cover preventing it from falling and breaking. This protective cover is ozone".

> "Ozone is a layer of clouds. Normally, it absorbs the ultraviolet sun rays".

4.2.1.2. The ozone depletion causes

All the subjects referred to the depletion of the ozone layer during the interviews. The central views reflected in all the stories concerning ozone depletion can be summarised as follows:

Ozone is destroyed by certain gases released on earth mainly by human activities. There was no consensus among the subjects concerning the identity or the sources of these gases. However, CFC's are gases typically considered guilty of destroying ozone:

> "It's a gas found in fridges, a chemical substance. Each time we open the freezer we see some gas coming out. I think this must be the CFC's. (It is also found) in sprays like deodorants, or pesticides. When we use sprays we can hear psssh... and then, gas comes out. That must be it".

These gases rise in the atmosphere and when they reach the ozone layer they destroy it. One student said:

"Liquids, like gasoline and sprays, float up in the atmosphere. They go up and irritate ozone".

And another:

"They go up in the atmosphere and harm ozone. The wind helps them rise. I imagine that CFC's are stronger than ozone and so they destroy it".

While another student imagined CFC's as

"...a bad substance. As if they sting ozone".

Several mechanisms where proposed as explanations for the ozone destruction:

"(CFC's) go into the ozone and destroy it, thinning its layer. As if they dilute it".

Another child proposed:

"CFC's absorb the ozone and take its place. There is no more ozone there to protect us".

4.2.1.3. The ozone depletion implications

The depletion of ozone results in the emergence of holes in the ozone layer.

"CFC's go up in the ozone, 25 kilometres high. They stay there and make holes: empty spaces that remain uncovered".

From the ozone holes the sun's harmful ultraviolet rays can enter the atmosphere causing problems to the health of living organisms. Here is an illustration of how many students view ultraviolet rays:

"Ultraviolet rays are a kind of rays coming from the sun, which apart from the standard quantity that rays reaching the earth must have, possess a bigger force and can pass through a tiny hole -they don't really need a big one- and harm us, as when they reach us, they cause various diseases".

As for their effects:

> "Ozone used to absorb the ultraviolet rays but now they can pass freely and harm people and other living things; plants, too. As the hole becomes bigger, more rays reach the earth and can burn the trees".

Ultraviolet rays are considered to be very strong, hence very hot. Thus, an increase of the amount of incoming ultraviolet radiation in the atmosphere results in an increase of the earth's temperature. Also, ultraviolet rays can melt the polar ice.

> "Assuming that the ozone layer is destroyed, the sun reaches the polar caps with more heat, the icebergs melt and the sea's level constantly rises".

4.2.1.4. Pollution

In almost all interviews at least one or two statements appeared about air pollution. There were also several cases where subjects considered pollution to be the primary focus and the most crucial concept of the whole conversation:

> "It was all about the pollution caused in the environment by the sprays we use in our homes, ... the environment's pollution and how it affects animals..."

> "There is carbon dioxide in the environment. It's a gas that pollutes the atmosphere seriously. Animals produce it when breathing but much more [is released] when we burn forests, coal, gasoline, or oil. It is a disastrous substance that harms the atmosphere and trees".

Thus, it was a common notion that atmosphere is polluted by cars, factories and rubbish, as well as by sprays:

> "Sprays pollute the atmosphere. When we use them, they have some substances that are harmful. Rubbish pollute the atmosphere because when they rot, some substances come out".

By breathing in the polluted air, animals are contaminated. The environment is destroyed. Oxygen is affected. Here are some original statements:

> "In the case of gasoline, for example, when it is being burnt, carbon dioxide is released and comes out of the car exhausts. The wind helps it go to the atmosphere. First of all it contaminates oxygen and then it goes to the atmosphere. That oxygen is then inhaled by various organisms, causing them several problems. They die... everything is contaminated".

The case of oxygen seemed to concern most of the students in the interviews. Oxygen is either believed to be contaminated by the presence of harmful or dangerous gases in the air, as in the above example, or depleted:

> "Coal and gasoline destroy oxygen. Little by little, as we burn a lot of gasoline and coal, carbon dioxide takes its place. To burn these elements, oxygen is needed".

> "Carbon dioxide destroys the atmosphere. Oxygen is substituted by carbon dioxide. Carbon dioxide pushes away oxygen.... With various harmful substances, with molecules, it destroys oxygen".

4.2.1.5. Trees and oxygen

In the course of the conversation, many children referred to the importance of trees and their role in the maintenance of the oxygen - carbon dioxide balance. Here is how one student views this process:

> "In order to make proteins for their food, trees take carbon dioxide and release oxygen".

And another:

> "Trees take carbon dioxide and give oxygen. From the stomata under their leaves, they take carbon dioxide from the atmosphere because they need it to photosynthesise and give oxygen, so there is more of it. When we burn trees, carbon dioxide comes out".

Again there is space for concern about the sufficiency of oxygen. The following statement expresses it more explicitly:

> "When we burn trees oxygen is getting less and less in the atmosphere; because they release oxygen from their leaves and absorb carbon dioxide which is harmful for us".

Also, quite often photosynthesis is viewed as a process determined to provide people with oxygen so that they can breathe:

> "Trees produce oxygen to give us fresh air so that we don't breathe in the dirty atmosphere, so that we live better".

4.2.2. Some "unique" stories

Apart from the common stories including explanations which where frequently offered during the interviews, we would like to present here some original stories of special interest, each encountered in only one interview, reflecting an exclusive point of view on a specific topic. Those "unique" stories either reflect misconceptions, or propose possible mechanisms, which are products of more refined reasoning.

4.2.2.1. Protective methane

In this case, methane, one of the greenhouse gases, was viewed as protecting the earth from the sun's harmful rays, hence possessing a selective quality concerning solar radiation, similar to ozone's:

> "Methane is like a glass above the earth and it absorbs the rays of the sun that are powerful and can't fall down to earth. It absorbs them and keeps them inside. Like a greenhouse. The sun sends the rays to the earth but methane prevents the harmful ones from entering. The ones that harm man cannot enter".

4.2.2.2. Cleansing CFC's

Chlorofluorocarbons, generally considered responsible for the depletion of the ozone layer, are here regarded as having the ability to 'fight' against atmosphere pollution:

"CFC's can do some good to earth. These were created by trees, by oxygen. Oxygen helps them spread everywhere. When they spread everywhere, they can clear the atmosphere in some way, they can clear ozone. Our earth becomes cleaner. They protect it somehow from the harmful substances. We could say that they send away the harmful substances".

4.2.2.3. Polluting plants

A quite interesting perspective of the carbon dioxide sources in the atmosphere was proposed by a student who concluded that trees and plants, in general, breath the same way as we do, thus overloading the atmosphere with carbon dioxide. Notice here that the notion of the oxygen - carbon dioxide cycle is completely absent:

"And now something bad about trees: when there are flowers in our home, we should not sleep in there; because flowers breathe as much as we do and both give carbon dioxide during the night. I believe during the day, too. We 've seen that in the physics' class. They must be like us, they must breathe, too. I am now breathing and so does the flower; we both give carbon dioxide and pollute the atmosphere".

4.2.2.4. Ultraviolet rays interacting with methane

Methane is considered here as possibly interacting with ultraviolet rays, reinforcing them even more:

"Perhaps ultraviolet rays, while coming down, catch methane and become stronger and then they have more serious effects on people and animals. I am not sure, I'm just making an assumption".

4.2.2.5. CFCs rising in the atmosphere

While discussing the interaction of CFC's and ozone in the upper layers of the atmosphere, one student suggested:

> "CFC's are gases; they are found in sprays, fridges, also in gasoline and coal. After those products are consumed, for example gasoline in cars, chlorofluorocarbons float into the atmosphere, leave the earth's layer and go to the ozone layer. They are probably evaporated by the sun's rays".

4.2.2.6. Ozone trapping the sun's thermal rays

When asked to choose three cards relative to the greenhouse effect, a student replied:

> "I chose the heat, the sun and the ozone: the sun passes through ozone, those [rays] that are permitted to do so, of course. When one ray tries to come down to earth and leave again, it meets ozone so it falls back to earth, until it finds a plant, for example, that needs this force".

4.2.3. Stories: concluding remarks

In reviewing the stories prompted by the interviews, the following points can be made:

- All the subjects talked about the existence of a protective ozone layer above and around the earth. This layer is depleted by various gases released on earth. The depletion of ozone affects all living organisms on earth, since the sun's ultraviolet rays may enter the atmosphere unhindered.
- Human activities pollute the atmosphere and the environment in general. The atmosphere is polluted by gases such as carbon dioxide, methane, and CFCs.
- According to the generally expressed views, the atmosphere pollution affects the balance between oxygen and other gases in the atmosphere. Oxygen is either depleted or contaminated and living things breathing in the polluted air are contaminated, too.

- The 'unique' stories, on the other hand, mainly concerned the sources, properties and actions of relatively unfamiliar entities, like methane and ultraviolet rays, or mechanisms like the greenhouse effect.

4.3. Metaphors

4.3.1. Classification of metaphors

The classification of the metaphors prompted during the interviews (see Figure 1) comprises three principal dimensions. Thus, metaphors can be distinguished as

a. conventional or new,
b. orientational and ontological, and
c. in terms of their function in stories, either as stoppers, or as facilitators of a story.

Each of these three dimensions can be further analysed. In the paragraphs that follow the complete schema of the metaphor analysis, shown in the network in figure 1, is introduced and illustrated with original examples.

a.1. Conventional metaphors

Lakoff and Johnson define as conventional those metaphors which structure the ordinary conceptual system of our culture which is reflected in our everyday language[14]. For the purposes of our analysis, as conventional we define those metaphors located in one or more transcripts, which have already been used either in everyday or in scientific language. A popular conventional metaphor concerning the function of greenhouses, is reflected in the following excerpt:

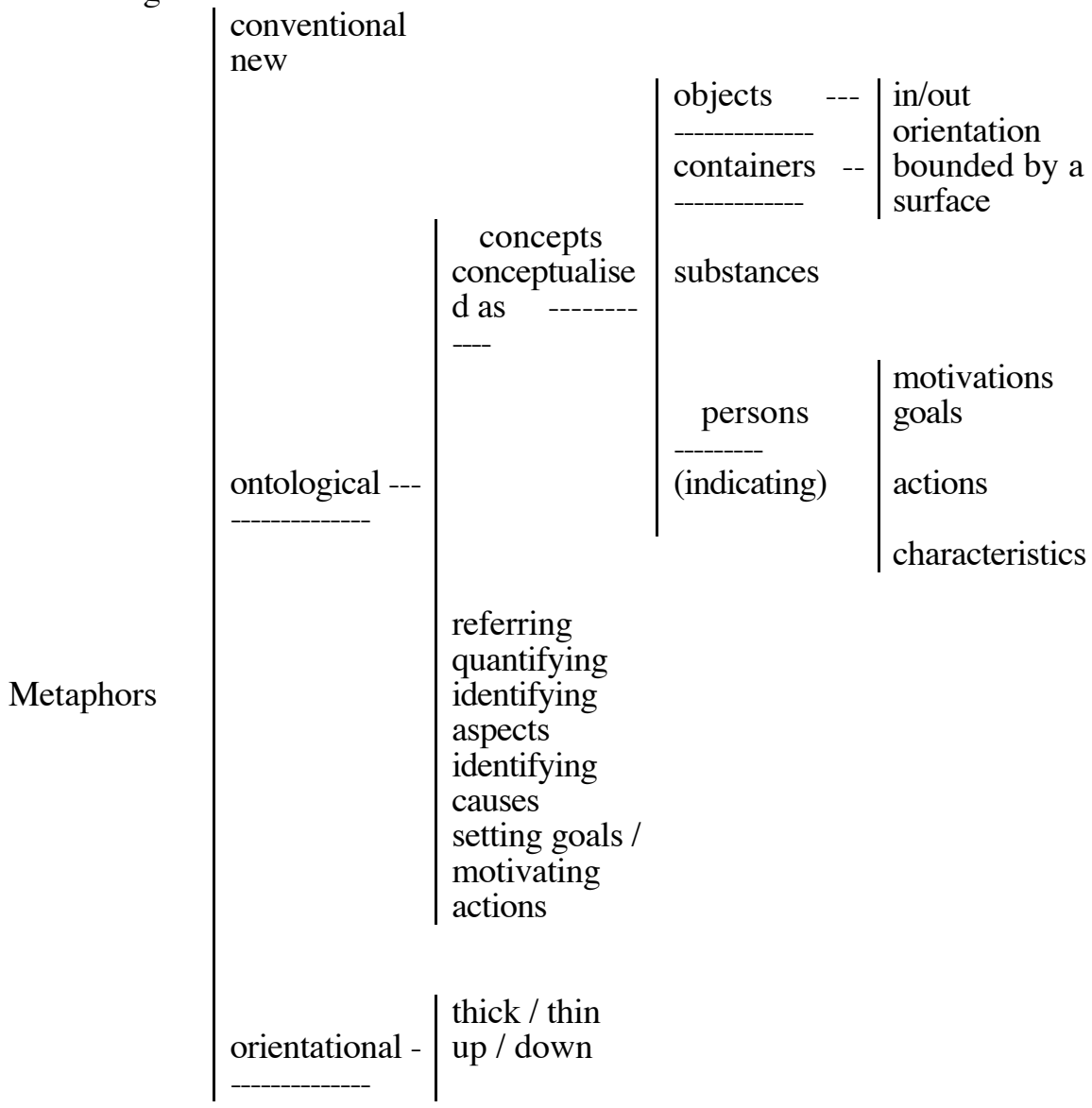
> "The greenhouse traps the rays of the sun and doesn't let them go, and so the plants can grow with [the help of] solar energy".

[14] Lakoff, G., Johnson, M., (1980), *Metaphors We Live By*. The University of Chicago Press.

a.2. New metaphors

New metaphors, in contrast to the conventional ones, are imaginative and creative because they lay outside our conventional conceptual system[15]. In the case of our research, we are referring to metaphors created, or invented by the student in his/her endeavour to conceptualise a process or an entity:

> "CFC's rise up like a big monster and eat the ozone; and so the ultraviolet rays of the sun enter our earth, causing the big disaster".



[15] op. cit.

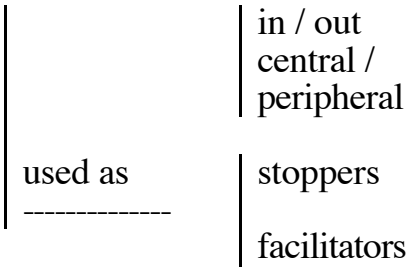


Figure 1: The network of metaphor analysis

b.1. Ontological metaphors

According to Lakoff and Johnson, we use ontological metaphors to comprehend events, actions, activities and states, in terms of objects, substances, containers, or persons. In their words, "understanding our experiences in terms of objects and substances allows us to pick out parts of our experience and treat them as discrete entities or substances of a uniform kind. Once we can identify our experiences as entities or substances, we can refer to them, categorise them, group them and quantify them-and, by this means, reason about them"[16]. We examine ontological metaphors along two distinct axis:

b.1.1. the type of concept used as a basis in order to render the unfamiliar concept understandable, and

b.1.2. the goal each ontological metaphor serves, in other words its function in a particular explanation.

b.1.1. Types of concepts forming the basis of ontological metaphors

In ontological metaphors, unfamiliar concepts can be conceptualised as

b.1.1.1. Objects

[16] op. cit.

Objects of everyday experience are identified as having clearly specified and directly perceptible limits:

> "[Ozone] is like a huge sheet very thin, something like an umbrella above the earth".

In this "double" metaphor, two familiar objects serve as basic concepts, namely the sheet and the umbrella.

Objects are also usually conceived of as bounded by a surface, imposing an in/out orientation:

> "[Carbon dioxide] lets the heat come in, but then it can't send it away, it can't reflect [the heat] back, because it causes something like an invisible wall".

b.1.1.2. Containers

Containers, like objects, are also bounded by a surface, have an in/out orientation and the capacity to hold other things inside them. Those properties can be illustrated by the following example:

> "[Ultraviolet rays] can come in through the ozone hole, but they can't go out, because ozone is like a glass around the earth, like plastic; it is as if [the earth] is wrapped with plastic".

Here, the metaphorical concepts employed for the conceptualisation of the ozone layer, impose the conception of the earth positioned inside a container made of glass, or plastic. Ultraviolet rays can enter the container, but they can't get out of it.

b.1.1.3. Substances

The issues discussed during the interviews, involve substances like carbon dioxide, ozone, or the CFC's, which are not directly perceptible, hence they are difficult for a primary school student to conceptualise. Thus, quite often they are described in terms of other substances, with more salient effects:

> "Ozone is like an umbrella made of gases that we can't sense of, and CFC's are gases... [they are] like an acid which makes holes on the umbrella".

b.1.1.4. Persons

Personifications allow us to perceive difficult concepts in human terms. Human terms which can be used as a basis in such ontological metaphors include:

b.1.1.4.1. Motivations

The anthropocentric view expressed in the story about trees and oxygen could also serve as an example of this kind of personification:

> "Trees produce oxygen to give us fresh air so that we don't breathe in the dirty atmosphere, so that we live better".

In this example, the sole trees' motivation for producing oxygen seems to be our well-being.

b.1.1.4.2. Goals

While talking about the popular among the subjects antagonistic relationship between oxygen and carbon dioxide, one student said:

> "Carbon dioxide destroys oxygen in some way; as if they are two opponent teams and carbon dioxide is a greater team and so it beats oxygen".

b.1.1.4.3. Actions

Human actions can be simple everyday movements. Thus, while explaining his painting, one student said:

> "Here are the North [Pole] icebergs which begin to melt, and here the sea begins to rise: [here I have painted the] stairs that the sea climbs up".

b.1.1.4.4. Characteristics

Let us go back to the story of polluting plants:

> "... flowers breathe as much as we do and give carbon dioxide during the night. I believe during the day, too. We 've seen that in the physics' class. They must be like us, they must breathe, too. I am now breathing and so does the flower; we both give carbon dioxide and pollute the atmosphere".

In this example, the human respiratory system is used as a basis for the comprehension of the role of plants in the oxygen - carbon dioxide cycle.

b.1.2. Functions of ontological metaphors in explanations

Considering the function of ontological metaphors in explanations, we concluded to the following categories:

b.1.2.1. Reference

There are cases in which a metaphorical concept is used in order to refer to another concept, without special reference to particular aspects or properties of the two concepts. The following example is an instance of such an occurrence of an ontological concept:

> "This dragon here is carbon dioxide that pollutes, eats away the ancient monuments, eats away plants, pollutes the environment; people cannot suffer carbon dioxide coming out of cars and motorcycles, plants die and the trees have too few leaves to give oxygen".

b.1.2.2. Quantification

Concepts like the ozone layer, or ultraviolet rays are quite difficult to conceptualise, especially for a primary school child. Thus, sometimes attributing to such concepts a quantifiable nature, may help in rendering a target concept more concrete. Here is an example of quantification:

> "[Now that there is the ozone hole] all the rays may come in, the ultraviolet rays that reach the earth and cause terrible diseases and much much heat, whereas when the protective cover, the ozone, is there, only half of them may come in and so it's not so hot".

b.1.2.3. Identification of crucial aspects

An ontological metaphor can be used in order to identify central aspects of the target concept. Thus, during the first interview, one child remarked:

> "This is a picture of a greenhouse, and the earth is quite similar; the sun rays come in, they go wherever they want to, where they have to go, but if some ray wants to go out, it cannot go out because the plastic, or the glass prevents it.

> The earth is also like this, since we release various gases up in the sky".

Notice also the strong personification of the sun's rays in this example, which are ascribed a potential of autonomous movement based on their volition.

b.1.2.4. Identification of causes

Metaphors are very frequently used in order to illuminate underlying causal relationships among important concepts:

> "The factory in this picture releases various fuels in the air, very harmful ones, that in some way fight this blanket we have above the earth, this blanket of ozone, and they make holes in the sky".

Here, the cause, namely the "fuels" that are released in the air, are metaphorically described as "fighting" the ozone layer, the patient in this causal relationship, which is also referred to as a blanket, another powerful ontological metaphor.

b.1.2.5. Motivation of actions

In several instances, the actions of different entities, like gases, greenhouses etc., are not simply viewed as properties, but are also assigned an underlying motive. This view applies in most of the examples already referred as instances of other categories, however we give one more typical example of this situation:

> "This is how a greenhouse looks from the inside, with plants growing in it. The plastic that covers it, lets the sun rays come in, but it doesn't let them go out. It traps them, so that the temperature rises in there and so the plants can also grow during the winter".

b.2. Orientational metaphors

Orientational metaphors attribute spatial characteristics to the target concepts in order to explain or simply describe them. Four basic categories of orientational metaphors were identified during the analysis of our data, implying the following concepts:

b.2.1. Thick / thin

Simply by referring to entities like the ozone layer, we employ ontological metaphors that involve certain spatial characteristics. One of them is the notion of a thick layer getting thinner, expressed in this example:

> "Those gases go to the ozone and make up a hole and the sun rays come in. [I imagine ozone] as a layer... [which] starts getting thinner and thinner".

b.2.2. Up / down

The up/down orientation is another spatial term that offers important explanatory possibilities in the discussion of topics concerning the atmosphere layers. Children unceasingly referred to gases going up, or rays coming down to earth. Here is one more example:

> "Carbon dioxide ... traps the sun rays and the temperature rises. (The sun rays) are reflected on the clouds and on this gas and go down again; [it's] almost the same as in greenhouses".

b.2.3. In / out

Ontological metaphors, and especially those referring to objects or containers with specific boundaries impose a spatial distinction between the space considered to be the interior and the outside of the object or container. In the example that follows, the container is the greenhouse:

> "The rays of the sun get trapped inside the greenhouse and it can't go out, and so we have light, warmth and security".

b.2.4. Central / peripheral

Another orientational distinction which seems appropriate for describing the earth and the atmosphere surrounding it, is the distinction between points found into the center of the system, usually considered to be the earth, in contrast to those found on the periphery, namely in the atmosphere around the earth. Thus,

> "Carbon dioxide and methane go up and spread around the earth. There they trap heat; this is the greenhouse effect".

c. The function of metaphors in stories

c.1. Metaphors as stoppers

The metaphors of this type were introduced during the interviews by the children, in order to establish an explanation already formulated, substantiating it through the identification of important similarities between the target concept and a basic, familiar one. When asked to describe how he viewed the ozone destruction process, one student recapitulated:

> "CFC's come out of rubbish, fridges, sprays, various products, they go to the atmosphere, and go to the ozone layer and make the ozone hole. They destroy it... they dig it".

Thus, finding a familiar human activity appropriate for expressing his representation of ozone depletion, this child has achieved his explanation.

c.2. Metaphors allowing a story to continue

Quite often a story is interrupted because some entity, or process is not clear enough. The discovery of the appropriate metaphor resolves the anomaly and allows the story to continue:

> "Methane, that comes out of rubbish and cows and sheep when they digest, together with carbon dioxide, which comes out of coal, gasoline and trees when they are burnt, go to the air and there they make something like a greenhouse. The climate becomes hot and there is much heat and there is the possibility that the polar ice will melt and many cities will be flooded".

In this example the function of carbon dioxide and methane in the atmosphere is explained through the greenhouse metaphor and therefore the conversation may move to the consequences of the greenhouse effect.

4.3.2. Metaphors in explanation and causality

As we mentioned earlier, one of the main concerns in our analysis of children's statements was the examination of the use of metaphors in the formation of explanations and causal relationships[17]. The scheme we used for the analysis of causal relationships is illustrated in Figure 2.

The causal relationships prompted by the interviews are primarily classified in terms of the occurrence or non-occurrence of a cause. Thus, we end up with the following gross categories:

a. Absence of cause

This category is further divided in the following two subcategories:

a1. Absence of cause may prevent an effect.

Thus, as we discussed already, normally trees release oxygen. However,

"As we go on burning forests, oxygen is getting less and less".

a2. Absence of cause may enhance effect.

A typical example of this category is this:

"When ozone used to be above us, there was no problem, it was protecting us from the ultraviolet rays, but now, with sprays, pesticides, and this kind of things, those ultraviolet rays start entering [the earth] and polar ice starts melting and the atmosphere is being destroyed".

[17] In our analysis of causal relationships suggested by the students we used the categories proposed by the CHATTS research team.

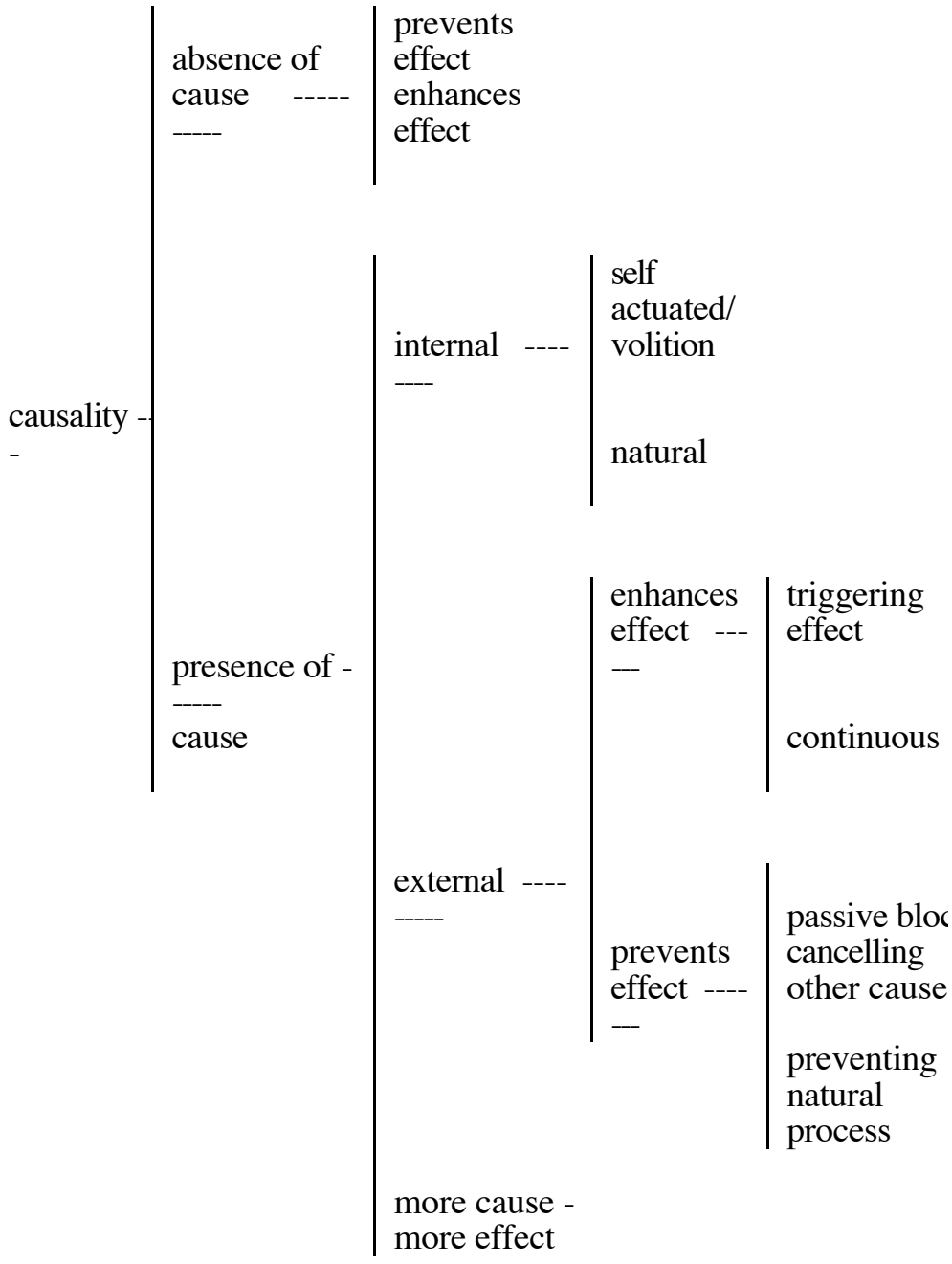


Figure 2: The categories of causal relationships

b. Presence of cause

When a cause is present, we encounter the following possibilities:

b1. Cause is an internal, or inherent capacity of an entity.

For example:

"Animals, when they eat, release gases, give methane. Rubbish also, when it is being burnt, it gives methane".

If further described, an internal cause may be

b1.1. self actuated, sometimes even implying volition.

"Ozone is like a greenhouse: from the ultraviolet rays it receives, it holds some inside, while it sends the rest of them away, so heat is generated in it. A kind of heat [which is] good for our health".

b1.2. a "natural behaviour" of the entity.

"The trees found in the forests breathe, sending oxygen to the atmosphere; but during the night I think they send out a substance which is a little bit dangerous for the man... I think it's called nitrous dioxide".

b2. The cause may be external to an entity, acting on it by contact.

"CFC's and methane rise up in the atmosphere and destroy ozone. They make the ozone hole. They enter the ozone and destroy it, make it thinner".

if further specified, external causes may be classified as:

b2.1. Triggering the effect.

"The gas coming out of coal rises up into the air and it can take oxygen with it and reverse it to carbon dioxide. Once it meets oxygen, the two of them combine and create carbon dioxide".

Usually, however, an external cause is viewed as

b2.2. Continuously acting on an entity.

"When someone sprays in a room this gas comes out, goes up and stands by ozone. There, little by little, it starts eating it".

b3. An external cause may prevent an effect.

"Ozone is a layer around the earth that protects us from the sun's ultraviolet rays".

In such cases, a mechanism is usually also proposed. Thus,

b3.1. The external cause may be acting as a passive block.

"Carbon dioxide and methane let the sun's rays pass [through] and warm our earth, they are allowed to come in freely, but they are arrested and they can't go out".

b3.2. Some entity or process may cancel another cause.

"Now that we burn trees, we will not have many trees to absorb carbon dioxide and give us oxygen. Now that we burn them, more carbon dioxide will be coming out and we will not have any oxygen".

b3.3 A cause may prevent a natural process.

"Ultraviolet rays reach the ground. When they enter the earth they cause bad things, because in the place where they reach, no plant can grow and even if they could, they wouldn't be natural plants, as we imagine them; as they are normally".

Last, apart from the occurrence or non-occurrence of causes or effects, a more continuous aspect of causal relationships, often experienced in everyday life, was evoked in several instances:

b4. More cause results in more effect.

Here are two examples:

"Carbon dioxide is reinforced by power plants, or it comes out whenever we burn trees, gasoline, or coal. We burn many trees and much coal and much gasoline, so carbon dioxide increases more and more. It accumulates".

"When we use sprays, the gas rises up in the sky, evaporates, and concentrates at some point. [There] it creates a small hole, but as the gas is getting more and more, [the hole] gets bigger and bigger".

4.3.3. Metaphors: concluding remarks

Some concluding remarks concerning the use of metaphors are as follows:

- Children frequently use metaphors during the construction of stories. Metaphors are primarily used in order to explain scientific processes, assigning specific causal relationships.
- The subjects interviewed in the course of our research did not restrict themselves to the conventional metaphors commonly used to describe the greenhouse effect or the ozone layer, but invented new ones.
- Children often see unfamiliar entities in terms of other, more familiar ones, through ontological metaphors.
- Moreover, the system of our planet surrounded by an atmosphere is readily described and explained with the use of orientational metaphors.
- Metaphors were used in the discussions either as closing statements, in order to conclude a story, or in order to allow a story to proceed.

4.4. Models

In their attempt to explain various processes during the conversation, children provided interesting models. These models involve totally personal constructions, since they reflect how each student represented the phenomena under consideration.

4.4.1. Gases in the atmosphere

A typical case in which a model was proposed, concerned the movement of various gases in the atmosphere.

"CFC's are a gas. They are found on earth. In the atmosphere. We can't see them, maybe we breathe them in. They are gases going up. All gases have this property. Perhaps something is caused to the earth's attraction so that the gas can go away... I'm not sure about that. Or, maybe,

they become lighter because they are polluted and they are warmer...?"

4.4.2. Ozone depletion process

The process of ozone depletion gave the opportunity for the development of some interesting models, too. Here is an example:

> "CFC's get out in the air and then they go to the atmosphere; to ozone. They harm ozone. They dilute it and spread through it so that ultraviolet rays can pass from that point. It's as if the CFC's pull ozone apart and pass through it and come out from the other side".

4.4.3. The mechanism of global warming

Another topic that demanded attention during the interviews was the fact that while the sun's rays can enter the atmosphere, they cannot leave the atmosphere. Thus, they can perfectly move in one direction -downwards, or towards the earth- but not in the opposite, since carbon dioxide and methane prevent them from escaping out. Here are some interesting solutions proposed by children for this apparently inconsistent situation:

> "Carbon dioxide is getting more and more. It concentrates close to the same altitude where ozone is found, about 25 kilometres, and covers the earth. [The sun's rays] get trapped and the temperature rises. They are reflected on the clouds and on this gas and they go back down again. [It's] the same thing that happens in a greenhouse. It's the same thing as a glass".

> "[Carbon dioxide and methane] let the sun's rays come in and warm up the earth because they can't get out. Maybe when they come downwards they are stronger so they can enter [the atmosphere], but after they have entered [the atmosphere] they become warm and they can't go out..."

> "Carbon dioxide and methane are like a cover above the earth, which lets the thermal rays in, but doesn't let them escape from the earth. The reason for this may be that when

> the sun sends the rays, they can pass through carbon dioxide, through this cover, because they are stronger... but when they try to go out they are not pushed from anywhere. Or, maybe this cover has a greater capacity of penetration for any object that passes, while it has penetration capacity in the opposite direction".

The concept of force, or strength, represented by the same word in Greek, is commonly used in everyday language when one refers to sun rays, or sunlight. Perhaps this is the reason why this concept was naturally used in the last two examples. The model that follows, provides an alternative approach:

> "I think that the light coming to the earth from the sun moves in the atmosphere at a speed of 300.000 kilometres per second. Hence, it can break carbon dioxide and come in, but it can't go out, because it doesn't have such a high speed after having passed through various layers".

The above examples are all unique. However, as we already mentioned while discussing the subjects' views of the greenhouse effect, several children seem to adopt the following schema as an explanation for the same greenhouse effect mechanism:

> "The sun's rays come to the earth, and carbon dioxide, CFC's and methane form a shield, like a glass, and prevent all this heat from getting out. They can come in because there is this ozone hole. Those elements destroy ozone so that the ultraviolet rays can enter the earth. But then there is this shield and they can't go out".

4.4.4. Models: some final words

During the interviews children's mental models concerning the ozone depletion and the greenhouse effect were prompted, reflecting their personal representations of the central scientific processes involved in the two phenomena. As we already mentioned, those models constitute what we call 'unique' stories, as should be expected, since mental models are personal constructs. The element which distinguishes those models from the rest of the unique stories is that the construction of such explanatory models requires that one goes beyond the level of information given to the students at the beginning of the interview.

5. CONCLUSIONS - LIMITATIONS

The stories generated by the interview transcripts indicate that there is a common core of beliefs among primary school children concerning the ozone layer depletion. This central core comprises complex processes. Children seem to believe that ozone is a gas forming a layer around the earth. This layer protects us from the sun's ultraviolet rays. Gases released on earth as a result of various human activities, rise up in the atmosphere. When those substances reach ozone, they destroy it making holes in its layer. The sun's harmful rays enter the earth through the ozone holes. When they reach us, ultraviolet rays cause serious problems to our health, as well as to all living things on earth. Ultraviolet rays may also cause the polar ice to melt.

This common core of children's ideas is quite consistent with the scientific views about the same phenomenon, except for the effects of ultraviolet rays on polar caps.

The widespread use of metaphors during the conversations indicates that metaphors can be powerful explanatory tools for the exploration of the greenhouse effect and the ozone layer. The most prevalent categories of metaphors encountered in our data include ontological metaphors in which concepts are conceptualised as containers, personifications, and orientational metaphors referring to the up/down and in/out orientations.

Children's understanding of complex scientific processes concerning environmental issues is thus complicated and their views were explicitly expressed during the conversations. However, despite the fact that the project design posed equal emphasis on the ozone layer depletion and the greenhouse effect, the subjects seemed more familiar with ozone depletion, whereas nearly half of them did not even refer to the greenhouse effect.

It is also worth noting at this point that although not all subjects referred to the greenhouse effect during the interviews, but mainly focused on ozone depletion, global warming provided far more opportunities for the development of original models. This fact could be attributed to the unfamiliarity of the latter phenomenon in relation to ozone depletion; greek children hear quite often about the dangers of ozone depletion, while few of them seemed to be aware of the greenhouse effect at the beginning of the conversation. In this case, they either simply ignored the existence of a phenomenon distinct from the depletion of the ozone layer, or ended up with models that seemed plausible as explanations to global warming.

This imbalance in the understanding of the two phenomena could possibly account for many misconceptions recorded by the interviews. Such misconceptions include the confusion between the causes of the two phenomena, the confusion of their consequences, or the conceptualisation of the two phenomena as one, very commonly encountered in the transcripts.

A possible explanation for such confusions is the parallel recording of the children's views about two distinct phenomena. Although the information material concerning the two phenomena were distinct, it is possible that the simultaneous examination of the two issues resulted in misinterpretations.

Another possible direction for further research could include a full examination of the role of metaphors in explanation, as well as the study of metaphors from a linguistic point of view, so as to arrive at a full understanding of the role of metaphors in explanation. Also, the causes of the confusions between the two phenomena should be determined, and the impact of the combined examination of the different issues on their conceptualisation should be evaluated.

If the impact of information about the ozone depletion on the conceptualisation of the greenhouse effect proves significant, then the next step for the researcher is to decide whether or not take the risk of creating misconceptions for the sake of introducing a relatively unknown phenomenon. This also reflects the types of dilemmas and decisions one has to make when it comes to designing teaching material.

Last, the views of primary school teachers about the ozone layer depletion and the greenhouse effect should be compared to those of children in order to determine the appropriate ways of training teachers for teaching those complex environmental issues, as well as design suitable educational material.